Demographic Dynamics, Preferences, and Economic Development

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Preface

This dissertation studies the demand side of the economy in terms of demographics, consumer preferences, and the interactions between them. Furthermore, it provides implications on the long-run economic effects of these aspects.

The demand side in the pre-industrial period is typically considered as non-influential in the economic literature. Before the transition from stagnation to sustained economic growth, a subsistence consumption constraint was always binding, so it seemed that the consumer behaviors played a trivial role in the economy. However, in the seventeenth and the eighteenth century, the consumer revolution happened in Western Europe, as evidenced by the increasing number of luxury goods in households at all wealth levels, regardless of the contemporaneous sluggish economy. Historical and sociological literature explains the consumer revolution as a reflection of an ongoing cultural transmission, which facilitated new tastes and the consequent novel consumption patterns.

In Chapter 1, this process is modeled as a demand-driven story using a general equilibrium framework. The dynamics of consumer taste come from the inter-generational transmission and social interactions over time. These two factors cooperatively shape the production structure and drive the economy towards an equilibrium. This results in a positive feedback loop, which ultimately triggers the social transition.

From a global perspective, the consumer revolution was strongly promoted by intercontinental trade. Following the voyage of Christopher Columbus and Vasco da Gama, the access to Asian luxury goods through the 300-year intercontinental trade boom fueled the aspirations of European consumers, no matter rich or poor, therefore stimulating the consumer revolution. As a consequence, Europeans started to produce substitutes of Asian imports, by doing research on indigenous resources (e.g. coal, iron, and steel) and experimenting with their own production systems. These techniques laid a solid foundation for the subsequent industrialization.

The baseline model in Chapter 1 is extended to an open-economy model in Chapter 2, where intercontinental trade enhances the dynamics and makes the transition earlier and faster. Afterwards, an endogenous growth model is built on the enhancing effects of trade. The dynamics of taste induce technological process, and the imitation-based innovation eventually leads to a sustain economic growth. Furthermore, the simulation results are able to replicate the pattern of income per capita of the United Kingdom from 1700 to 2000.

In addition to the effects on the long-run economic development, luxury consumption is also a vital part of the modern economy. For instance, the LVMH Group is the largest European company and ranked 20 in the world, according to the market capitalization in 2021.[1] At the same time, the LVMH group is also the first company to have 5 brands among the 100 most valuable global brands in 2021, as announced by Interbrand.[2] Furthermore, the LVMH group had a much higher revenue growth rate in the US compared to the US GDP growth rate from 2009 to 2019 before the Covid crisis.[3] The IBIS market research found that several other luxury companies experienced similar or higher growth rates compared to the US GDP growth after the Great Recession in 2009, so they argued that the luxury industry was leading the economic recovery in the US (Panteva, 2011).

From the consumer side, Millennials have attracted attention in related research because they spend a higher share of their expenses on luxury goods than any preceding generations.

[1]Details on the ranking are reported by Statista, available at *https://www.statista.com/statistics/263264/top-companies-in-the-world-by-market-capitalization/* (accessed 07 February 2022), or can also be found at *https://www.visualcapitalist.com/the-biggest-companies-in-the-world-in-2021/* (accessed 07 February 2022) reported by Visual Capitalist.

[2]See, for example, *https://www.prnewswire.com/news-releases/tesla-leapfrogs-the-competition-in-interbrands-2021-best-global-brands-report-301401379.html* (accessed 07 February 2022) for the report from PR Newswire.

[3]Data on revenue of the LVMH Group in the US are from Statista, available at *https://www.statista.com/statistics/410667/lvmh-group-revenue-united-states/* (accessed 07 February 2022). Data on the US GDP are from the World Bank.

However, it remains unclear to which extent this is explained by their young age. Therefore, Chapter 3 investigates the influences of age and generation effects on luxury expenditure. Using panel data on consumption behaviors from the US, age and generation effects on luxury expenditure are separately identified via a variety of different approaches. First, multiple regression models including a full set of age and generation dummies and several other demographic characteristics are estimated. Next, a supervised machine learning technique based on deep learning is leveraged to model non-linear and interactive relationships among these variables. All approaches consistently show that Millennials spend less on luxury goods than the preceding generations, both in absolute terms and as a share of total expenditure, conditional on age and other demographics. Thus, the high luxury expenditure of Millennials observed in the cross section can be fully attributed to their young age.

These results challenge the stereotype of Millennials as a spoiled generation indulging in luxury. Such finding also sheds lights on some emerging evidences showing that nowadays the new generations have been facing lots of obstacles and challenges, especially due to the demographic change such as the increasing peer competition and population aging. Following this direction, Chapter 4 analyzes how the previous restrictive fertility policy in China affects elderly suicides in the contemporary aging society.

Elderly suicide is an important public health issue in China. With a rapidly aging population and profound socioeconomic changes, overall elderly suicides show a downward trend, but the share of suicides committed by the elderly is increasing. Chapter 4 presents an empirical investigation of the hypothesis that the exposure to the restrictive fertility policies of the Chinese "Later, Longer, Fewer" campaign in the 1970s contributes to the dynamics and patterns of elderly suicides in China in the period 2004–2017. The identification strategy exploits variations in the exposure to this policy across birth cohorts, time, and space. It is based on the quasi-random timing of the implementation of fertility policies across Chinese provinces. The results show that those with a greater exposure to the restrictive fertility policy in the 1970s exhibit higher suicide rates during old ages.

Chapter 1

Modeling the Consumer Revolution[1]

1.1 Introduction

In models of long-run development, the pre-industrial world is often modeled as one of stagnant income and a life in which only basic needs are satisfied by consuming simple and basic, unrefined goods. In reality, income was not stagnant, but experienced phases of growth which were followed by stagnation or even decline. Likewise, consumption was not limited to subsistence, but instead there was a market for very refined luxury goods, whose quality is often unmatched until today. The taste for such refined goods is often seen as reflection of a culturally advanced society that had not only the means to produce these goods beyond satisfying subsistence needs, but also an appreciation of quality of different commodities, ranging from food and clothing to household appliances and durable consumption goods like art. Since societies had to be able to both produce and appreciate such goods, this raises questions about the interplay between cultural and economic development.

While the role of culture has received intensified research interest in the long-run development literature, the related work mostly focused on culture in terms of productive traits, entrepreneurship, and other production-related aspects. Pre-industrial consumers are

[1]This chapter is joint work with Uwe Sunde.

often considered as trapped in the Malthusian stagnation, and cultural factors are seen as facilitating the supply-side-driven transition to sustained growth. The role of culture in the sense of refined taste for luxury consumption has received little interest. Conceptually, this aspect is related to the demand side, as it refers to the desire and appreciation of particular types of goods. However, demand-side factors have been largely neglected in the context of the transition, partly due to the lack of systematic data (see, e.g., Gilboy, 1972).

This chapter investigates the role of culture as reflected in the appreciation of, and demand for, refined luxury goods for long-run development by developing a simple general equilibrium framework of the consumer revolution. The model is motivated by historical research, which has emphasized the changes in consumption patterns in Europe during the seventeenth and the eighteenth century by pointing towards the consumer revolution, "a significant increase in the amounts and sorts of goods consumed by a growing segment of the population" (Rönnbäck, 2010, p. 178). In fact, this consumer revolution is viewed as a monumental social transition, which happened in a historical phase that was characterized by the absence of sustained and substantial economic growth (McKendrick *et al.*, 1982; Fairchilds, 1993; Smith, 2002; Fouquet and Broadberry, 2015). Nevertheless, in this phase during the seventeenth and the eighteenth century, luxury and aesthetics began to reach a large share of the population by gaining importance in consumer preferences (Berg and Eger, 2003b). Moreover, the consumer revolution happened before the demographic transition, when formal schooling was still negligible, which makes parental cultivation even more relevant.

Our model investigates why and how a larger share of the population became interested in luxury goods, as well as the implications of the increase in the demand for refined goods for income growth. The model is kept deliberately simple and focuses on a population with heterogeneous preferences for luxury goods. These preferences evolve over time, as the result of inter-generational transmission of taste due to parental cultivation efforts and the increasing intensity of exposure to taste from social interactions. The focus on the inter-generational transmission of taste builds on theoretical and empirical foundations for parental cultivation related to consumption practices. For instance, Bourdieu (1984) shows that these practices are strongly linked to education and family background, and the latter gains additional importance in extracurricular areas, such as cooking, clothing, and interior decoration. Furthermore, the attitude towards children was civilized from autocratic and ferocious to compassionate and benevolent during the seventeenth century (Plumb, 1975). This change of attitude empirically supports the aspect of altruism used in the proposed model. Parents are preoccupied with their children's future, and thus have an incentive to impose their preferred taste on children even with additional cost.

The model simplifies taste traits by dividing individuals into high-taste and low-taste groups, where the high-taste group prefers fancy goods to basic goods. Each individual tries to cultivate the taste of her child by buying her refined, fancy goods because of altruism. On the production side, workers earn the same amount of income from working in either the basic-good sector or the fancy-good sector. This implies that all individuals face the same budget constraint, so consumption decisions depend entirely on personal taste. In addition, the assumption of constant returns to labor in the fancy-good sector allows labor to freely shift between sectors, promptly adjusting to the aggregate demand in the market. Together, the composition of the population in terms of taste as well as the taste intensity represent demand-side forces of the economy that shape the production structure and drive the social equilibrium. The inter-generational taste transmission (that enlarges the share of high-taste individuals) and the social taste upgrading (that increases the relative taste level of high-taste individuals) form the equilibrium labor allocation which positively affects the taste level of the next generation. The accumulation of taste and the positive feedback loop between demand and supply reallocation ultimately triggers a transition that completely changes the preference composition of society and the structure of production.

Contribution to the Literature. Although the transition from the medieval scarcity to modern materialism has already interested historians (Brewer and Porter, 1993), it is still lacking an economic analysis. Inspired by related historical and sociological research, this chapter firstly contributes to the economic literature by theoretically modeling the consumer revolution in the early modern Europe.

Besides, this chapter supplements the economic literature in the field of fashion and luxury consumption. Regarding this topic, a common methodology is to quantify the theories of Veblen (1899) or Simmel (1957), based on the idea of consumption externality that individual consumer behaviors depend on the consumption of others (see, e.g., Leibenstein, 1950; Coelho and McClure, 1993; Pesendorfer, 1995; Di Giovinazzo and Naimzada, 2015). However, income is always assumed to vary among different groups in the literature. This makes it difficult to identify the pure effects of taste because changes in price and income can explain diverse behaviors, according to Stigler and Becker (1977). Restricted by this, most related research only uses a partial equilibrium framework to study consumer behaviors in short-run fashion cycles, without examining the long-run dynamics of taste-driven development in a general equilibrium setup, which is exactly investigated in this chapter.

Furthermore, the main mechanism in the proposed framework, parental cultivation, is an innovative application of the theory of cultural transmission to the long-run growth literature. Earlier work has focused on supply-side mechanisms to explain the transition from stagnation to growth, emphasizing the role of human capital accumulation as consequence of technological change (see, e.g., Galor and Weil, 2000), health improvements (Cervellati and Sunde, 2005), or trade-related specialization (Galor and Mountford, 2008). This literature has also emphasized the role of cultural transmission of productive traits (Galor and Moav, 2002). In contrast to these models of unified growth, in which demand only plays a role after the industrialization as a passive result of the supply-driven transition, our model puts culturally-transmitted demand patterns to the center stage. By rooting the demand changes in parental and societal influences, our approach relates to the more recent literature on cultural transmission. This literature has focused on two main lines or research, as summarized by Sáez-Martí and Zilibotti (2008). The first one is the paternalistic model, where parents use their own preference to evaluate the utility of their children and try to impose their own taste types on their children (see, e.g., Bisin and Verdier, 2001; Hauk and Sáez-Martí, 2002; Olivier *et al.*, 2008; Sáez-Martí and Zenou, 2012). Second, in the non-paternalistic model parents only consider the preference of their children while evaluating the utility of their children (see, e.g., Doepke and Zilibotti, 2008, 2014). However, in this chapter, we assume that parents are only altruistic with respect to the level of "taste" and not the lifetime well-being of their children. In addition, taste is independent of occupation choices, so the proposed model only describes the demand side without any expansion of production possibilities on the supply side.

Last but not least, this chapter provides new inspirations for studies on the Industrial Revolution. In addition to the "Protestant ethic" by Weber (1958[1905]) and the "spirit of capitalism" by Doepke and Zilibotti (2008, 2014), consumer desire is systematized in this framework as another aspect of the cultural transformation. Pomeranz (2009) stresses the importance of this transition of taste: Very little evidence shows that Western Europe was more productive than other societies before the industrialization. However, Europeans indeed showed stronger incentive to consume luxuries and novelties compared to people elsewhere, which might be able to explain Europe's divergence from the rest of the world. The luxury consumption resulting from transformed attitudes restructured the social production, triggered the Industrial Revolution, and stimulated the modern economic growth (see, e.g., Mukerji, 1983; Pomeranz, 2009; McKendrick *et al.*, 1982; Mokyr, 2001; De Vries, 1994). Based on the dynamics of the social demand investigated in this chapter, Chapter 2 models the long-run growth effects of the consumer revolution.

The remainder of this chapter is structured as follows: Section 1.2 introduces empirical examples by showing historical, regional inventory data on luxury possessions. Section 1.3 describes the theoretical model. Section 1.4 characterizes the long-run dynamics derived from the model, and Section 1.5 concludes. Analytical results and proofs of propositions are detailed in the Appendix.

1.2 Conceptual and Historical Background

1.2.1 The Historical Consumer Revolution

While luxury consumption and the pursuit of fashion date back to antiquity, the material culture had typically been monopolized by a small group of privileged elites (McKendrick *et al.*, 1982). Possessed by the ruling classes to signify authority, such "old luxury" was characterized by excess and vanity, and thus the majority of the population was not involved due to lacking financial capacity. The consumer revolution in the early modern Europe marked the shift from "old luxury" to "new luxury" which was developed by a more heterogeneous urban society to communicate cultural meanings and express personal feelings (Campbell, 1987; De Vries, 2003b; Blondé and Ryckbosch, 2015). Comfort and fantasy evolved into a new trend: For example, the popularized cheaper and lighter fabrics relaxed individual budget constraints, therefore providing the masses with access to luxury.

During this transition, luxury goods beyond life necessities were progressively consumed by both the rich and the poor. Apart from wealthy merchants and artisans, poor farmers also owned luxury items such as belts, ribbons, and silver buttons, and "drug food" like sugar, tobacco, coffee, and tea (Mukerji, 1983; Pomeranz, 2009). According to Medick (1982), the possession of these goods constituted the urban "plebeian culture": People in Württemberg who were too poor to eat more than potatoes "would consider themselves less than human if they were compelled to give up their morning coffee" (Medick, 1982, p. 95). Furthermore, refinement and elegance were added to previous utilitarian objects. Goods that once symbolized status now turned into the expression of taste (Berg, 2007). The conservative, stable, and stratified medieval clothing was superseded by comfortable and stylish replacements (Mukerji, 1983). Meanwhile, Europeans also learned to eat, drink, and socialize with sophistication, especially in the newly emerged coffee houses and theaters (Berg and Eger, 2003a).

To explain the consumer revolution, the classic theories like "conspicuous consumption" by Veblen (1899) and "class differentiation" by Simmel (1957) are not directly applicable, as they strongly rely on the concept of "class" which already became ambiguous in the early modern Europe. Additionally, given the background of the economic stagnation in the early modern Europe, this process can not be explained by conventional economic doctrines either, but instead requires concepts from the cultural domain (Smith, 2002; Ryckbosch, 2015). Campbell (1987) and Fairchilds (1993) argue that consumers were motivated by a desire to materialize their ideologies and express personal value systems through consumption. This is an issues of taste, instead of the emulation of superiors (Bourdieu, 1984; Berg and Eger, 2003a). McKendrick *et al.* (1982) also state that certain attitudes and beliefs must have been developed to initiate the consumer revolution in early modern Europe: "for this to succeed required men and women to believe in growth, in change, in modernity; to believe that the future was bright, far brighter than the past; to believe, also, that what was new was desirable, whether it was the cut of a dress, the ascent of a balloon, or a new variety of auricula" (McKendrick *et al.*, 1982, p. 316). Mukerji (1983) acknowledges this as a cultural transmission in the Western world from the Middle Ages. By specifically studying England, Campbell (1987) realizes that the growing self-consciousness and subjectivity facilitated the taste for novelty in the newly established bourgeois society.

1.2.2 The Consumer Revolution in Europe

Countries across Europe were experiencing a similar trend of the consumer revolution during the seventeenth and the eighteenth century, revealed by regional probate inventories (Ryckbosch, 2015). The affected areas specifically discussed in the following include England, France, Low Countries, peripheral areas like the Baltic region, and European colonial counterparts.

England and France. By using large samples of probate inventories, Weatherill (1988) and Shammas (1990) unfold a Tudor-Stuart consumer society, during which the recorded number and variety of goods increased dramatically, especially from 1675 to 1725. The sample of Weatherill (1988) includes almost 3000 recorded probate inventories in England.

The frequencies of some selected household goods are presented in Table 1.1. These goods can be grouped into three categories. “Backstage” goods were basic furniture and utensils that were already fairly common in the seventeenth century. “Frontstage” goods occasionally showed up initially and became modestly more common over time. “Novel” goods were almost unknown in 1675, but their frequency increased drastically compared to others. The dissemination of “novel” goods confirmed the occurrence of the consumer revolution in England.

Table 1.1: *Percentage of England Probate Inventories Containing Selected Household Items (%)*

	“Backstage” goods			“Frontstage” goods			“Novel” goods		
Year	Tables	Cooking pots	Pewter	Looking glasses	Pewter dishes	Earthenware	China	Utensils for hot drinks	Pictures
1675	87	66	94	22	39	27	0	0	7
1685	88	68	93	28	46	27	1	0	8
1695	89	69	93	31	44	34	2	1	9
1705	90	71	93	36	47	36	4	2	14
1715	91	74	95	44	56	47	8	7	24
1725	91	76	91	40	55	57	9	15	21

Notes: This table reports the percentage of households owning the selected items in the recorded probate inventories. The 3000 total records are distributed relatively even across time, with 390–520 records in each decade.

Sources: Weatherill (1988, p. 26), original sources are summarized by Weatherill (1988, p. 240)

DeJean (2005) extensively describes the origin of French fashion and style that was developed under Louis XIV’s patronage. By the beginning of the eighteenth century, the French redefined the modern society with elegance and aesthetics, enlightened people all over Europe about luxury and high-end experiences, and elevated the knowledge of fashion. Specifically, DeJean (2005) summarizes “the stories of the shoemaker, the hairdresser, the cosmetologist, the cookbook writers, the chef, the diamond merchant, the couturieres and the fashion queens, the inventors of the folding umbrella... and of champagne” (DeJean, 2005, p. 19).

Low Countries. De Vries (1975) uses 512 recorded inventories to analyze the consumption of peasants in the Dutch province of Friesland from 1550 to 1750 and indeed finds that peasants who were self-contained actually owned luxury objects. Understandably, the introduction of an urban culture and a new taste caused a discernible transformation of consumption patterns in these rural households. Poukens and Provoost (2011) examine the case of Lier in Brabant, a small town near Antwerp, where the demand for novelty was also growing during the period of the consumer revolution. It is worth noting that during the investigated period from 1690 to 1770, Lier was actually experiencing an economic decline, and the stagnation lasted until the mid-eighteenth century. Therefore, Poukens and Provoost (2011) suggest that the new consumer culture enabled these seemingly contradictory circumstances.

At the same time, Antwerp was under economic hardship as well, as suffering from de-industrialization and drawbacks since 1648. Nevertheless, the material culture and the demand for luxury was developing prospectively without any interruption (Blondé and Van Damme, 2010). For example, fashion shops in Antwerp spread in a large scale from the end of the seventeenth century, overlapping with the worst years of the economic crisis (Blondé and Van Damme, 2010), as shown in Figure 1.1. The new, taste-driven consumption pattern rationalized the expansion of fashion markets during this period.

From a consumer perspective, Blondé and Van Damme (2010) study the new-fashioned utensils used for novel hot drinks between 1680 and 1730. They group the inventory owners in the samples into different social categories, from "I" being the poorest to "VI" being the richest (ranked by the number of owned rooms). The substantial increase in the frequency of every selected item in Table 1.2 delineates the fast blossoming of the new consumption culture. This trend appears across all social categories, and even the poorest people started adopting it.

Furthermore, Blondé and Van Damme (2010) empirically prove the pattern of the transition from "old luxury" to "new luxury". The former is typically characterized by "intrinsic value", while the latter features "cheaper material but more fashionable design".

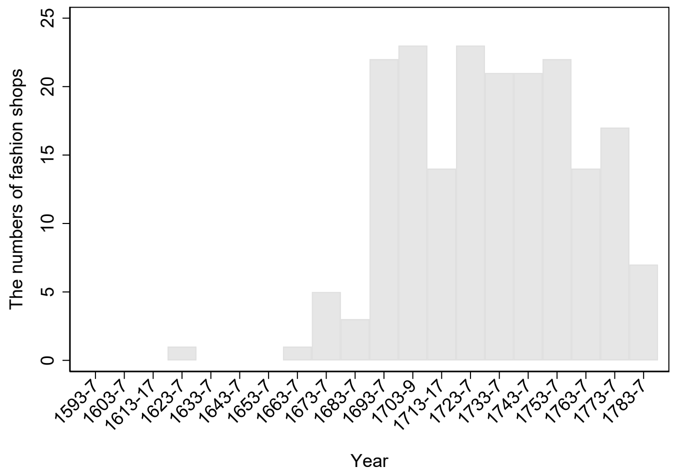

Figure 1.1: *The Numbers of Fashion Shops in Antwerp*

Sources: Blondé and Van Damme (2010, p. 650), original sources are from the Municipal Archives of Antwerp (MAA) (Blondé and Van Damme, 2010, p. 642)

Table 1.3 uses the percentage composition of different chair types as an example, where the social categories are defined as in Table 1.2. It is noted that consumers switched from expensive and sumptuous Spanish leather chairs to cheaper and lighter rush-bottomed chairs in Antwerp between 1680 and 1730, regardless of their social categories.

Other European Countries. Consumers from other parts of Europe, like the Baltic region and Ireland, were also benefiting from the consumer revolution. By using sugar as the main indicator of the new consumption culture, Rönnbäck (2010) quantitatively demonstrates the existence of the consumer revolution in Denmark and Sweden. Likewise, Flavin (2011) shows the substantial changes of consumption patterns resulting from the material culture in Ireland in the sixteenth century.

European Colonies. Interestingly, research shows that European emigrants in oversea settlements were not doing worse in the consumer revolution compared to local Europeans. Fourie (2013) portrays a relatively prosperous society in the eighteenth-century Dutch Cape Colony using the data of household probate inventories. In addition, the idea of luxury and

Table 1.2: *Percentage of Antwerp Probate Inventories Containing Household Items Related to Hot Drinks (%)*

Social category	Chocolate		Tea		Coffee		Sugar	
	1680 (n=86)	1730 (n=93)	1680 (n=86)	1730 (n=93)	1680 (n=86)	1730 (n=93)	1680 (n=86)	1730 (n=93)
I	0	12	0	59	0	0	8	22
II	0	36	0	64	0	14	17	27
III	3	25	0	58	0	29	8	21
IV	0	63	0	89	0	47	8	21
V	18	71	0	86	0	75	9	43
VI	40	100	0	100	0	83	0	29

Sources: Blondé and Van Damme (2010, p. 645), original sources are from the Municipal Archives of Antwerp (MAA) (Blondé and Van Damme, 2010, p. 661)

Table 1.3: *Percentage of Antwerp Probate Inventories Containing Chairs by Type (%)*

Social category	Spanish chairs		Rush-seated chairs	
	1680 (n=86)	1730 (n=93)	1680 (n=86)	1730 (n=93)
I	36	20	30	50
II	54	8	33	56
III	46	35	15	29
IV	47	39	3	33
V	58	39	7	26
VI	42	25	0	28

Sources: Blondé and Van Damme (2010, p. 644), original sources are from the Municipal Archives of Antwerp (MAA) (Blondé and Van Damme, 2010, p. 661)

fashion already crossed the Atlantic Ocean and arrived in Chesapeake by then (Carr and Walsh, 1988). Comparably, by using probate inventories from the eighteenth-century New England, Main and Main (1988) find that households at all levels of wealth possessed an rising number of novel goods, as Table 1.4 displays. The increasing frequencies of these goods represent a taste change towards the new material culture which even reached the poorest households.

Table 1.4: *Percentage of Southern New England Probate Inventories Containing Selected Novel Items (%)*

	Poorest third		Middling third		Richest third	
Items	1650–1674	1760–1774	1650–1674	1760–1774	1650–1674	1760–1774
Imported goods	2.6	44.4	8.6	62.9	17.3	72.8
Forks	0.0	39.7	0.0	51.1	0.0	58.4
Fine earthenware	0.0	11.9	4.3	16.1	3.9	23.1
Coarse earthenware	35.9	49.2	52.7	67.2	58.3	78.5
Linenware	69.2	70.6	81.7	84.4	89.8	83.3
Silverware	5.1	10.3	9.7	14.5	27.6	39.9
Time pieces	2.6	4.0	1.1	3.8	3.2	22.0
Wigs	0.0	5.6	0.0	10.2	0.0	24.3
Pictures	0.0	4.0	0.0	4.3	0.8	10.4

Sources: Main and Main (1988, p. 43), original data are listed in the "the coverage of the probate records" by Main and Main (1988, p. 45)

1.3 The Model

1.3.1 Population Structure

This section presents the theoretical framework to model the dynamics of the consumer revolution, from the perspective of cultural transmission (see, e.g., Bourdieu, 1984; Bisin and Verdier, 2001; Doepke and Zilibotti, 2014). The model is based on distinct preferences for necessities (denoted "basic goods") and luxuries (denoted "fancy goods"). Based on changes in the consumption patterns of these goods, the transition is characterized by the dynamics in the taste distribution—the increase in the share of population with stronger preference for fancy goods in the model.

Consider a discrete number of generations denoted by $t \in \mathbb{N}^+$. Each individual of generation t gives birth to one child asexually, so the population size is fixed and normalized to one for simplicity. The economy is closed and consists of two sectors, which produce basic goods denoted by b and fancy goods denoted by f, with the prices $P_{b,t}$ and $P_{f,t}$ respectively. Due to the homogeneous and inelastic labor supply, individuals of the same generation t earn the same amount of income m_t. There is no physical capital or other storage technology, so all income is spent on consumption.

There are two taste traits, high taste h and low taste l, and each individual carries either of them. The preference for fancy goods relative to the preference for basic goods is defined as taste. High-taste individuals have a stronger preference for fancy goods, with the relative taste level $\alpha_t > 1$, while for low-taste individuals this level always equals one. The share of high-taste individuals of generation t is q_t. Taste originates from parental cultivation. Individuals are altruistic, thus deriving utility not only from goods, but also from the taste of their children. Hence, besides the consumption of goods, individuals also have to decide how much effort $e_{l,t}$ or $e_{h,t}$ they want to invest in cultivating their children's taste. Taste transmission is stochastic, and the parental cultivation effort positively and linearly affects the probability of children having high taste. In addition, the share of high-taste individuals of the parent generation t is complementary to the cultivation effort in a concave manner. Therefore, the probability of children having high taste is

$$\mathbb{P}_{l,t} = e_{l,t} \cdot \frac{q_t}{q_t + 1};$$
$$\mathbb{P}_{h,t} = e_{h,t} \cdot \frac{q_t}{q_t + 1}$$

for low-taste and high-taste parents respectively. If children develop high taste, their relative taste level will be α_{t+1}. If children do not develop high taste, their taste level equals one, implying the expected taste level of children:

$$\mathbb{E}_{l,t} = \mathbb{P}_{l,t} \cdot \alpha_t + (1 - \mathbb{P}_{l,t}) \cdot 1 = e_{l,t} \cdot \frac{q_t}{q_t + 1} (\alpha_t - 1) + 1;$$
$$\mathbb{E}_{h,t} = \mathbb{P}_{h,t} \cdot \alpha_t + (1 - \mathbb{P}_{h,t}) \cdot 1 = e_{h,t} \cdot \frac{q_t}{q_t + 1} (\alpha_t - 1) + 1$$

for low-taste and high-taste parents respectively. Thus, the level of taste of a generation increases with the parental cultivation effort and the share of high-taste individuals of the parent generation. Note that parents take α_t from their own generation as the reference while calculating the expected taste level of children because parents do not have information about the future.

The cost of the cultivation effort is directly translated into a monetary loss. Parents enjoy having high-taste children, but a higher probability of having high-taste children implies higher costs. In particular, parental cultivation requires low-taste parents to buy $k \cdot e_{l,t}$ units of fancy goods for children, and the cultivation cost is $k \cdot e_{h,t}$ for high-taste parents, where $k > 0$ is a parameter. As a result, the budget constraint faced by low-taste and high-taste individuals is

$$P_{b,t} \cdot b_{l,t} + P_{f,t} \cdot f_{l,t} + k \cdot P_{f,t} \cdot e_{l,t} = m_t; \tag{1.1}$$

$$P_{b,t} \cdot b_{h,t} + P_{f,t} \cdot f_{h,t} + k \cdot P_{f,t} \cdot e_{h,t} = m_t. \tag{1.2}$$

1.3.2 Preferences and Consumption Patterns

Both high-taste and low-taste individuals choose the optimal consumption of basic goods, fancy goods, and the optimal cultivation effort. Low-taste individuals choose $b_{l,t}$, $f_{l,t}$, and $e_{l,t}$ to maximize the utility

$$u_{l,t} = \ln b_{l,t} + \ln f_{l,t} + \gamma \cdot \ln \mathbb{E}_{l,t}, \tag{1.3}$$

and similarly, the preference of high-taste individuals is defined over $b_{h,t}$, $f_{h,t}$, and $e_{h,t}$ as

$$u_{h,t} = \ln b_{h,t} + \alpha_t \cdot \ln f_{h,t} + \gamma \cdot \alpha_t \cdot \ln \mathbb{E}_{h,t}. \tag{1.4}$$

α_t distinguishes between individuals with different taste traits of generation t: Low-taste individuals give the same weight to both kinds of goods (i.e., $\alpha_t = 1$), while high-taste individuals prefer fancy goods to basic goods ($\alpha_t > 1$). Therefore, α_t acts as the relative taste level of high-taste individuals compared to low-taste individuals whose taste level is always one. In addition, high-taste parents are more altruistic than low-taste parents. In particular, we assume that the preference weight of altruism depends on the usual "warm glow" parameter γ, which is complemented by taste. Hence, the effective altruism weight of low-taste parents is $\gamma \cdot 1 > 0$, while for high-taste parents the effective altruism is given by $\gamma \cdot \alpha_t$. Notice that all individuals share the same preference structure, but there is heterogeneity in preferences due to differences in taste. This setup of the utility functions allows for identifying a unique set of interior solutions via first-order conditions. The solutions are ${b_{l,t}}^*$, ${f_{l,t}}^*$, and ${e_{l,t}}^*$ for low-taste individuals, and ${b_{h,t}}^*$, ${f_{h,t}}^*$, and ${e_{h,t}}^*$ for high-taste individuals, as solved in detail in Appendix A.1, with the following relations:

$$b_{l,t}{}^{*} > b_{h,t}{}^{*}, \quad f_{l,t}{}^{*} < f_{h,t}{}^{*}, \quad \text{and} \quad e_{l,t}{}^{*} < e_{h,t}{}^{*}.$$

Intuitively, high-taste individuals consume more fancy goods compared to low-taste individuals at the optimum, even with the same amount of income m_t. At the same time, high-taste parents invest more effort $e_{h,t}{}^{*}$ in cultivating children as they allocate a higher weight to the utility from the taste of their children. Through the channel of marginal returns to consumption and cultivation, the taste difference triggers heterogeneous individual behaviors. This suggests a cultural explanation to the dynamics of social demand and thus the consumer revolution.

For any generation t, the share of high-taste individuals q_t is given, so the aggregate consumption of basic goods is

$$D_{b,t} = q_t \cdot b_{h,t}{}^{*} + (1 - q_t)\, b_{l,t}{}^{*},$$

while the aggregate consumption of fancy goods is

$$D_{f,t} = q_t \left(f_{h,t}{}^{*} + k \cdot e_{h,t}{}^{*} \right) + (1 - q_t) \left(f_{l,t}{}^{*} + k \cdot e_{l,t}{}^{*} \right),$$

where parents have to buy $k \cdot e_{l,t}$ or $k \cdot e_{h,t}$ units of fancy goods to cultivate the taste of their children besides their own consumption.

1.3.3 Production

We close the model with a deliberately simple and transparent production side with labor as the only factor of production and two production sectors. Individuals are homogeneous in the labor market because the taste difference does not affect the productivity in both sectors. The sectors differ in terms of their respective technology. We assume constant returns to labor in the fancy-good sector and diminishing returns to labor in the basic-good sector. This assumption is motivated by two aspects. First, intuitively, the basic-good sector is assumed to represent a harder, less pleasant working environment, for instance due to greater physical demands. In contrast, the fancy-good sector provides a less wearing environment, with sheltered workplaces, modern factories and offices, and state-of-the-art equipment, so that labor does not suffer from diminishing returns. Second, technically the linear production function in the fancy-good sector implies that any increase in demand can be satisfied because labor can shift to the fancy goods sector smoothly.

The share of labor in the fancy-good sector of generation t is denoted by $n_{f,t}$, so firms produce basic goods or fancy goods according to the following production functions:

$$Y_{b,t} = B\left(1 - n_{f,t}\right)^{\beta}, \quad 0 < \beta < 1; \tag{1.5}$$

$$Y_{f,t} = F \cdot n_{f,t}. \tag{1.6}$$

$B > 0$ and $F > 0$ are the time-invariant production parameters in the basic-good sector and the fancy-good sector and β represents for diminishing returns in the basic-good sector.

We assume perfect competition in both sectors, so the wage in the basic-good and fancy-good sector is

$$w_{b,t} = \frac{P_{b,t} \cdot Y_{b,t}}{1 - n_{f,t}} = P_{b,t} \cdot B\left(1 - n_{f,t}\right)^{\beta - 1}; \tag{1.7}$$

$$w_{f,t} = \frac{\partial\left(P_{f,t} \cdot Y_{f,t}\right)}{\partial n_{f,t}} = P_{f,t} \cdot F. \tag{1.8}$$

This suggests a downward-sloping labor demand curve in the basic-good sector and a horizontal labor demand curve in the fancy-good sector. The competitive wage earned by homogeneous labor should be equal in both sectors:

$$w_{b,t} = w_{f,t}$$

as the unique point of the intersection between the two labor demand curves. The wage equality determines the relative price, or the price of fancy goods $P_{f,t}$ as a function of the price of basic goods $P_{b,t}$:

$$P_{f,t} = \frac{P_{b,t} \cdot B\left(1 - n_{f,t}\right)^{\beta - 1}}{F}. \tag{1.9}$$

Moreover, each individual of generation t receives the same amount of income m_t:

$$m_t = w_{b,t} = P_{b,t} \cdot B \left(1 - n_{f,t}\right)^{\beta - 1}. \tag{1.10}$$

1.3.4 Equilibrium

Given the price and the income, the optimization behaviors of individual consumers and firms lead to the general equilibrium in the competitive market, where the price and the income make the market clear. Specifically, market clearing requires that the aggregate consumption of basic goods and fancy goods, $D_{b,t}$ and $D_{f,t}$, equals the aggregate production of both sectors, $Y_{b,t}$ and $Y_{f,t}$, respectively:

$$q_t \cdot b_{h,t}{}^* + (1 - q_t)\, b_{l,t}{}^* = B\big(1 - n_{f,t}\big)^{\beta};$$
$$q_t \left(f_{h,t}{}^* + k \cdot e_{h,t}{}^*\right) + (1 - q_t)\left(f_{l,t}{}^* + k \cdot e_{l,t}{}^*\right) = F \cdot n_{f,t}.$$

The interior solutions to the consumer problems solved in Appendix A.1 are in terms of the price of fancy goods $P_{f,t}$ in Eq. (1.9) and the income m_t Eq. (1.10). Based on the model setup, the share of high-taste individuals q_t and their relative taste level α_t are taken as given for any generation t. Accordingly, market clearing leads to the equilibrium characterized in Proposition 1.

PROPOSITION 1 (Equilibrium Labor Allocation)**.** *For any generation t, given the share of high-taste individuals q_t and the relative taste level of high-taste individuals α_t, the unique equilibrium share of labor in the fancy-good sector is*

$$n_{f,t}{}^* = N_f\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right) \tag{1.11}$$
$$\textit{with} \quad \gamma > 0, \quad k > 0, \quad \textit{and} \quad F > 0.$$

In addition, it must hold that

$$\frac{\partial n_{f,t}{}^*}{\partial \alpha_t} > 0 \quad \textit{and} \quad \frac{\partial n_{f,t}{}^*}{\partial q_t} > 0.$$

Proof. See Appendix A.2. □

For any generation t, the share of high-taste individuals q_t and the taste level of high-taste individuals α_t cooperatively formulate the equilibrium labor allocation ${n_{f,t}}^*$. Both q_t and α_t are variables affecting the economy through consumer behaviors, so they can be viewed as the demand side. On the contrary, ${n_{f,t}}^*$ is a variable in the production function which belongs to the supply side. Proposition 1 states that ${n_{f,t}}^*$ increases with both q_t and α_t, suggesting that the demand side positively drives the supply side to reach the equilibrium. It is worth noting that the share of labor in each sector is always between zero and one because the utility function guarantees a positive demand for both basic goods and fancy goods.

1.3.5 Taste Transmission

For individual consumers, the optimization of any generation t is implemented with the pre-determined share of high-taste individuals q_t and the pre-determined taste level of high-taste individuals α_t. Consequently, the optimal parental cultivation effort ${e_{l,t}}^*$ and ${e_{h,t}}^*$ of generation t determines the share of high-taste individuals of generation $t+1$. This section clarifies this inter-generational process.

At the individual level, the probability of children having high taste $\mathbb{P}_{l,t}$ or $\mathbb{P}_{h,t}$ depends on both the parental cultivation effort and the share of high-taste individuals of the parent generation. At the aggregate level, the expected value of this probability (or the weighted average between the probability of high-taste parents and the probability of low-taste parents with weights q_t and $(1-q_t)$ respectively) is exactly the share of high-taste individuals of the next generation:

$$q_{t+1} = q_t \cdot {\mathbb{P}_{h,t}}^* + (1-q_t)\,{\mathbb{P}_{l,t}}^*$$
$$\text{with} \quad {\mathbb{P}_{h,t}}^* = {e_{h,t}}^* \cdot \frac{q_t}{q_t+1} \quad \text{and} \quad {\mathbb{P}_{l,t}}^* = {e_{l,t}}^* \cdot \frac{q_t}{q_t+1}.$$

Proposition 2 in the following shows that in equilibrium, the share of high-taste individuals of generation $t+1$ is determined by the demand side variables of generation t, namely q_t and α_t.

PROPOSITION 2 (Taste Transmission Process)**.** *In equilibrium, the share of high-taste individuals of generation $t+1$ depends on the demand side variables of generation t (the share of high-taste individuals q_t and the relative taste level of high-taste individuals α_t) which are taken as given by generation t:*

$$q_{t+1} = Q\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right) \tag{1.12}$$

$$\textit{with} \quad \gamma > 0, \quad k > 0, \quad \textit{and} \quad F > 0.$$

In addition, it must hold that

$$\frac{\partial q_{t+1}}{\partial \alpha_t} > 0, \quad \frac{\partial q_{t+1}}{\partial q_t} > 0, \quad \textit{and} \quad \frac{\partial^2 q_{t+1}}{\partial {q_t}^2} < 0.$$

Proof. See Appendix A.3. □

Therefore, for any generation t in equilibrium, the share of high-taste individuals q_t is determined positively and concavely by the demand side variables q_{t-1} and α_{t-1} of generation $t-1$. This process works through the altruistic parental cultivation in the individual optimization problems.

1.3.6 The Upgrading of Taste

So far, the evolution of taste only referred to the share of high-taste individuals, while the relative taste level of high-taste individuals α_t was treated as given and fixed. In the following, we also endogenize the evolution of α_t over time.

The positive spillover in the fancy-good market refines the consumer taste, so the relative taste level α_t is influenced through three distinct channels: First, α_t evolves from α_{t-1} of the previous generation and monotonically increases. This implicitly assumes that taste, once acquired, is not expected to deteriorate. Second, taste is influenced positively by the share of high-taste individuals in the population, q_t (the population composition that determines demand). This implicitly assumes that consumers are inspired from social interactions, reflecting the idea of the collective selection by Blumer (1969). Third, taste is promoted by the equilibrium share of labor in the fancy-good sector ${n_{f,t}}^*$ (a supply side variable). This reflects the idea that a larger fancy-good sector leads to a higher exposure of worker-consumers to fancy goods, thereby naturally initiating a learning process that upgrades their taste.

Note that α_t can not increase to infinity and must be bounded by an upper bound $\overline{\alpha}$ which makes $q_{t+1} = 1$ because of $\frac{\partial q_{t+1}}{\partial \alpha_t} > 0$ from Proposition 2.[2] Appendix A.4 contains a derivation of the upper bound $\overline{\alpha}$.

ASSUMPTION 1 (Taste Upgrading)**.** *The relative taste level of high-taste individuals evolves according to the process*

$$\alpha_{t+1} = \alpha_t + \lambda \cdot {n_{f,t}}^* \cdot q_t \cdot \frac{\overline{\alpha} - \alpha_t}{\overline{\alpha}}, \quad \lambda > 0.$$

Assumption 1 describes that α_t increases until reaching the upper bound $\overline{\alpha}$, and the growth is negatively affected by the distance to the upper bound. α_{t+1} depends on both the demand side (q_t and α_t) and the supply side (${n_{f,t}}^*$) in equilibrium. This process is referred to as taste upgrading as it describes how the taste level rises in the economic environment. For any generation t, the equilibrium ${n_{f,t}}^*$ is driven by q_t and α_t as shown in Proposition 1, so the taste upgrading process is only determined by the demand side variables:

$$\alpha_{t+1} = \Lambda\left(\alpha_t,\ q_t\ ;\ \gamma,\ \lambda,\ k,\ F,\ \overline{\alpha}\right). \tag{1.13}$$

1.4 The Dynamics

This section combines all model components and presents the dynamic system and the respective equilibrium dynamics.

1.4.1 Dynamic System

The taste transmission process in Eq. (1.12) and the taste upgrading process in Eq. (1.13) together form a dynamic system, characterized by a positively reinforcing feedback among

[2]Recall that α_t denotes the taste level of high-taste individuals relative to the taste level of low-taste individuals. Intuitively, the imposed upper bound prevents this taste difference from exploding.

the two demand side variables q_t (the share of high-taste individuals) and α_t (the relative taste level of high-taste individuals):

$$\begin{cases} q_t = Q\left(\alpha_{t-1},\ q_{t-1}\ ;\ \gamma,\ k,\ F\right) \\ \alpha_t = \Lambda\left(\alpha_{t-1},\ q_{t-1}\ ;\ \gamma,\ \lambda,\ k,\ F,\ \overline{\alpha}\right). \end{cases} \tag{1.14}$$

This is a discrete first-order dynamic system where an autonomous process is described by the infinite sequence $\{\alpha_t,\ q_t\}_{t\in[0,\,1,\,2,\,...,\,\infty)}$.

For individuals of any generation t, q_t and α_t are given at birth, as a consequence of the optimal choices of generation $t-1$. Based on q_t and α_t, the equilibrium share of labor in the fancy-good sector ${n_{f,t}}^*$ is reached, which allows determining the demand side variable α_{t+1} of generation $t+1$. At the same time, q_t and α_t together determines q_{t+1}. Subsequently, individuals of generation $t+1$ repeat the same recursive process, and the economy ultimately converges to a steady-state equilibrium with

$$q_{t-1} = q_t.$$

In this model, the consumer revolution is characterized by the expansion of the share of high-taste individuals. Before the beginning of the modern consumption society, the share of high-taste individuals is low, and, therefore, q_t starts from an initial level q_0 that is bounded by a positive lower bound $\underline{q}$, derived in Appendix A.4. The social transition of the consumer revolution only emerges when the majority of the population realizes the importance of fanciness and adopts a different life style. Correspondingly, this long-run development is captured by the endogenous shift from one steady-state equilibrium to another. As Eq. (1.12) shows, the share of high-taste individuals of each generation is only determined by the demand side of the previous generation. Thus, the consumer revolution, symbolized by the evolution of the steady-state equilibria of q_t in the proposed model, can be explained in a purely demand-driven manner.

1.4.2 Dynamic Evolution

The dynamics of the steady-state equilibria can be seen by plotting the difference equation in Eq. (1.12). Figure 1.2 sequentially graphs the dynamics with increasing α_t, where the thick curve represents the difference equation, and the dashed line corresponds to the 45° line. The origin $(q_0,\ q_0)$ represents for the initial condition, reflecting the share of high-taste individuals that has been stagnant before the consumer revolution. The points of the intersection give the share of high-taste individuals in steady-state equilibria. Proposition 3 summarizes the dynamic evolution.

PROPOSITION 3 (Dynamic Evolution)**.** *Based on the dynamic system in Eq.* (1.14) *and starting from the initial conditions q_0 and α_0, the dynamic evolution proceeds in line with the following phases:*

1. *q_0 is the unique steady-state equilibrium, which is globally stable, and the economy converges here.*

2. *Although there are multiple steady-state equilibria, the economy stays trapped at q_0 which is always locally stable.*

3. *The economy converges to a new steady-state equilibrium with a large share of high-taste individuals, which is unique and globally stable.*

Proof. With q_t as the *x-axis* and q_{t+1} as the *y-axis*, the difference equation in Eq. (1.12) is an increasing and concave curve because Proposition 2 states $\frac{\partial q_{t+1}}{\partial q_t} > 0$ and $\frac{\partial^2 q_{t+1}}{\partial {q_t}^2} < 0$. The curve shifts upwards when α_t increases because of $\frac{\partial q_{t+1}}{\partial \alpha_t} > 0$ as shown in Proposition 2. α_t increases in $[\underline{\alpha},\ \overline{\alpha}]$ due to the taste upgrading process in Eq. (1.13). The lower bound $\underline{\alpha}$ is also derived in Appendix A.4.

Assume that the system starts from the initial conditions q_0 and α_0. The origin of Figure 1.2 is $(q_0,\ q_0)$. Firstly, since α_0 is very low, the transmission curve is located in the bottom right in Figure 1.2(a), far from the 45° line. In this case, the share of high-taste individuals always converges to q_0, which is the only globally stable steady-state equilibrium.

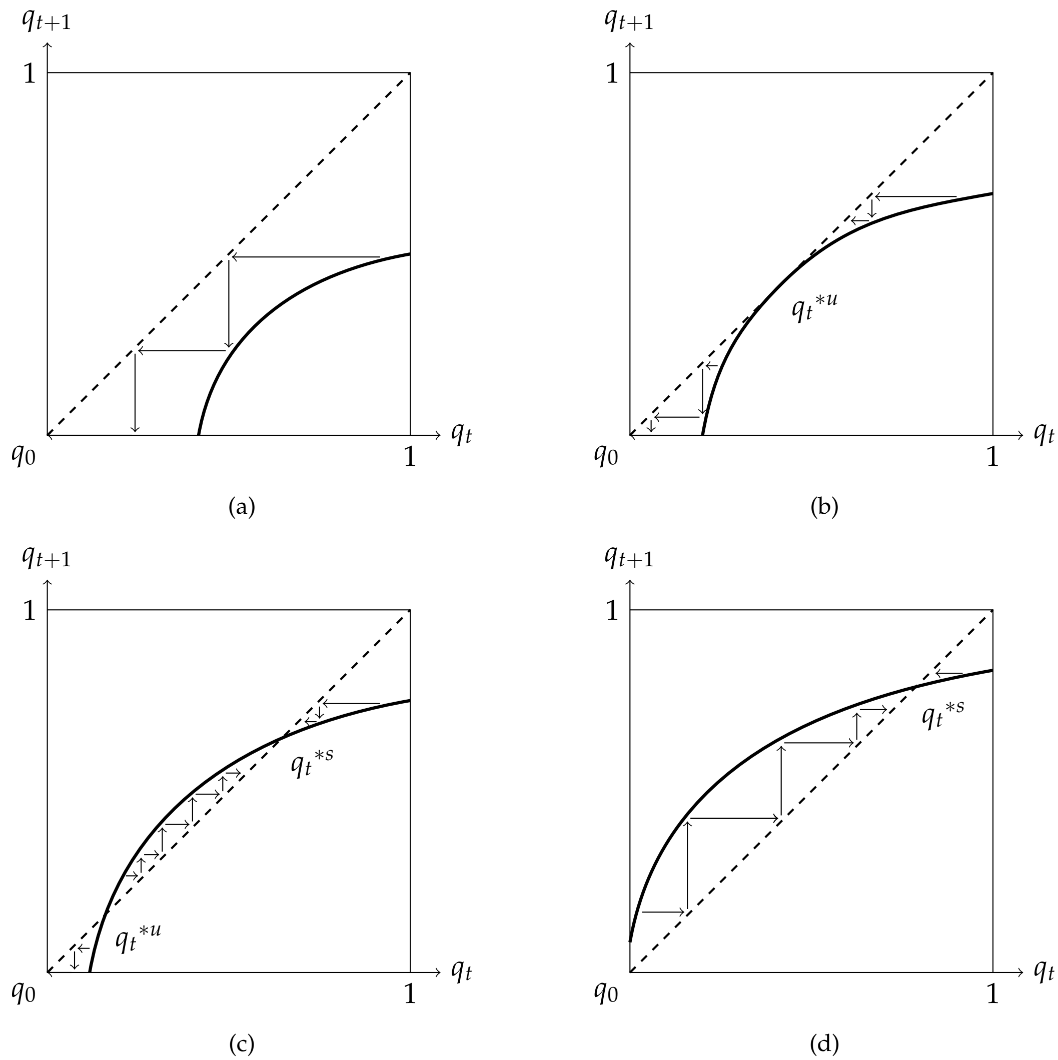

Figure 1.2: *Steady-state Equilibria*

At this stage of development, very few individuals have high taste, and their relative taste level α_t is also fairly low.

With a steadily increasing α_t, the transmission curve slowly moves upwards and becomes tangent to the 45° line once as displayed in Figure 1.2(b). From this point onwards, there are two steady-state equilibria: $(q_0,\ q_0)$ and the point of tangency with $q_t = q_t{}^{*u}$, but of these only $(q_0,\ q_0)$ is locally stable. Given the initial condition q_0 inherited from Figure 1.2(a), the system will remain at the initial condition $(q_0,\ q_0)$ unless there is an exogenous shock which drives q_t above or exactly at the point of tangency.

Subsequently, with further development in taste, the transmission curve intersects with the 45° line at two points, as shown in Figure 1.2(c). Both intersections represent steady-state equilibria, with the intersection at lower levels of q_t being unstable and the intersection at higher levels of q_t being locally stable. However, in the absence of major shocks to the share of high-taste individuals, the system does not switch to the stable high steady state. In the scenarios of Figure 1.2(b) and Figure 1.2(c), although there are multiple steady-state equilibria, the economy stays trapped at q_0, which is locally stable.

With further development, the unstable steady state eventually reaches q_0, and at this point the transition occurs, as illustrated in Figure 1.2(d). The upward-moving curve intersects with the *y-axis* above the origin at $(q_0,\ q_t')$ with $q_t' > q_0$, and only one intersection with the 45° line remains. In this scenario, the system converges to the point of intersection $q_t = q_t^{*s}$ as the only globally stable steady-state equilibrium within few generations. The resulting equilibrium is one with a relatively large share of high-taste individuals. Afterwards, the continuing increase in α_t keeps shifting the transmission curve and the point of intersection upwards, until it approaches its upper bound $\overline{\alpha}$ when the society consists only of high-taste individuals. □

In reality, q_0 stands for the share of social elites who historically were always investing in luxury consumption. As long as this was a limited elite with moderate taste differences relative to the rest of the population, this share of high-taste individuals stayed low. In addition to the stagnation of mass aesthetics in the pre-transition period, the taste level of the social elite, α_t, only barely increased due to the insufficient positive spillover from the society, visualized in Figure 1.2. At this early stage, the fancy-good market was inactivate and only had a minor impact, but the taste upgrading process in Eq. (1.13) guarantees an monotonic increase in α_t. Despite the moderate development of taste, the labor reallocation already started even when the share of high-taste individuals was still trapped at q_0 because Proposition 1 states that $n_{f,t}^*$ increases with α_t. Conversely, the expansion of the fancy-good sector ameliorated α_t in virtue of the taste upgrading in Eq. (1.13), gradually magnifying the feedback effects as well. The continuous increase in α_t and the development of the fancy-good sector ${n_{f,t}}^*$ eventually transformed preferences and consumption patterns of low-taste individuals. As a result, the economy experienced a substantial transition to a new and unique globally stable steady-state equilibrium, marked by the high values of both q_t and α_t. Eventually, the consumer revolution occurred in the early modern Europe, which led to an endogenous expansion of the production of fancy goods.

1.4.3 Implications for Aggregate Income Dynamics

The historical consumer revolution happened during the pre-industrial era, a time when technology-driven growth was still very moderate and income exhibited episodes of moderate growth and subsequent declines (see, e.g., Fouquet and Broadberry, 2015). The model presented so far allows to shed light on a demand-driven growth impulse that might well have affected incomes during this period. The underlying mechanism is related to the supply reactions that were triggered by the taste-driven demand dynamics. In particular, we model the production parameters B and F in both sectors and the total labor supply as time-invariant and fixed. Nevertheless, the aggregate income changes due to general equilibrium reactions that affect the production side of the economy. The aggregate income changes with the equilibrium labor reallocation ${n_{f,t}}^*$, which is activated by the dynamics of the demand-side variables q_t and α_t.

COROLLARY 1 (Aggregate Income)**.** *With constant labor supply and production parameters, the aggregate income in equilibrium increases with the demand variables q_t and α_t through the reallocation of labor across sectors.*

Proof. Because the total population (or labor) is normalized to one, the aggregate income equals the income received by individuals m_t in Eq. (1.10). Without loss of generality, the normalization $P_{b,t} = \delta \cdot F$ leads to the following expression of the aggregate income in equilibrium:[3]

$$Y_t = \delta \cdot B \cdot F \left(1 - {n_{f,t}}^*\right)^{\beta-1}. \tag{1.15}$$

[3]The normalization $P_{b,t} = \delta \cdot F$ is helpful in expressing the aggregate income in growth in Eq. (2.51). Compared to the simple normalization $P_{b,t} = 1$, it makes the results consistent and comparable.

The signs of the first-order derivatives of Eq. (1.15) with respect to q_t and α_t dictate how the demand side affects the aggregate income in equilibrium based on fixed productivity and labor supply. According to the chain rule,

$$\frac{\partial Y_t}{\partial q_t} = \frac{\partial Y_t}{\partial n_{f,t}{}^*} \cdot \frac{\partial n_{f,t}{}^*}{\partial q_t} = \delta \cdot B \cdot F\,(1-\beta)\left(1-n_{f,t}{}^*\right)^{\beta-2}\frac{\partial n_{f,t}{}^*}{\partial q_t} > 0$$

must hold because of $\frac{\partial n_{f,t}{}^*}{\partial q_t} > 0$ from Proposition 1. Hence, the aggregate income in equilibrium increases with the share of high-taste individuals q_t. Analogously, it can be shown that the aggregate income in equilibrium increases with α_t, the proof is omitted for brevity. □

The resulting increase in the aggregate income sheds new light on the importance of cultural change and consumer demand. The instantaneous response of the labor reallocation to the demand dynamics, and the difference in returns to scale in the two sectors, implies an increase in production and incomes. Such production restructuring influences the aggregate income, even in the absence of any economic growth that is driven by an expansion of the production possibilities frontier.

1.5 Conclusion

For much of human history, individuals did not give careful considerations to the fanciness of goods while making purchasing decisions. Luxury existed, but it was never a social trend without being publicly disseminated. So the majority of the population was ignoring fashion and aesthetics due to the lack of taste. This chapter has presented a simple general equilibrium model that rationalizes the occurrence of the consumer revolution in the early modern Europe and demonstrates the implications of changes in taste for long-run development. The model is able to rationalize the social transition towards increasing public awareness and demand for sophisticated goods that occurred during the seventeenth and eighteenth century. In the model, this revolution in consumption patterns is modeled as the outcome of an accumulative but inconspicuous process, in which the refined taste for fancy goods emerges from the increasing share of high-taste individuals and the upgrading of their taste in terms of intensity. This process is the result of inter-generational taste transmission. Eventually, this led to a revolution in consumption patterns, with larger and larger shares of consumers developing a stronger preference for luxury goods and appreciating aesthetic values. In contrast to the usual microeconomic perception of luxury consumption, this process is not the result of major income growth. Instead, by focusing on the dynamics of individual preferences for certain types of goods, the model provides a purely demand-driven mechanism of cultural change that leads to growth in a pre-industrial environment without notable improvements in production technology. Hence, growth is the result, not the cause, of increased desire for refined, "fancy" luxury goods.

While the material in this chapter provides a mechanism of long-run development, it leaves open where the technology for the production of fancy goods came from in the beginning. The next chapter provides further insights by developing a model that incorporates the larger historical context and, in particular, considers the role of global trade that experienced a first expansion after the voyages of Christopher Columbus and Vasco da Gama.

Chapter 2

Consumer Revolution, Intercontinental Trade, and Economic Growth[1]

2.1 Introduction

Following the voyage of Christopher Columbus and Vasco da Gama, the world experienced a first wave of globalization and an intercontinental trade boom over the period 1500–1800. As consequence, unknown commodities, new crops, and products became available to European consumers at all wealth levels. While many of the new products and commodities were initially considered an unheard-of luxury, the continuing exposure and availability changed tastes and habits, and products like coffee, cacao, but also porcelain, soon became part of a cultivated yet common style of life. The consequences of this exposure to intercontinental trade for long-run development have received surprisingly little attention in the literature on long-run development. Yet, maybe this intercontinental trade boom and its implications might shed new light on the still unresolved question why the transition to sustained growth first occurred in Europe.

This chapter presents a general equilibrium model of long-run development that incorporates some of the key features of intercontinental trade patterns, and thereby extends

[1]This chapter is joint work with Uwe Sunde.

the existing literature in several dimensions. In particular, the model includes an explicit account of the endogenous dynamics of preferences for certain types of goods that results from exposure to these goods, reflecting the changes in tastes of European consumers in the context of the historical consumer revolution. The model also accounts for differences in the global patterns of comparative advantages that was responsible for the intercontinental trade boom, as well as for the historical specificities of this intercontinental trade network. In particular, we consider the patterns of trade between Europe and Asia, which was characterized, on the one hand, by a technological advantage of Asia in refined consumption goods, and, on the other hand, by a structural demand for silver by China as the result of currency re-basing. This demand could be satisfied by European powers as result of local extraction and extraction from colonies. For some time, these conditions enabled mutually beneficial trade, until China closed its borders for trade, leaving Europe short of the refined goods. European consumers had learned to enjoy and therefore initiated a process of directed innovation in order to be able to produce these goods, or close substitutes, locally.

The model delivers several novel insights. Based on gains from trade and an endogenous change in tastes as the result of exposure to refined goods from Asia, we derive the trade equilibrium in Europe and Asia. This allows us to conduct comparative dynamics and show the implications of trade for development in comparison to the counterfactual path of development that would have occurred in autarky. This amounts to evaluating the role of the first wave of globalization and intercontinental trade for the development trajectories of Europe and Asia in the context of endogenous taste dynamics. An extension of the model to account for endogenous growth due to imitation and innovation allows us to explore the role of intercontinental trade as well as its sudden end in the early 19th century, for growth in Europe. The results suggest that, by influencing the dynamics of tastes for certain products, the exposure to foreign goods had a profound and long-run consequence for growth in Europe that worked through an intensification of R&D.

The analysis proceeds in two steps. First, the baseline closed-economy model developed in Chapter 1 is extended to intercontinental trade, thus providing a global perspective on the consumer revolution. Second, an endogenous growth model is built on the dynamics of the consumer demand to explain the economic "take-off" and the subsequent sustained growth.

The consumer side of the European economy extends the framework developed in Chapter 1. To make trade more attractive than self-production for Europeans, the Asian economy is modeled with a more productive sector that produces refined ("fancy") goods. In the context of intercontinental trade, the European economy specializes in the production of basic goods and silver, which is used as means of exchange for fancy goods from Asia. Trade occurs since the Asian price of fancy goods, including the trade cost, is still relatively cheaper than home production of fancy goods in Europe. Asians work in the basic-good and fancy-good sector, but different from autarky, they can derive additional utility from the silver produced and traded by Europeans. Therefore, the entire world demand for fancy goods is satisfied by the Asian supply thanks to the higher productivity. In addition, it is assumed that the preferences for fancy goods of Asian consumers are static in order to focus on the feedback effects of trade on the European economy. With the extended setup compared to the autarky model in Chapter 1, it can be shown that intercontinental trade enhances the demand dynamics, thereby triggering an earlier and faster taste transition, and related an increase in welfare, in Europe.

The second part of the analysis considers the situation after intercontinental trade stops. The analysis again focuses on the closed economy in Europe, where the production of basic goods and fancy goods in both sectors resumes after the end of intercontinental trade. However, unless there is an increase in the productivity, the demand for fancy goods can not be satisfied by the European local production since during the phase of intercontinental trade and after being exposed to Asian fancy goods for an extended period of time, European consumers developed a higher taste for fancy goods. This excess demand ultimately results in economic growth in the fancy-good sector. In particular, based on a textbook endogenous growth model, the analysis shows how the cultivated taste for fancy goods tilts the technological progress from imitation to innovation, eventually leading to sustained endogenous growth.

The dynamics are illustrated by quantitative simulations of a calibrated version of the model. The share of high-taste individuals is initially trapped at the initial condition. Eventually, during the consumer revolution in the early modern period, the share of high-taste individuals increases swiftly. In addition, the relative taste level of high-taste individuals increases in a sustained way, but also experiences a boost during the transition period. The simulation illustrates that the model is able to match real data for income per capita for the United Kingdom, indicating that the demand-based model can account for the long-run dynamics of development.

Contribution to the Literature. This chapter makes several main contributions to the related literature. The analysis is based on an increasing amount of studies that document the change of taste and the European consumer revolution during the early modern period and that rationalize these dynamics in a global context (see, e.g., Mukerji, 1983; Finlay, 1998; Berg, 2004; McCants, 2007; Pomeranz, 2009; Berg, 2012; Gerritsen and McDowall, 2012; Berg *et al.*, 2015; Perez-Garcia, 2019). Following the voyage of Christopher Columbus and Vasco da Gama, the intercontinental trade boom in the period that occurred in the period 1500–1800 fueled the aspirations for luxury imports from the East among European consumers at all wealth levels, leading to the consumer revolution in the seventeenth and eighteenth century (Mukerji, 1983; McCants, 2007).

Before the price convergence from the 1820s, intercontinental trade was dominated by non-competing luxury goods (O'Rourke and Williamson, 2002): from spices, coffee, and tea, to manufactured goods like silk, fine cotton and muslin, porcelain and lacquerware, etc. These Asian goods were transported in large scales by East Indian companies, and gained a great popularity in Europe. Eastern elements inspired new life styles and activated the taste reorientation away from the local obsolescence, and the majority of participants in this process was the urban middle and lower classes and their rural counterparts (McCants, 2007). Contemporaneously, the Asian society was relatively self-sufficient and not interested in goods abroad, except for the strong and stable preference for silver in China. Chronic destructive fiscal and monetary policies for centuries essentially "silverized" the economy (Flynn and Giráldez, 1995). Without any local silver supply in China, almost one quarter of the world population was beset with a monetary crisis. However, the unprecedentedly rich silver mines were discovered by Europeans in Latin America, and this fortuity provided a smooth environment for intercontinental trade which thrived for around three hundred years.

Beyond consumerism, Eastern manufactured goods spurred the local production in Europe (see, e.g., Clifford, 1999; Styles, 2000; Berg, 2002; Parthasarathi, 2002; Lemire, 2003; Berg, 2004). While global trade catalyzed the expansion of luxury goods and thus the transmission of new taste in Europe, mercantilism emerged at the national level in order to protect domestic industries. Therefore, the only solution to the dilemma of unsatisfied demand was to produce substitutes of Asian imports. Because direct copies of products were not feasible (Berg, 2004), Europeans started to research indigenous resources and experiment with their own production processes. This imitation-based innovation equipped them with not only the knowledge of new materials like coal, steel, and iron, but also the experience with a novel mass production system. In this case, institutions reacted supportively, by adopting encouraging policies that promoted inventions. Ultimately, these new techniques and skills were converted into advantages in industrialization later on. Our framework is able to rationalize these patterns within a single coherent framework.

Our methodology to analyze the pre-industrial intercontinental trade complements the earlier literature on global trade, which has focused mainly on trade since the nineteenth century, featuring the price convergence and the market integration (O'Rourke and Williamson, 2002, 2005). Although the 300-hundred-year trade boom resulting from the Voyages of Discovery is already well documented by historical literature, this chapter economically models the special pattern of directly swapping goods without any modern money measurement concept. O'Rourke and Williamson (2002) do build a quantitative model to decompose the causes of Europe's overseas trade boom between 1500 and 1800, but as McCants (2007) argues, they only use surplus income to measure the growth of the demand for imports in

Europe and completely ignore the changing preferences. Furthermore, the dynamics of taste in this chapter are modeled as affecting the production structure and causing specialization which is taken as a pure supply issue in most trade theories.

Our work also contributes a theory of trade and growth that is applied to the historical background of intercontinental trade. Most existing work on trade and growth focuses on the modern era and can be classified broadly into two strands of literature (see, e.g., Gancia and Zilibotti, 2005, for a survey): scale effects from the market integration (see, e.g., Rivera-Batiz and Romer, 1991; Devereux and Lapham, 1994) and product cycles driven by the process from imitation to innovation (see, e.g., Grossman and Helpman, 1991; Helpman, 1993). The former is more suitable for the trade among countries at similar development levels, while the latter is usually used in modern North-South models, so neither refers to the pre-industrial context. This chapter applies the standard model of technology diffusion (Howitt, 2000; Acemoglu *et al.*, 2006; Acemoglu, 2009) to historical trade. Europeans started from imitating through observation and physical contacts with Asian imports and ended up with innovation after reaching the Asian productivity level. Furthermore, in this chapter the dynamics of taste facilitate technology adoption, while Nelson and Phelps (1966) argue that this is related to human capital.

Our paper is closest in spirit to recent work by O'Rourke *et al.* (2019) who investigate the reasons for the great divergence during the 19th century and present a model of endogenous biased technological change and intercontinental trade that can rationalize the divergence. By focusing on the role of intercontinental trade mainly prior to the 19th century and investigating the role of trade exposure for taste dynamics, our work complements theirs in terms of focus and coverage, while being consistent with their assessment of the driving forces of growth. Other related work by Meyerheim *et al.* (2022) investigates the role of international relations in terms of trade, technology, and health, for long-run development and focuses on the conditionality of the effects depending on demographic development. In contrast, our work focuses on long-run dynamics and the role of cultural factors.

The structure of the remainder is as follows: Section 2.2 introduces the historical background in more detail. Section 2.4 models the consumer revolution by extending the baseline closed-economy model in Chapter 1 to intercontinental trade, and Section 2.5 compares the European economy in autarky and trade. Afterwards, Section 2.6 develops an endogenous growth model for the trade-inspired technological progress. Section 2.7 illustrates simulations of the taste dynamics and compares the generated aggregate income from the model with real data of the United Kingdom. Section 2.8 concludes, and analytical results and some proofs are presented in the Appendix.

2.2 Historical Background

This section provides a brief overview of boom in intercontinental trade during the period 1500–1800, and describes the transition from imitation to innovation, inspired by goods from the East. We illustrate the key aspects using several archetypal examples.

2.2.1 Intercontinental Trade

Following the European Voyage of Discovery, epitomized by Columbus' discovery of the Americas, intercontinental trade grew by a sustained annual growth rate of 1.1% from 1500 to 1800 (O'Rourke and Williamson, 2002; De Vries, 2015). Although this 1.1% growth appears small compared to the growth rate of international trade after 1820, it is still relatively high considering the contemporary Malthusian stagnation of income and population, and it can be translated to a 25-fold trade volume increase (O'Rourke and Williamson, 2002; De Vries, 2015). As Figure 2.1 shows, intercontinental trade grew actively from the 1580s (De Vries, 2003a).

During this period, around 90% of Asia's imports from Europe were silver (Pomeranz, 2009). Since the eleventh century, the over-issuing of paper money gradually destroyed China's monetary system, which left the country without a widely acceptable monetary medium by the middle of the fifteenth century (Pomeranz, 2009). As a solution, individual consumers firstly started using silver for transactions and as a monetary base (Flynn and Giráldez, 2002). This trend moved from the bottom up and was eventually institutionalized

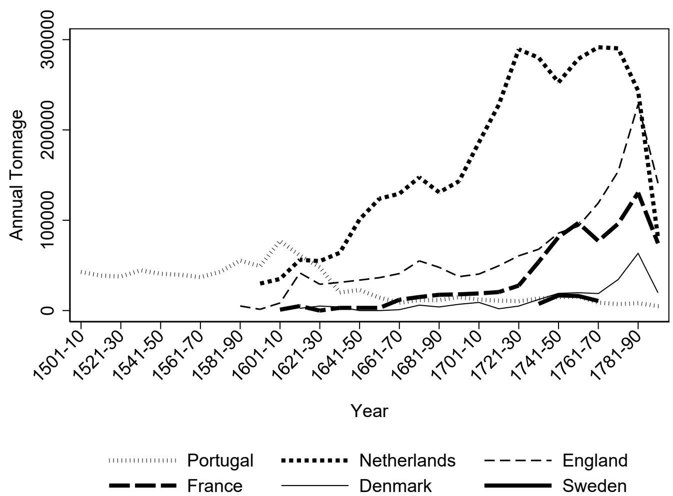

Figure 2.1: *Asia-bound Tonnage Estimates*

Sources: De Vries (2003a, p. 46–49), for each country, the author estimates the tonnage based on different original sources summarized by De Vries (2003a, p. 46–49)

as the "Single-Whip Tax Reform" of the 1570s, which "silverized" the economy by making silver the standard tax collection unit (Flynn and Giráldez, 1995). Given that China owned 40% of the world's economy but barely had any domestic silver supply, it acted like a "suction pump" (*bomba aspirante*) for silver (Godinho, 1963). Even with a self-sufficient society and the traditional Asian attitude of lacking interest in foreign goods, the relentless silver demand from a quarter of the world's population created major arbitrage opportunities and spurred new trade networks across the globe (Von Glahn, 2003).

Discovered by Europeans, the unprecedentedly rich mines in Latin America produced more than 80% of the world's silver from 1493 to 1800 (Barrett, 1990). In 1571, the city of Manila was founded, which built the direct link among all continents (Flynn and Giráldez, 2004). From then on, large amounts of American silver were flooding across the Pacific Ocean into the East, in exchange for luxury goods. Figure 2.2 depicts an upsurge of silver inventory in China during the trade period. It is worth mentioning that, silver should be treated as a luxury good in Asia based on the stock demand (Flynn and Giráldez, 2004, 2008; Pomeranz, 2009). Before the modern globalization from the 1820s (O'Rourke and Williamson, 2002), goods were swapped for goods in trade (Flynn and Giráldez, 2008). Silver was essentially a manufactured luxury product, where the West had an advantage in the endowment as well as the process of refinement (Pomeranz, 2009).

Figure 2.2: *Silver Inventory of Chinese Central Government*

Sources: Cao and Flynn (2019, p. 9–10), original sources are from Shi (2016) (Cao and Flynn, 2019, p. 10)

The 1500–1800 intercontinental trade was dominated by non-competing luxury goods, with high value-to-bulk ratios (O'Rourke and Williamson, 2002). Due to the high transport costs and the absence of substitutes in destination markets, the mark-ups of these goods stayed high, for example for silver in Asia and for Asian fancy goods in Europe (O'Rourke and Williamson, 2002). Nonetheless, trade was slowly restructuring markets, so the specific types of non-competing goods were changing since luxury goods often evolved into everyday necessities over time (Flynn and Giráldez, 2004), or imperfect substitutes occasionally appeared (Findlay and O'Rourke, 2003). It can be seen from Table 2.1 that the composition of main imports varied over time, implying that the definitions of basic and fancy goods were not constant. Evidences also support the taste-related explanations of the trade boom because the emergent European mercantilism could not effectively restrain the consumption due to the insistent demand (Mukerji, 1983; Perez-Garcia, 2019). In the eighteenth-century Mediterranean Spain, royal decrees were banning imports from China. However, the consumption of Chinese porcelain continued increasing in spite of the reduction of the official supply, due to demand-driven smuggling (Perez-Garcia, 2019).

Table 2.1: *Composition of the European Main Imports by Invoice Value (%)*

	Imports of VOC (Dutch East India Company)					
Items	1619–1621	1648–1650	1668–1670	1698–1700	1738–1740	1778–1780
Pepper	56.5	50.4	30.5	11.2	8.1	9.0
Other spices	17.6	17.9	12.1	11.1	6.1	3.1
Textiles	16.1	14.2	36.5	54.7	41.1	49.5
Tea and coffee	0.0	0.0	0.0	4.2	32.2	27.2
Drugs, perfumes and dye-stuffs	9.8	8.5	5.8	8.3	2.8	1.8
Sugar	0.0	6.4	4.2	0.2	3.7	0.6
Saltpeter	0.0	2.1	5.1	3.9	2.6	4.4
Metals	0.1	0.5	5.7	5.3	1.1	2.7
Miscellaneous	0.0	0.2	0.1	0.4	2.3	1.7
	Imports of EIC (English East India Company)					
Items	1668–1670	1698–1700	1738–1740	1758–1760		
Pepper	25.25	7.02	3.37	4.37		
Textiles	56.61	73.98	69.58	53.51		
Raw silk	0.6	7.09	10.89	12.27		
Tea	0.03	1.13	10.22	25.23		
Coffee	0.44	1.93	2.65	0.00		
Indigo	4.25	2.82	0.00	0.00		
Saltpeter	7.67	1.51	1.85	2.97		
Miscellaneous	5.15	4.52	1.44	1.65		

Sources: Findlay and O'Rourke (2003, p. 18), original sources are from Prakash (1998) and Steensgaard (1995) (Findlay and O'Rourke, 2003, p. 19)

Intercontinental trade between silver and Asian luxury goods gradually weakened from the beginning of the nineteenth century. Benefiting from the transport revolution and liberal trade policies in Europe (Williamson, 2011), the commodity price converged from 1820 (O'Rourke and Williamson, 2002). This price convergence completely switched trade towards basic goods and homogeneous bulk commodities like grain, animal products, and raw materials, which affected factor prices in a Heckscher-Ohlin style (O'Rourke and Williamson, 2005). Instead of silver, opium was imported by force in Asia from the late eighteenth century, ultimately leading to the Opium War in 1840 (Lin, 1990). Latin America was experiencing decolonization, and silver production dropped dramatically. In a nutshell, the world entered a new era, when luxury trade stopped and industrialization started.

2.2.2 From Imitation to Innovation

Imports of Asian luxury goods profoundly influenced European consumers who learnt about the existence of unheard-of products (De Vries, 2015). This led to a change in the patterns of consumption and the newly developed culture of consumption led to an increasing demand to imitate and produce these goods locally. The admiration for Asian arts and manufactures was expressed in encyclopedias and dictionaries. For example, Postlethwayt and Savary (1774) urged people to learn the Asian craftsmanship on textile, lacquer, and porcelain by observing imports (Berg, 2004, p. 125):

> "in whatever mechanical or manufactured arts other nations may excel Great Britain, our artists should be upon the watch, not only to imitate, but surpass, if possible... Those which are imported, and which they can see, handle and minutely examine, they are most like to imitate or excel".

Likewise, Englishmen like Thomas Smith realized the long-run advantage of producing domestically even with a higher short-run cost (Parthasarathi, 2002). At the state level, mercantilistic policies against imports were adopted to protect the local production.

According to Berg (2004), the precise Asian production process was not directly transferable as European merchants did not have access to actual producers, as factors of production were completely different in Europe and because copying the Asian production system proved also very complicated. Nevertheless, Europeans speculated how luxury goods were made and initiated experiments through observation on imported goods. They relied on available indigenous raw materials, and catered to the local taste via tailored designs. For instance, English imitators were obsessed with Chinese porcelain teapots but radically reformed them into silver objects due to limited budget and materials (Styles, 2000). What's more, rococo style and Greek classical mode ornamented British knock-offs of Asian ceramics (Berg, 2004). In the textile industry, the famous floral patterns of East Indian products were integrated into cloth designs, but European artisans also added indigenous Western elements while keeping the original botanic motifs (Lemire, 2003).

Institutions also took effective measures to improve the domestic industry. In 1754, William Shipley helped to found an art society which later became the Royal Society for the Encouragement of Arts, Manufactures and Commerce (RSA). From there on, "making the east in the west" was motivating Western world to discover local or colonial resources and develop domestic fancy products, in order to be less dependent on Asian imports (Berg, 2004, p. 135). The Society of Arts provided a premium to especially advocate import substitutes. For example, a reward was issued for the improvement in varnish corresponding to the Asian lacquer in 1758 and 1763 (Berg, 2002). Meanwhile, the patent system was also developed in Europe. The British patent history originated from 1624, albeit France did not pass a patent act until 1791. Berg (2002) finds that from 1627 to 1825, imitation was frequently mentioned in British patents.

While attempting to imitate, Europeans created new production systems based on indigenous raw materials such as coal and alloys. Like Hume (1742) summarizes (Berg, 2004, p. 130):

> "foreign trade has preceded any refinement in home manufactures, and given birth to domestic luxury... It rouses men from their indolence; and, presenting the gayer and more opulent part of the nation with objects of luxury which they never before dreamed of, raises in them a desire of a more splendid way of life than what their ancestors enjoyed... Imitation soon diffuses all those arts, while domestic manufactures emulate the foreign in their improvements, and work up every home commodity to the utmost perfection of which it is susceptible. Their own steel and iron, in such laborious hands, become equal to gold an rubies of the Indies".

Steel and iron not only worked as alternatives in the luxury production, but also functioned as the main materials in machinery. As a result, new processing techniques for steel and iron, which were learned from imitating Asian manufactured products, helped Europeans in subsequent industrialization.

2.2.3 An Example: Cotton

The cotton industry is a typical example experiencing the entire process of intercontinental trade, imitation, and innovation. It also played a vital role in the British Industrial Revolution

(Mukerji, 1983; Lemire, 1991; Lemire and Riello, 2008; Riello, 2009; Berg, 2013).

Wool had always been the traditional textile in England until the intercontinental trade boom when Britons had access to fabrics from the East (Mukerji, 1983). Founded in 1600, the East India Company firstly brought India calicoes to the British market, which initiated the new fashion trend. The permanent color, washability, lightness, and design (Riello, 2009) made Indian calico highly competitive in clothing and interior decoration (Lemire, 2003). Moreover, the low price allowed all social classes to be involved in the consumer revolution (Riello, 2009). Defoe described this in 1708: "everything that used to be made of wool or silk, relating either to the dress of the women or the furniture of our houses, was supplied by the Indian trade" (Lemire, 1991, p. 16). In 1664, imports of calicoes accounted for 73% of the English East India Company's trade volume (Lemire, 1991), and afterwards, the amount of imports increased by more than ten times until the end of the trade boom. Figure 2.3 delineates the textile imports of the English and Dutch East India Companies. Since 1680, the imported Indian calicoes dominated the European textile market, regarded as the "calico craze" (Rothstein, 1964; Douglas, 1969; Mukerji, 1983; Lemire, 1991).

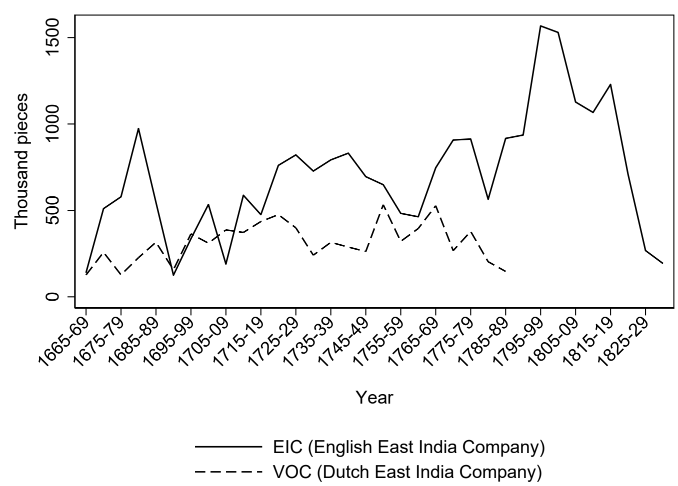

Figure 2.3: *Textile Imported from Asia by EIC and VOC*

Sources: Riello (2009, p. 265), original sources are summarized by Riello (2009, p. 265)

The "calico craze" gradually drew political attention due to its threats to the domestic textile industry (Mukerji, 1983; Riello, 2009). Mercantilist policies were quickly developed to firstly limit them with high duties, and then ban the imported Indian calicoes (Lemire and Riello, 2008). Following the first bill proposed by the House of Commons issued in 1696, the first act for the prohibition of Indian manufactures was enacted in 1701, which only allowed imports of some unfinished materials. In 1721 a total ban on all kinds of cotton textiles came into effect (Lemire, 1991). Despite the fact that smuggling was still active, the overseas competitive threat was officially removed. However, the "calico craze" still existed and even flourished. Without any local substitutes, the growing demand for the new fashion inevitably caused a "calico crisis", so Britons developed their own cotton industry to solve this social problem (Mukerji, 1983).

The 1721 Act prohibited imports of finished cotton, but it did not apply to goods produced domestically, which actually stimulated imitation in Europe (Wadsworth and Mann, 1931). Riello (2009) agrees that the ban did affect the production side much stronger than the consumption side. During the eighteenth century, Britons were striving for mechanical and chemical solutions to create a comparable product: Machines were invented in textile manufacturing for spinning and weaving. Chemical experiments were implemented to improve bleaching, printing and dyeing methods (Mukerji, 1983). Until 1776 some people still thought that the domestic supply was far behind demand (Lemire, 1991), but the production rocketed in the last quarter of the eighteenth century. Evidences are graphed in Figure 2.4, where the British local cotton industry grows dramatically from almost zero, quickly replacing the foreign cotton which have dominated the market.

Subsequently, the cotton industry started exploring the new overseas market after satisfying the domestic demand. Figure 2.5 plots a comparison of the development of cotton and wool exports. The cotton exports were minor for a long period, but eventually surpassed wool which had been the traditional textile exports for centuries. Britons not only permanently solved the fashion problem, but also developed a completely new mass production system, from which industrialization began.

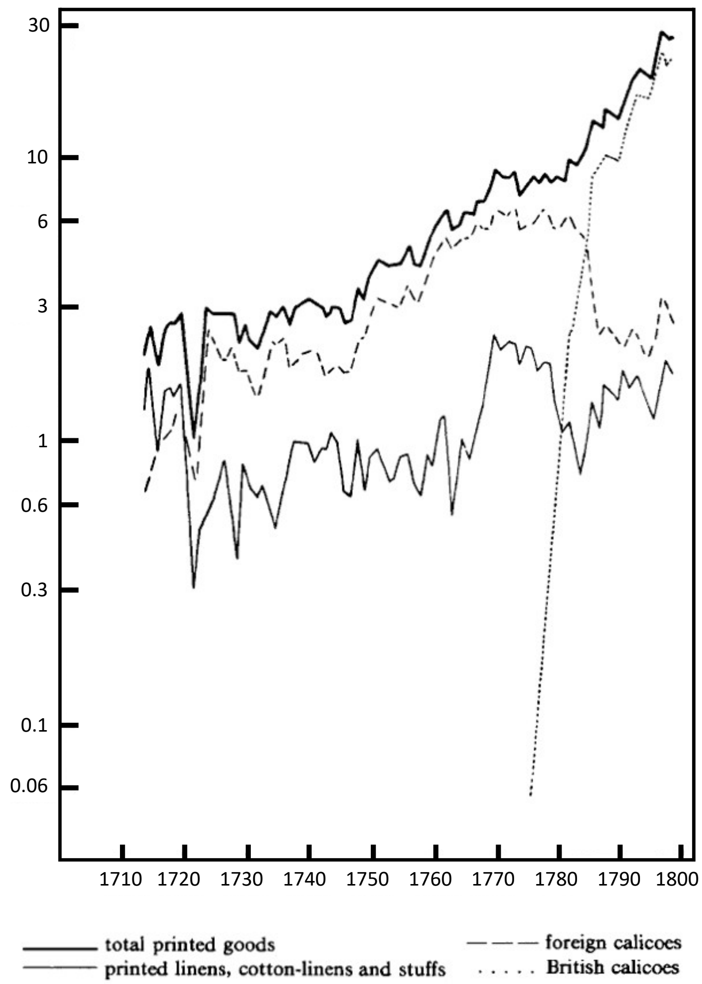

Figure 2.4: *Printed Goods Charged with Duty (yards ($\times 10^6$))*

Sources: Mukerji (1983, p. 239), original sources are summarized by Mukerji (1983, p. 239)

2.2.4 Other Examples

In addition to cotton, other contemporary industries experienced similar trends, like porcelain and silk.

The production techniques of the Asian porcelain were even more complicated than cotton, but the influences were equally significant (Berg, 2004). During the seventeenth and eighteenth century, porcelain was one of the most regular goods transported by the East Indian Companies (Gerritsen and McDowall, 2012). Chinese porcelain was produced

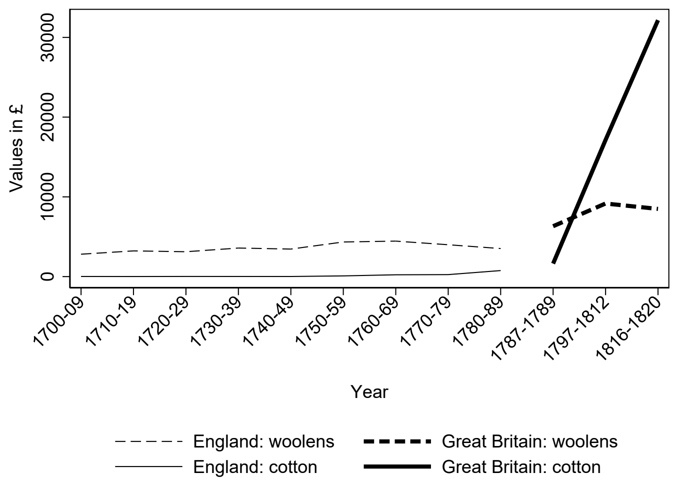

Figure 2.5: *Exports of Woolens and Cotton*

Sources: Deane and Cole (1962, p. 59) and Riello (2009, p. 285), original sources are summarized by Deane and Cole (1962, p. 59) and Riello (2009, p. 285)

in a single center, Jingdezhen, which was far from the coast and relatively enclosed, so copying the production process was almost impossible. Nevertheless, stimulated by the demand from the "demonstration effect" (De Vries, 2015), adaption and experimentation with available input factors like coal instead of wood fuel were employed (Berg, 2004). In 1710, the first true hard-paste porcelain was finally created in Meissen, symbolizing the end of China's monopoly which had lasted for more than one thousand years (Gerritsen and McDowall, 2012). The following earthenware (e.g. Staffordshire) and creamware (e.g. Wedgwood) were even cheaper and decorated with more classical designs (Berg, 2004). With the increasing price of Chinese porcelain after 1750, European producers obtained the nearly full market share since the beginning of the nineteenth century (De Vries, 2015).

Silk is another example for the process from imitation to innovation. While the cotton fashion only started from the trade boom, Asian silk had slowly arrived in Europe through what was known as the Silk Road since the century 1 CE. Therefore, the silk industry had already been established in several production centers in Europe by the beginning of the global trade boom (Farrell, 2014). However, Asian silk was quickly introduced into Europe through the newly built trade routes, which reshaped both the European consumer taste and the production system. To compete with the silk from the East, local European silk producers improved quality and styles, gradually marginalizing Asian imports (De Vries, 2015). Different from the innovation of the cotton production that focused on the finishing process, the main technical improvement in the silk industry was the cultivation of raw silk (Farrell, 2014). The Society of Arts even tried to produce raw silk in the New World to substitute imports from the East.

2.3 A Simple Model of Two World Regions in Autarky

2.3.1 The European Economy in Autarky

The model of the European economy in autarky resembles the same setup as in Section 1.3. For completeness, we briefly recall the most important features.

Consumption. The model is based on distinct preferences for necessities (denoted "basic goods") and luxuries (denoted "fancy goods"). There are two taste traits, high taste h and low taste l, and each individual carries either of them. The intensity of the preference for fancy goods relative to the preference for basic goods is defined as taste. High-taste individuals have a stronger preference for fancy goods, with the relative taste level $\alpha_t > 1$, while for low-taste individuals this level always equals one. The share of high-taste individuals of generation t is q_t. Taste originates from parental cultivation. Individuals are altruistic, thus deriving utility not only from goods, but also from the taste of their children. Hence, besides the consumption of goods, individuals also have to decide how much effort $e_{l,t}$ or $e_{h,t}$ they want to invest in cultivating their children's taste. Taste transmission is stochastic, and the parental cultivation effort positively and linearly affects the probability of children having high taste. The cost of the cultivation effort is directly translated into a monetary loss and while parents enjoy having high-taste children, a higher probability of having high-taste children implies higher costs.

Production. Production takes place in two sectors, the basic-good sector and the fancy-good sector, and labor is the only factor of production in both sectors. Individuals are homogeneous in the labor market as taste differences do not affect the productivity in both sectors, but the sectors differ in terms of their respective technology. We assume constant returns to labor in the fancy-good sector and diminishing returns to labor in the basic-good sector. Intuitively, the basic-good sector is assumed to represent a harder, less pleasant working environment than the fancy-good sector. Technically, the linear production function in the fancy-good sector implies that any increase in demand can be satisfied because labor can shift to the fancy-good sector.

Equilibrium. For any generation t, given the share of high-taste individuals q_t and the relative taste level of high-taste individuals α_t, there exists a unique equilibrium share of labor in the fancy-good sector, as discussed in detail in Section 1.3.

2.3.2 The Asian Economy in Autarky

This section models the Asian economy in autarky. Although it does not have any global effects, this baseline model lays a foundation for the trade model in Section 2.4.2 below. Moreover, it provides a benchmark for the comparison between the autarky and trade equilibrium of the Asia economy.

Consumption. There is no heterogeneity among Asian consumers for simplicity, so each individual values basic goods b and fancy goods f equally. The consumer preference is static. In addition, each individual has one child asexually, and the total population size is normalized to one. In the following, we use the superscript "AA" for variables of the Asian economy in the autarky model. Therefore, the utility maximization problem of a representative Asian consumer is characterized as

$$\max_{b_t^{AA},\, f_t^{AA}} \ln b_t^{AA} + \ln f_t^{AA} \tag{2.1}$$

$$\text{s.t.} \quad P_{b,t}^{AA} \cdot b_t^{AA} + P_{f,t}^{AA} \cdot f_t^{AA} = m_t^{AA}. \tag{2.2}$$

$P_{b,t}^{AA}$ is the price of basic goods, while $P_{f,t}^{AA}$ is the price of fancy goods.[2] m_t^{AA} is the income individuals get from their homogeneous labor supply. The interior solutions are

$$b_t^{AA*} = \frac{m_t^{AA}}{2P_{b,t}^{AA}} \quad \text{and} \quad f_t^{AA*} = \frac{m_t^{AA}}{2P_{f,t}^{AA}}.$$

Production. The production patterns of both sectors in Asia are the same as in the European economy in the autarky model. The total labor supply equals the total population size which is normalized to one. Labor is the only factor of production, with diminishing returns in the basic-good sector and constant returns in the fancy-good sector. The share of labor in the fancy-good sector is denoted by $n_{f,t}^{AA}$. So the production functions of both sectors are defined as

$$Y_{b,t}^{AA} = B^A \left(1 - n_{f,t}^{AA}\right)^{\beta^A}, \quad 0 < \beta^A < 1; \tag{2.3}$$

$$Y_{f,t}^{AA} = F^A \cdot n_{f,t}^{AA}. \tag{2.4}$$

B^A and F^A are constant production parameters of the Asian economy, while β^A ensures diminishing returns.[3] The competitive wage in the basic-good and fancy-good sector is

$$w_{b,t}^{AA} = \frac{P_{b,t}^{AA} \cdot Y_{b,t}^{AA}}{1 - n_{f,t}^{AA}} = P_{b,t}^{AA} \cdot B^A \left(1 - n_{f,t}^{AA}\right)^{\beta^A - 1}; \tag{2.5}$$

$$w_{f,t}^{AA} = \frac{\partial \left(P_{f,t}^{AA} \cdot Y_{f,t}^{AA}\right)}{\partial n_{f,t}^{AA}} = P_{f,t}^{AA} \cdot F^A. \tag{2.6}$$

[2] The superscript "AA" is used for variables of the Asian economy in the autarky model to distinguish from the related variables in the trade model in Section 2.4.2.

[3] The superscript "A" is used for constant parameters of the Asian economy to distinguish from the related parameters of the European economy.

As labor is homogeneous in the economy, the wages in both sectors, $w_{b,t}^{AA}$ and $w_{f,t}^{AA}$, are equal to each other. Thus, $P_{f,t}^{AA}$ expressed in terms of $P_{b,t}^{AA}$ is

$$P_{f,t}^{AA} = \frac{P_{b,t}^{AA} \cdot B^A \left(1 - n_{f,t}^{AA}\right)^{\beta^A - 1}}{F^A}. \tag{2.7}$$

Moreover, homogeneous individuals of generation t receive the amount of income

$$m_t^{AA} = w_{b,t}^{AA} = P_{b,t}^{AA} \cdot B^A \left(1 - n_{f,t}^{AA}\right)^{\beta^A - 1}, \tag{2.8}$$

similar to Eq. (1.10) in Chapter 1.

Equilibrium. In the competitive Asian market, the market clearing in both sectors leads to Lemma 1.

LEMMA 1 (Equilibrium of the Asian Economy in the Autarky Model)**.** *In the autarky model, for any generation t in Asia, the equilibrium share of labor in the fancy-good sector is*

$$n_{f,t}^{AA*} = \frac{1}{2}. \tag{2.9}$$

Proof. In the fancy-good sector, with the price $P_{f,t}^{AA}$ in Eq. (2.7) and the income m_t^{AA} in Eq. (2.8), the aggregate demand is $f_t^{AA*} = \frac{F^A}{2}$. The equilibrium share of labor in the fancy-good sector $n_{f,t}^{AA*} = \frac{1}{2}$ is solved from the market clearing condition $\frac{F^A}{2} = F^A \cdot n_{f,t}^{AA}$ $\square$

With the equilibrium $n_{f,t}^{AA*} = \frac{1}{2}$, if the price of basic goods is normalized as $P_{b,t}^{AA} = 1$, the aggregate income based on Eq. (2.8) will be

$$Y_t^{AA} = 2B^A \left(\frac{1}{2}\right)^{\beta^A} \tag{2.10}$$

which is constant. Appendix B.1.3 shows how intercontinental trade adds dynamics to the aggregate income of the Asian economy.

2.4 A Model of Intercontinental Trade

The burgeoning intercontinental trade provided European consumers with access to a large amount of exotic luxury goods, significantly contributing to the consumer revolution. This chapter complements and extends the baseline autarky model sketched in the previous section and analyzed in Chapter 1 to a two-region trade model and demonstrates the dynamics of taste in the context of an open economy setting. The analysis is meant to rationalize development patterns in two regions that represent the historical patterns of trade between Europe and Asia.

The model is based two different consumption goods, "basic goods" that reflect necessities that cover the basic needs of individuals, and refined goods (denoted "fancy goods") that represent luxuries. As discussed previously, we assume that the two economies differ in terms of comparative advantage. In particular, consistent with the historical accounts, we assume that Europeans were preoccupied with fancy goods from Asia because they did not have a comparable capacity to produce substitutes. At the same time, however, Europeans discovered rich silver mines in Latin America during the Voyage of Discovery. This coincidence made it possible to fulfill the strong and stable demand for silver in Asia, therefore providing a perfect environment for intercontinental trade. We model silver as a further product in the model according to the literature (see, e.g., Flynn and Giráldez, 2004, 2008; Pomeranz, 2009). The silver commodity was needed as a means of exchange in Asia as consequence of the break-down of the monetary system. For simplicity, we implement this as silver being a consumable commodity in Asia. Because silver is produced by Europeans but consumed by Asians, it affects the production structure in Europe and complicates the consumer preference in Asia, compared to the model in autarky sketched in the previous section and analyzed in Chapter 1. In addition, we assume that basic goods are always domestically produced and not involved in trade. Domestic labor is the only factor of production in both regions and in all sectors.

2.4.1 Intercontinental Trade: The European Economy

The model setup is similar to the setup in Chapter 1, with superscript ET referring to variables of the European economy. Individuals are divided into two groups based on their taste traits. The taste level of high-taste individuals relative to low-taste individuals is α_t^{ET}, with the taste level of low-taste individuals normalized to one.[4] The share of high-taste individuals of generation t is denoted by q_t^{ET}. The population size is constant and reproduction is asexual. We normalize the population size to 1 as each individual only has one child. In the labor market, labor is homogeneous and all individuals of generation t receive the same amount of labor income m_t^{ET} by supplying labor inelastically.

Production. The open European economy is comprised by three sectors of production: the basic-good sector, the fancy-good sector, and the silver sector. Given that basic goods are not traded with Asia and that silver guarantees the existence of intercontinental trade, the share of labor in these two sectors, $n_{b,t}^{ET}$ and $n_{s,t}^{ET}$, must be strictly positive. However, the share of labor in the fancy-good sector, $n_{f,t}^{ET}$, can be zero if Europeans exclusively depend on imports for fancy goods. The production function of the basic-good sector exhibits decreasing returns whereas the production in the fancy-good sector exhibits constant returns, replicating the setup as in Eq. (1.5) and Eq. (1.6) in Chapter 1. In addition, the silver sector exhibits constant returns to labor with a production parameter $S > 0$. The production functions of the three sectors are then

$$Y_{b,t}^{ET} = B\left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{\beta}, \quad 0 < \beta < 1; \tag{2.11}$$

$$Y_{f,t}^{ET} = F \cdot n_{f,t}^{ET}; \tag{2.12}$$

$$Y_{s,t}^{ET} = S \cdot n_{s,t}^{ET}. \tag{2.13}$$

[4] The superscript "ET" is used for variables of the European economy in the trade model to distinguish from related variables in the autarky model in Chapter 1.

In each sector, the competitive wage is

$$w_{b,t}^{ET} = \frac{P_{b,t}^{ET} \cdot Y_{b,t}^{ET}}{1 - n_{f,t}^{ET} - n_{s,t}^{ET}} = P_{b,t}^{ET} \cdot B \left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{\beta - 1}; \tag{2.14}$$

$$w_{f,t}^{ET} = \frac{\partial \left(P_{f,t}^{ET} \cdot Y_{f,t}^{ET}\right)}{\partial n_{f,t}^{ET}} = P_{f,t}^{ET} \cdot F; \tag{2.15}$$

$$w_{s,t}^{ET} = \frac{\partial \left(P_{s,t}^{ET} \cdot Y_{s,t}^{ET}\right)}{\partial n_{s,t}^{ET}} = P_{s,t}^{ET} \cdot S. \tag{2.16}$$

Equalizing wages in the basic-good sector in Eq. (2.14) and the fancy-good sector in Eq. (2.15) gives the price of fancy goods $P_{f,t}^{ET}$, expressed in terms of the price of basic goods $P_{b,t}^{ET}$, similar to Eq. (1.9) in Chapter 1:

$$P_{f,t}^{ET} = \frac{P_{b,t}^{ET} \cdot B \left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{\beta - 1}}{F}. \tag{2.17}$$

The price of silver in terms of the price of basic goods is derived by equalizing Eq. (2.14) and Eq. (2.16):

$$P_{s,t}^{ET} = \frac{P_{b,t}^{ET} \cdot B \left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{\beta - 1}}{S}. \tag{2.18}$$

At last, the individual income m_t^{ET} is

$$m_t^{ET} = w_{b,t}^{ET} = P_{b,t}^{ET} \cdot B \left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{\beta - 1}. \tag{2.19}$$

In the setting with trade, in the European fancy-good market the domestic competitive price of fancy goods can not be lower than the price of Asian imports. Otherwise, Europeans would be self-sufficient in the fancy-good sector and intercontinental trade would not exist. An iceberg trade cost $\tau > 1$ is introduced to adjust the price of imports, meaning that Europeans need to buy τ units of fancy goods from Asia for every one unit of fancy goods to arrive in Europe. With $P_{f,t}^{AT}$ denoting the competitive price of fancy goods in Asia, the price of imports in the European market becomes $\tau \cdot P_{f,t}^{AT}$. The following condition is imposed on the trade model.

PROPOSITION 4 (The Condition for Intercontinental Trade)**.** *If* $\tau \cdot P_{f,t}^{AT} \leq P_{f,t}^{ET}$*, the production* *in the fancy-good sector in Europe is zero and the consumption of fancy goods in Europe completely depends on Asian imports, implying that*

$$n_{s,t}^{ET} \leq \frac{F^A}{\tau \cdot F} - \frac{2\tau}{\alpha^A \cdot S}. \tag{2.20}$$

Proof. See Appendix B.2.1. □

The threshold value depends on the trade cost and production parameters of both regions. When the European productivity in the fancy-good sector F is low relative to the Asian productivity, meaning that $\frac{F^A}{\tau \cdot F} - \frac{2\tau}{\alpha^A \cdot S}$ is high, Europeans can shift more labor into the silver sector because the price difference is large. The same mechanism works when the Asian fancy-good productivity F^A or the European silver productivity S is high. With regard to the effects from the trade cost, the maximum amount of labor in the silver sector will decrease when τ increases. When there is no local production of fancy goods in Europe, $n_{f,t}^{ET} = 0$, the competitive wage in the fancy-good sector $w_{f,t}^{ET}$ in Eq. (2.15) and the price of fancy goods $P_{f,t}^{ET}$ in Eq. (2.17) will be dropped from the system.[5]

Consumption. The consumer preference follows the baseline model in Chapter 1. Individuals derive utility from the consumption of basic goods b, fancy goods f, and the taste of their children, thus making the optimal consumption and cultivation choices. The cultivation effort $e_{l,t}^{ET}$ and $e_{l,t}^{ET}$ of low-taste and high-taste individuals generates the expected taste level of their children:

$$\mathbb{E}_{l,t}^{ET} = \mathbb{P}_{l,t}^{ET} \cdot \alpha_t^{ET} + \left(1 - \mathbb{P}_{l,t}^{ET}\right) \cdot 1 = e_{l,t}^{ET} \cdot \frac{q_t^{ET}}{q_t^{ET} + 1} \left(\alpha_t^{ET} - 1\right) + 1;$$
$$\mathbb{E}_{h,t}^{ET} = \mathbb{P}_{h,t}^{ET} \cdot \alpha_t^{ET} + \left(1 - \mathbb{P}_{h,t}^{ET}\right) \cdot 1 = e_{h,t}^{ET} \cdot \frac{q_t^{ET}}{q_t^{ET} + 1} \left(\alpha_t^{ET} - 1\right) + 1,$$

[5]In reality, intercontinental trade happened because Asia had an advantage in the fancy-good sector, so that the condition the trade in Eq. (2.20) could always be fulfilled.

where the probability of children having high taste $\mathbb{P}_{l,t}^{ET}$ and $\mathbb{P}_{h,t}^{ET}$ is defined as

$$\mathbb{P}_{l,t}^{ET} = e_{l,t}^{ET} \cdot \frac{q_t^{ET}}{q_t^{ET}+1};$$
$$\mathbb{P}_{h,t}^{ET} = e_{h,t}^{ET} \cdot \frac{q_t^{ET}}{q_t^{ET}+1}.$$

Similar to Eq. (1.3) and Eq. (1.4) in the autarky model, the utility function of low-taste and high-taste individuals is

$$u_{l,t}^{ET} = \ln b_{l,t}^{ET} + \ln f_{l,t}^{ET} + \gamma \cdot \ln \mathbb{E}_{l,t}^{ET}; \tag{2.21}$$
$$u_{h,t}^{ET} = \ln b_{h,t}^{ET} + \alpha_t^{ET} \cdot \ln f_{h,t}^{ET} + \gamma \cdot \alpha_t^{ET} \cdot \ln \mathbb{E}_{h,t}^{ET}, \tag{2.22}$$

where $\alpha_t^{ET} > 1$ indicates the difference between the two groups of generation t.

For European consumers the price of basic goods is denoted by $P_{b,t}^{ET}$. Based on the condition for trade from Proposition 4, there are no domestic fancy goods in Europe. So the price of fancy goods in the European market is equal to the price of imports $\tau \cdot P_{f,t}^{AT}$. This leads to the budget constraint of high-taste and low-taste consumers:

$$P_{b,t}^{ET} \cdot b_{l,t}^{ET} + \tau \cdot P_{f,t}^{AT} \cdot f_{l,t}^{ET} + \tau \cdot P_{f,t}^{AT} \cdot k \cdot e_{l,t}^{ET} = m_t^{ET}; \tag{2.23}$$
$$P_{b,t}^{ET} \cdot b_{h,t}^{ET} + \tau \cdot P_{f,t}^{AT} \cdot f_{h,t}^{ET} + \tau \cdot P_{f,t}^{AT} \cdot k \cdot e_{h,t}^{ET} = m_t^{ET}. \tag{2.24}$$

The interior solutions to the individual optimization problems of European consumers in the trade model are derived in Appendix B.2.2. $b_{l,t}^{ET*}$, $f_{l,t}^{ET*}$, and $e_{l,t}^{ET*}$ are the optimal choices of low-taste individuals, and $b_{h,t}^{ET*}$, $f_{h,t}^{ET*}$, and $e_{h,t}^{ET*}$ are for high-taste individuals. The resulting aggregate demand is

$$D_{b,t}^{ET} = q_t^{ET} \cdot b_{h,t}^{ET*} + \left(1 - q_t^{ET}\right) b_{l,t}^{ET*};$$
$$D_{f,t}^{ET} = q_t^{ET} \left(f_{h,t}^{ET*} + k \cdot e_{h,t}^{ET*}\right) + \left(1 - q_t^{ET}\right) \left(f_{l,t}^{ET*} + k \cdot e_{l,t}^{ET*}\right)$$

for basic goods and fancy goods respectively.

2.4.2 Intercontinental Trade: The Asian Economy

The Asian economy in trade is an extension of the Asian economy in autarky described in Section 2.3.2.

Consumption. In the two-region trade model, Asians import silver, which can not be produced domestically. To reflect the demand for silver that was driven by historical domestic reasons (the breakdown of the monetary system in China) in the simplest possible way, we assume that Asians derive utility from silver in a quasi-linear manner, in addition to utility from basic goods and fancy goods. The original utility maximization problem in Eq. (2.1) in the autarky model is thus expanded as

$$\max_{b_t^{AT},\, f_t^{AT},\, s_t^{AT}} \ln b_t^{AT} + \ln f_t^{AT} + \alpha^A \cdot s_t^{AT} \tag{2.25}$$

with $\alpha^A > 0$ denoting the (time-invariant) preference for silver.[6] The Asian economy is self-sufficient in the basic-good and fancy-good sector, so consumers face the local price of basic goods $P_{b,t}^{AT}$ and fancy goods $P_{f,t}^{AT}$. However, silver is entirely imported based on the European competitive price $P_{s,t}^{ET}$, and the same iceberg trade cost $\tau > 1$ is introduced to adjust the price in the Asian market. Besides, as individuals are homogeneous in the labor market and thus receive the same amount income m_t^{AT}, the budget constraint of Asian consumers is

$$P_{b,t}^{AT} \cdot b_t^{AT} + P_{f,t}^{AT} \cdot f_t^{AT} + \tau \cdot P_{s,t}^{ET} \cdot s_t^{AT} = m_t^{AT}. \tag{2.26}$$

The interior solutions to the utility maximization problem are

$$b_t^{AT*} = \frac{\tau \cdot P_{s,t}^{ET}}{\alpha^A \cdot P_{b,t}^{AT}}, \quad f_t^{AT*} = \frac{\tau \cdot P_{s,t}^{ET}}{\alpha^A \cdot P_{f,t}^{AT}}, \quad \text{and} \quad s_t^{AT*} = \frac{m_t^{AT}}{\tau \cdot P_{s,t}^{ET}} - \frac{2}{\alpha^A}$$

conditional on $m_t^{AT} > \frac{2\tau \cdot P_{s,t}^{ET}}{\alpha^A}$. Appendix B.1.2 proves that this condition holds in the trade equilibrium.

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[6]The superscript "*AT*" is used for variables of the Asian economy in the trade model to distinguish from related variables in the autarky model in Section 2.3.2. The superscript "*A*" is used for constant parameters of the Asian economy to distinguish from the related parameters of the European economy.

Production. The Asian economy produces basic goods and fancy goods, using labor as the only production factor. As the total amount of labor directly comes from the population size which is normalized to one, the share of labor in the fancy-good and basic-good sector is $n_{f,t}^{AT}$ and $1 - n_{f,t}^{AT}$. All production parameters remain identical compared to the autarky model in Section 2.3.2, so the production functions are similar to Eq. (2.3) and Eq. (2.4) in the autarky model:

$$Y_{b,t}^{AT} = B^A \left(1 - n_{f,t}^{AT}\right)^{\beta^A}, \quad 0 < \beta^A < 1; \tag{2.27}$$

$$Y_{f,t}^{AT} = F^A \cdot n_{f,t}^{AT}. \tag{2.28}$$

Competitive wages in both sectors follow Eq. (2.5) and Eq. (2.6) in the autarky model:

$$w_{b,t}^{AT} = \frac{P_{b,t}^{AT} \cdot Y_{b,t}^{AT}}{1 - n_{f,t}^{AT}} = P_{b,t}^{AT} \cdot B^A \left(1 - n_{f,t}^{AT}\right)^{\beta^A - 1}; \tag{2.29}$$

$$w_{f,t}^{AT} = \frac{\partial \left(P_{f,t}^{AT} \cdot Y_{f,t}^{AT}\right)}{\partial n_{f,t}^{AT}} = P_{f,t}^{AT} \cdot F^A. \tag{2.30}$$

The price of fancy goods $P_{f,t}^{AT}$ is derived by equalizing Eq. (2.29) and Eq. (2.30), parallel to the price $P_{f,t}^{AA}$ in Eq. (2.7) in the autarky model:

$$P_{f,t}^{AT} = \frac{P_{b,t}^{AT} \cdot B^A \left(1 - n_{f,t}^{AT}\right)^{\beta^A - 1}}{F^A}. \tag{2.31}$$

Finally, the individual income m_t^{AT} follows the expression of m_t^{AA} in (2.8) in the autarky model:

$$m_t^{AT} = P_{b,t}^{AT} \cdot B^A \left(1 - n_{f,t}^{AT}\right)^{\beta^A - 1}. \tag{2.32}$$

2.4.3 Intercontinental Trade: Equilibrium

The global general equilibrium is shaped by the intertwined economic activities between Europe and Asia. The equilibrium of the Asian economy is derived as dependent on the European economy which is driven by the taste dynamics of European consumers.

Equilibrium of the Asian Economy. The aggregate demand for basic goods in Asia equals the optimal consumption b_t^{AT*} since the population size is normalized to one. The market clearing requires that the consumption is covered by the local production of basic goods $Y_{b,t}^{AT}$:

$$\frac{\tau \cdot P_{s,t}^{ET}}{\alpha^A \cdot P_{b,t}^{AT}} = B^A \left(1 - n_{f,t}^A\right)^{\beta^A}.$$

In addition, the aggregate consumption of silver in Asia s_t^{AT*} should be satisfied by the total silver production adjusted by the iceberg trade cost τ. With the aggregate supply in Asia $\frac{Y_{s,t}^{ET}}{\tau}$, the market clearing in the silver sector is achieved by

$$\frac{m_t^{AT}}{\tau \cdot P_{s,t}^{ET}} - \frac{2}{\alpha^A} = \frac{S \cdot n_{s,t}^{ET}}{\tau}.$$

These two conditions pinpoint the equilibrium share of labor in the fancy-good sector of the Asian economy. It is derived as a function of the share of labor in the silver sector, characterized in Lemma 1′.

LEMMA 1′ (Equilibrium of the Asian Economy in the Trade Model)**.** *In the intercontinental trade model, for any generation t in Asia, the equilibrium share of labor in the fancy-good sector is*

$$n_{f,t}^{AT*} = \frac{\alpha^A \cdot S \cdot n_{s,t}^{ET} + \tau}{\alpha^A \cdot S \cdot n_{s,t}^{ET} + 2\tau} \tag{2.33}$$

$$\textit{with} \quad \tau > 1, \quad \alpha^A > 0, \quad \textit{and} \quad S > 0.$$

Proof. See Appendix B.1.1. □

As long as Asia participates in trade, the Asian economy in equilibrium will not be independent of the dynamics in Europe. Because $n_{f,t}^{AT*}$ increases with $n_{s,t}^{ET}$, the fancy-good sector of Asia will expand if there are more workers in the silver sector of the European economy.

Equilibrium of the European Economy. In Europe, individuals are self-sufficient in the basic-good sector with $D_{b,t}^{ET} = Y_{b,t}^{ET}$, while the aggregate consumption of fancy goods $D_{f,t}^{ET}$ is entirely supported by imports. Considering the aggregate demand for fancy goods in Asia

f_t^{AT*} and the trade cost τ, the amount of Asian products that enter Europe is $\frac{Y_{f,t}^{AT}-f_t^{AT*}}{\tau}$. So the market clearing in Europe implies

$$q_t^{ET} \cdot b_{h,t}^{ET*} + \left(1 - q_t^{ET}\right) b_{l,t}^{ET*} = B\left(1 - n_{s,t}^{ET}\right)^{\beta};$$
$$q_t^{ET}\left(f_{h,t}^{ET*} + k \cdot e_{h,t}^{ET*}\right) + \left(1 - q_t^{ET}\right)\left(f_{l,t}^{ET*} + k \cdot e_{l,t}^{ET*}\right) = \frac{Y_{f,t}^{AT} - f_t^{AT*}}{\tau}.$$

The resulting general equilibrium in the context of intercontinental trade is summarized in Proposition 1′, corresponding to the autarky equilibrium in Proposition 1.

PROPOSITION 1′ (Equilibrium of the European Economy in the Trade Model)**.** *In the intercontinental trade model, for any generation t in Europe, given the share of high-taste individuals q_t^{ET} and the relative taste level of high-taste individuals α_t^{ET}, the unique equilibrium share of labor in the silver sector is*

$$n_{s,t}^{ET*} = N_s^{ET}\left(\alpha_t^{ET},\, q_t^{ET}\,;\, \tau,\, \gamma,\, \alpha^A,\, k,\, S,\, F^A\right) \tag{2.34}$$

with

$$\tau > 1, \quad \gamma > 0, \quad \alpha^A > 0, \quad k > 0, \quad S > 0, \quad \text{and} \quad F^A > 0.$$

In addition, it must hold that

$$\frac{\partial n_{s,t}^{ET*}}{\partial \alpha_t^{ET}} > 0 \quad \text{and} \quad \frac{\partial n_{s,t}^{ET*}}{\partial q_t^{ET}} > 0.$$

Proof. See Appendix B.2.3. □

According to Lemma 1′, $n_{s,t}^{ET}$ affects the equilibrium labor allocation in Asia. Therefore, the Asian economy adjusts to the equilibrium of the European economy which is driven by European taste variables q_t^{ET} and α_t^{ET}.

2.4.4 Dynamics of the European Economy

This section shows that the dynamics of the autarky equilibrium in Chapter 1 also work in the trade equilibrium through similar mechanisms.

Taste Transmission. The optimal cultivation choice of generation t determines the share of high-taste individuals of generation $t+1$, as in the autarky model:

$$q_{t+1}^{ET} = q_t^{ET} \cdot \mathbb{P}_{h,t}^{ET*} + \left(1 - q_t^{ET}\right) \mathbb{P}_{l,t}^{ET*}$$
$$\text{with} \quad \mathbb{P}_{h,t}^{ET*} = e_{h,t}^{ET*} \cdot \frac{q_t^{ET}}{q_t^{ET}+1} \quad \text{and} \quad \mathbb{P}_{h,t}^{ET*} = e_{l,t}^{ET*} \cdot \frac{q_t^{ET}}{q_t^{ET}+1}.$$

Corresponding to Proposition 2, the difference equation in the trade equilibrium only depends on the demand side variables q_t^{ET} and α_t^{ET} as well. This is described in the following in Proposition 2'.

PROPOSITION 2' (Taste Transmission Process in the Trade Model)**.** *In the trade equilibrium, the share of high-taste individuals of generation $t+1$ depends on the demand side variables of generation t (the share of high-taste individuals q_t^{ET} and the relative taste level of high-taste individuals α_t^{ET}) which are taken as given by generation t:*

$$q_{t+1}^{ET} = Q^{ET}\left(\alpha_t^{ET},\, q_t^{ET}\,;\, \tau,\, \gamma,\, \alpha^A,\, k,\, S,\, F^A\right) \tag{2.35}$$

with

$$\tau > 1, \quad \gamma > 0, \quad \alpha^A > 0, \quad k > 0, \quad S > 0, \quad \textit{and} \quad F^A > 0.$$

In addition, it must hold that

$$\frac{\partial q_{t+1}^{ET}}{\partial \alpha_t^{ET}} > 0, \quad \frac{\partial q_{t+1}^{ET}}{\partial q_t^{ET}} > 0, \quad \textit{and} \quad \frac{\partial^2 q_{t+1}^{ET}}{\partial {q_t^{ET}}^2} > 0.$$

Proof. See Appendix B.2.4. □

Taste Upgrading. The evolution of the relative taste level α_t^{ET} in the trade model follows Assumption 1 in the autarky model.

ASSUMPTION 1' (Taste Upgrading in the Trade Model)**.** *The relative taste level of high-taste individuals evolves according to the process*

$$\alpha_{t+1}^{ET} = \alpha_t^{ET} + \lambda \cdot n_{s,t}^{ET*} \cdot q_t^{ET} \cdot \frac{\overline{\alpha^{ET}} - \alpha_t^{ET}}{\overline{\alpha^{ET}}}, \quad \lambda > 0.$$

With the equilibrium share of labor in the silver sector derived in Eq. (2.34), the taste upgrading is a demand driven process:

$$\alpha_{t+1}^{ET} = \Lambda^{ET}\left(\alpha_t^{ET},\, q_t^{ET}\,;\, \tau,\, \gamma,\, \lambda,\, \alpha^A,\, k,\, S,\, F^A,\, \overline{\alpha^{ET}}\right). \tag{2.36}$$

Appendix B.2.5 derives the upper bound $\overline{\alpha^{ET}}$ in the trade model.

The Dynamics. Analogous to Eq. (1.14) in the autarky equilibrium, the dynamic system in the trade equilibrium is

$$\begin{cases} q_t^{ET} = Q^{ET}\left(\alpha_{t-1}^{ET},\, q_{t-1}^{ET}\,;\, \tau,\, \gamma,\, \alpha^A,\, k,\, S,\, F^A\right) \\ \alpha_t^{ET} = \Lambda^{ET}\left(\alpha_{t-1}^{ET},\, q_{t-1}^{ET}\,;\, \tau,\, \gamma,\, \lambda,\, \alpha^A,\, k,\, S,\, F^A,\, \overline{\alpha^{ET}}\right). \end{cases} \tag{2.37}$$

Starting from the same initial conditions q_0 and α_0 of the autarky equilibrium in Chapter 1, the dynamic evolution in the trade equilibrium follows the process displayed in Figure 1.2: The share of high-taste individuals stays stagnant at q_0 until the transition, when α_t^{ET} is high enough to drive q_t^{ET} to a new globally steady-state equilibrium.

PROPOSITION 3′ (Dynamic Evolution in the Trade Model)**.** *Based on the dynamic system in Eq.* (2.37) *and starting from the same initial conditions q_0 and α_0, the dynamic evolution proceeds in line with the same phases summarized in Proposition 3.*

Proof. See the proof of Proposition 3. □

2.4.5 Aggregate Income of the European Economy

In Chapter 1, Corollary 1 proves that in the autarky equilibrium the aggregate income increases with the dynamics of taste even though the productivity is fixed, through the channel of the labor reallocation. This section confirms the same effects in the trade equilibrium.

COROLLARY 1′ (Aggregate Income of the European Economy in the Trade Model)**.** *With constant labor supply and production parameters, the aggregate income of the Europe economy in the trade equilibrium increases with the demand variables q_t^{ET} and α_t^{ET} through the labor reallocation.*

Proof. The aggregate income equals the individual income m_t^{ET} in Eq. (2.19) because the total amount of labor is normalized to one. By normalizing $P_{b,t}^{ET} = \delta \cdot F$, the aggregate income of the European economy in the trade equilibrium is

$$Y_t^{ET} = \delta \cdot B \cdot F \left(1 - n_{s,t}^{ET*}\right)^{\beta - 1} \tag{2.38}$$

with $n_{f,t}^{ET} = 0$ in the trade model.[7] The effects depend on the signs of the first-order derivatives of Y_t^{ET} with respect to q_t^{ET} and α_t^{ET}. According to the chain rule,

$$\frac{\partial Y_t^{ET}}{\partial q_t^{ET}} = \frac{\partial Y_t^{ET}}{\partial n_{s,t}^{ET*}} \cdot \frac{\partial n_{s,t}^{ET*}}{\partial q_t^{ET}} = \delta \cdot B \cdot F \left(1 - \beta\right) \left(1 - n_{s,t}^{ET*}\right)^{\beta - 2} \frac{\partial n_{s,t}^{ET*}}{\partial q_t^{ET}} > 0$$

must hold because of $\frac{\partial n_{s,t}^{ET*}}{\partial q_t^{ET}} > 0$ from Proposition 1′. Hence, the aggregate income of the European economy in the trade equilibrium increases with the share of high-taste individuals q_t^{ET}. It can be shown in the same way that the aggregate income of the European economy in the trade equilibrium increases with α_t^{ET}, but it is omitted for brevity here. □

2.5 Comparison: European Economy in Autarky and Intercontinental Trade

Section 2.4 has shown that the dynamics of the European economy in the autarky model and the trade model work in the same pattern, but the effects of trade are still unclear. This section connects the two models and documents that the European economy performs better in the trade equilibrium. Appendix B.1.3 shows the corresponding comparison for the Asian economy.

Although the autarky equilibrium ${n_{f,t}}^*$ and the trade equilibrium $n_{s,t}^{ET*}$ evolve independently, it is possible to quantitatively compare the equilibrium paths conditional on the same starting points. To be specific, for generation t with given q_t and α_t, one of the two equilibria

[7] The normalization $P_{b,t}^{ET} = \delta \cdot F$ is helpful in expressing the aggregate income of the European economy in growth in Eq. (2.51). Compared to the simple normalization $P_{b,t} = 1$, it makes the results consistent and comparable.

is reached depending on the living environment. They are compared in the following.[8]

If generation t lives in an open economy, the trade equilibrium $n_{s,t}^{ET*}$ in Eq. (2.34) will be reached:

$$n_{s,t}^{ET*} = N_s^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right).$$

The condition for trade $n_{s,t}^{ET*} \leq \frac{F^A}{\tau \cdot F} - \frac{2\tau}{\alpha^A \cdot S}$ from Proposition 4 has to be fulfilled, which puts a constraint on the production parameter F:

$$F \leq F_t^{ET}, \tag{2.39}$$

where the function F_t^{ET} is derived in Appendix B.3.1.

PROPOSITION 5 (Linking Trade to Autarky)**.** *For any generation t, given the share of high-taste individuals q_t and the relative taste level of high-taste individuals α_t, $n_{s,t}^{ET*}$ and q_{t+1}^{ET} in the intercontinental trade model will be the same as ${n_{f,t}}^*$ and q_{t+1} in the autarky model if F is replace with F_t^{ET}:*

$$n_{s,t}^{ET*} = N_s^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) = N_f\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right); \tag{2.40}$$

$$q_{t+1}^{ET} = Q^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) = Q\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right). \tag{2.41}$$

In addition, it must hold that

$$\frac{\partial F_t^{ET}}{\partial \alpha_t} < 0 \quad \textit{and} \quad \frac{\partial F_t^{ET}}{\partial q_t} < 0.$$

Proof. See Appendix B.3.1. □

Intuitively, the European silver trade with Asia has the same effects as an increase in the productivity in the fancy-good sector from F to F_t^{ET}. Additionally, an increase in q_t or α_t results in a smaller F_t^{ET}, so the benefits decreases, but the trade equilibrium is always preferred.

Nevertheless, the comparison between α_t in Eq. (1.13) and α_t^{ET} in Eq. (2.36) is still

[8]It does not matter whether generation $t-1$ is in autarky or trade, as q_t and α_t formed by generation $t-1$ are taken as given by generation t.

ambiguous because the upper bounds $\overline{\alpha}$ and $\overline{\alpha^{ET}}$ contain different parameters.[9] Nevertheless, Appendix B.3.2 proves that $\overline{\alpha}$ and $\overline{\alpha^{ET}}$ are essentially equivalent, based on Assumption 2:

$$\overline{\alpha} = \overline{\alpha^{ET}}. \tag{2.42}$$

ASSUMPTION 2 (Upper Bound of the Equilibrium Share of Labor in the Silver Sector)**.** *Assume that the upper bound of the equilibrium share of labor in the silver sector equals the threshold value of the condition for intercontinental trade from Proposition 4:*

$$\overline{n_s^{ET*}} = \frac{F^A}{\tau \cdot F} - \frac{2\tau}{\alpha^A \cdot S}.$$

Assumption 2 simplifies the comparison without affecting the original dynamics. Based on Proposition 5 and Eq. (2.42), Corollary 2 summarizes the effects of intercontinental trade by quantitatively comparing the autarky and trade equilibrium.

COROLLARY 2 (The Enhancing Effects of Intercontinental Trade)**.** *For any generation t, given the share of high-taste individuals q_t and the relative taste level of high-taste individuals α_t, the following three statements hold.*

1. *The trade equilibrium $n_{s,t}^{ET*}$ in Eq.* (2.34) *is larger than the autarky equilibrium ${n_{f,t}}^*$ in Eq.* (1.11)*.*

2. *The share of high-taste individuals of generation $t+1$ formed in the trade equilibrium q_{t+1}^{ET} in Eq.* (2.35) *is larger than q_{t+1} in Eq.* (1.12) *formed in the autarky equilibrium.*

3. *The relative taste level of high-taste individuals of generation $t+1$ formed in the trade equilibrium α_{t+1}^{ET} in Eq.* (2.36) *is higher than α_{t+1} in Eq.* (1.13) *formed in the autarky equilibrium.*

Proof. Firstly, the trade equilibrium $n_{s,t}^{ET*}$ of generation t follows Eq. (2.40) according to Proposition 5:

$$n_{s,t}^{ET*} = N_s^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) = N_f\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right).$$

[9]Appendix A.4 and Appendix B.2.5 derive $\overline{\alpha}$ and $\overline{\alpha^{ET}}$ respectively.

The autarky equilibrium ${n_{f,t}}^*$ in Eq. (2.34) is

$${n_{f,t}}^* = N_f\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right).$$

Due to $\frac{\partial {n_{f,t}}^*}{\partial F} > 0$ from Appendix B.3.3, $F_t^{ET} > F$ in Eq. (2.39) indicates

$$n_{s,t}^{ET*} = N_f\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right) > N_f\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right) = {n_{f,t}}^*.$$

Secondly, q_{t+1}^{ET} in the trade equilibrium diverges from q_{t+1} in the autarky equilibrium because of Eq. (2.41) and $\frac{\partial q_{t+1}}{\partial F} > 0$ from Appendix B.3.3:

$$\begin{aligned} q_{t+1}^{ET} &= Q^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) \\ &= Q\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right) > Q\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right) = q_{t+1}. \end{aligned}$$

Finally, the comparison between α_{t+1} in the autarky equilibrium and α_{t+1}^{ET} in the trade equilibrium shows a similar pattern. Using the prior results $n_{s,t}^{ET*} > {n_{f,t}}^*$ and $q_{t+1}^{ET} > q_{t+1}$, it must hold that

$$\alpha_{t+1}^{ET} = \alpha_t + \lambda \cdot n_{s,t}^{ET*} \cdot q_t^{ET} \cdot \frac{\overline{\alpha^{ET}} - \alpha_t}{\overline{\alpha^{ET}}} > \alpha_t + \lambda \cdot {n_{f,t}}^* \cdot q_t \cdot \frac{\overline{\alpha} - \alpha_t}{\overline{\alpha}} = \alpha_{t+1}$$

with the same upper bounds $\overline{\alpha^{ET}} = \overline{\alpha}$ based on Eq. (2.42). □

Therefore, the equilibrium implies a better static and dynamic performance under intercontinental trade when compared to autarky, given the demand variables q_t and α_t for any generation t. Although the difference shrinks over time because F_t^{ET} decreases with q_t and α_t as explained in Proposition 5, the effect will remain positive as long as trade continues. Such positive feedback effects in the trade equilibrium accelerate the development path and transition in Figure 1.2. Compared to autarky, all future generations benefit from intercontinental trade, though the surplus drops over time as a result.

Consumption. With the enhancing effects of trade summarized in Corollary 2, the difference between consumption in the autarky and trade equilibrium is clear. In the basic-good sector, the aggregate consumption of the European economy is

$$B\left(1-{n_{f,t}}^{*}\right)^{\beta}; \qquad \text{(Autarky)}$$
$$B\left(1-n_{s,t}^{ET*}\right)^{\beta}, \qquad \text{(Trade)}$$

which always equals the local production due to self-sufficiency. Because of $n_{s,t}^{ET*} > {n_{f,t}}^{*}$ from Corollary 2, the aggregate consumption of basic goods is lower in the trade equilibrium.

The aggregate consumption of fancy goods equals the aggregate production in the autarky equilibrium, but in the trade equilibrium it is more complex. The following analysis is based on the analysis of the supply side. Asians trade with Europeans after satisfying their own demand for fancy goods, and the long-distance transportation induces the trade cost τ. With the equilibrium share of labor in the fancy-good sector of the Asian economy derived in Eq. (2.33), the consumption of fancy goods in Europe is

$$F \cdot {n_{f,t}}^{*}; \qquad \text{(Autarky)}$$
$$\frac{F^A \cdot n_{f,t}^{AT*} - f_t^{AT*}}{\tau} = \frac{\alpha^A \cdot S \cdot F^A \cdot n_{s,t}^{ET*}}{\tau \cdot \alpha^A \cdot S \cdot n_{s,t}^{ET*} + 2\tau^2}. \qquad \text{(Trade)}$$

${n_{f,t}}^{*} < n_{s,t}^{ET*}$ from Corollary 2 leads to $F \cdot {n_{f,t}}^{*} < F \cdot n_{s,t}^{ET*}$. The condition for trade $n_{s,t}^{ET*} < \frac{F^A}{\tau \cdot F} - \frac{2\tau}{\alpha^A \cdot S}$ from Proposition 4 leads to

$$F \cdot n_{s,t}^{ET*} < \frac{\alpha^A \cdot S \cdot F^A \cdot n_{s,t}^{ET*}}{\tau \cdot \alpha^A \cdot S \cdot n_{s,t}^{ET*} + 2\tau^2}.$$

Therefore, Europeans consume more fancy goods in the trade equilibrium.

Income and Share of Fancy-Good Expenditures. As already shown in Eq. (1.15) and Eq. (2.38), the aggregate income of the European economy (conditional the same normalization $P_{b,t} = P_{b,t}^{ET} = \delta \cdot F$) in the autarky and trade equilibrium is

$$Y_t = \delta \cdot B \cdot F\left(1-{n_{f,t}}^{*}\right)^{\beta-1}; \qquad \text{(Autarky)}$$
$$Y_t^{ET} = \delta \cdot B \cdot F\left(1-n_{s,t}^{ET*}\right)^{\beta-1}. \qquad \text{(Trade)}$$

Given ${n_{f,t}}^* < n_{s,t}^{ET*}$ from Corollary 2, the aggregate income is higher in the trade equilibrium. As a result, trade benefits the European economy even with the iceberg cost τ.

The higher aggregate income and the lower consumption of basic goods already imply a larger share of income spent on fancy goods in the trade equilibrium. Quantitatively, the share of expenditure on fancy goods in the autarky and trade equilibrium is calculated as

$$\frac{P_{f,t} \cdot F \cdot {n_{f,t}}^*}{Y_t} = {n_{f,t}}^*; \tag{Autarky}$$

$$\frac{\tau \cdot P_{f,t}^{AT} \left(\frac{F^A \cdot n_{f,t}^{AT*} - f_t^{AT*}}{\tau} \right)}{Y_t^{ET}} = n_{s,t}^{ET*}. \tag{Trade}$$

With ${n_{f,t}}^* < n_{s,t}^{ET*}$, it is unambiguous that intercontinental trade enlarges the share of income spent on fancy goods for European consumers.

2.6 Demand-driven Growth

This section investigates the implications of the intercontinental trade regime on long-run growth through its effects on the evolution of taste and aggregate demand. The analysis is based on a counterfactual experiment that is rooted in the historical demise of intercontinental trade. At the beginning of the nineteenth century intercontinental trade ended, after having been discouraged already for about one century at that point. This end of the intercontinental trade regime was the result of Chinese isolation policy, which was driven by domestic politics. Europeans reacted to the trade impediment by inspecting Asian fancy goods in order to decipher the production process. This chapter simplifies the trade transformation period and divides it into two separate phases: trade and growth. The following section constructs an endogenous growth model to investigate how economic growth in Europe might have been initiated by intercontinental trade.

Suppose that trade suddenly stops at generation t. The members of this generation and their offspring can only consume domestic goods. As consequence, the market allocation is restructured because labor is released from the silver sector and reallocated to local production. Importantly, the preference of generation t is shaped by generation $t-1$ in trade. Corollary 2 shows that trade enhances the preference for fancy goods, so it is unclear whether the domestic supply could keep up with the higher demand from the increased taste level.

PROPOSITION 6 (Labor Reallocation After Trade Stops)**.** *Assume that trade stops from generation t. While the amount of labor needed in the basic-good sector does not change after the market re-clearing, the amount of labor released from the silver sector* $n_{s,t}^{ET*}$ *can not produce enough fancy goods, unless F increases to* F_t^{ET} *defined in Eq.* (2.39).

Proof. See Appendix B.4. □

After having been cultivated under the period of intercontinental trade, the taste of European consumers have improved. Hence, when trade stops, the demand for fancy goods is higher than the domestic supply, unless there is a productivity improvement so that the market returns to equilibrium. In the European history as described in Section 2.2, the demand for fancy goods started to rise, which required an increase in productivity, and this eventually led to economic growth. Initially, producers imitated Asian fancy goods to provide consumers with substitutes of luxury imports, corresponding to the increase in the productivity from F to F_t^{ET} in the model. Afterwards, the increased productivity pushes the technological progress further, such that the economy eventually grows on a balanced path.

2.6.1 Model Setup

This section models the technological progress from imitation to innovation in the fancy-good sector, by employing a textbook lab-equipment model of Schumpeterian growth (Acemoglu, 2009). With the lab-equipment model, individuals can remain homogeneous in the labor market because research only requires investment in laboratories as an alternative to employing scientists. Therefore, individuals still receive the same amount of income from working in either the basic-good or fancy-good sector. Following Nelson and Phelps (1966) who argue that human capital is more helpful in adopting new technology or innovating compared to producing goods, the taste variables q_t^{EG} and α_t^{EG} facilitate the technological progress instead of acting as production factors.[10]

Fancy Goods. Fancy goods are competitively produced using labor and a unique type of intermediate goods with the following production function:

$$Y_{f,t}^{EG} = \frac{1}{1-\theta} \cdot Q_t \cdot x_t^{1-\theta} \cdot n_{f,t}^{EG\,\theta}, \quad 0 < \theta < 1.$$

$n_{f.t}^{EG}$ is the share of labor in the fancy-good sector, and x_t is the quantity of intermediate goods used in the production, which fully depreciate after being used. Q_t is the productivity or the quality of intermediate goods, acting as the engine of growth in the model. The aggregate output in the fancy-good sector

$$Y_{f,t}^{EG} = C_t + X_t + Z_t$$

consists of the aggregate consumption C_t, the cost of new intermediate goods X_t after full depreciation, and the investment in research Z_t.

Intermediate Goods. Fancy goods are produced competitively. The inverse demand function of intermediate goods

$$p_t = \frac{\partial \left(P_{f,t}^{EG} \cdot Y_{f,t}^{EG} \right)}{\partial x_t} = P_{f,t}^{EG} \cdot Q_t \cdot x_t^{-\theta} \cdot n_{f,t}^{EG\,\theta}$$

is derived from the marginal products, where p_t is the price of intermediate goods and $P_{f,t}^{EG}$ is the price of final fancy goods. In the intermediate-good sector, the production of any generation t takes place under new technology Q_t which creates a monopoly power. Thus, the producer charges the monopolistic price p_t given the demand

$$x_t = \left(\frac{P_{f,t}^{EG} \cdot Q_t}{p_t} \right)^{\frac{1}{\theta}} n_{f,t}^{EG}.$$

[10] The superscript "*EG*" is used for variables of the European economy in the growth model to distinguish from the related variables in the autarky model in Chapter 1 and the trade model in Section 2.4.

Assuming that p_t is unconstrained for simplicity, the monopolist can get the full markup over the marginal cost $\psi \cdot P_{f,t}^{EG} \cdot Q_t$ which is proportional to the quality of intermediate goods Q_t. Since the cost of intermediate goods X_t directly comes from the final output $Y_{f,t}^{EG}$, the price of final goods $P_{f,t}^{EG}$ also proportionally affects the unconstrained monopolistic price p_t. Hence, the monopolist solves the following problem to maximize the profit π_t:

$$\max_{p_t} \quad \pi_t = x_t \left(p_t - \psi \cdot P_{f,t}^{EG} \cdot Q_t \right), \quad x_t = \left(\frac{P_{f,t}^{EG} \cdot Q_t}{p_t} \right)^{\frac{1}{\theta}} n_{f,t}^{EG}.$$

The resulting monopolistic price is $p_t = \frac{\psi}{1-\theta} \cdot P_{f,t}^{EG} \cdot Q_t$. Without loss of generality, ψ can be normalized as $\psi = 1 - \theta$, implying the unconstrained monopolistic price

$$p_t = P_{f,t}^{EG} \cdot Q_t,$$

and the demand for intermediate goods

$$x_t = \left(\frac{P_{f,t}^{EG} \cdot Q_t}{p_t} \right)^{\frac{1}{\theta}} n_{f,t}^{EG} = n_{f,t}^{EG}.$$

R&D: Free Entry Condition. The maximum profit is simplified as

$$\pi_t^* = x_t \left(p_t - \psi \cdot P_{f,t}^{EG} \cdot Q_t \right) = \theta \cdot P_{f,t}^{EG} \cdot Q_t \cdot n_{f,t}^{EG}.$$

The profit motivates the investment in research because π_t is supposed to cover the expenditure on the quality improvement of intermediate goods $P_{f,t}^{EG} \cdot Z_t$. This free entry condition results in

$$Z_t = \theta \cdot Q_t \cdot n_{f,t}^{EG}.$$

Net Output of the Fancy-Good Sector. With $x_t = n_{f,t}^{EG}$, the aggregate production of fancy goods can be rewritten as

$$Y_{f,t}^{EG} = \frac{1}{1-\theta} \cdot Q_t \cdot n_{f,t}^{EG}.$$

Excluding the spending on intermediate goods $X_t = n^{EG}_{f,t}\,(1-\theta)\,Q_t$ and the investment in research $Z_t = \theta \cdot Q_t \cdot n^{EG}_{f,t}$, the net output of the fancy-good sector is

$$Y^{EG^{\text{net}}}_{f,t} = Y^{EG}_{f,t} - X_t - Z_t = \frac{\theta}{1-\theta} \cdot Q_t \cdot n^{EG}_{f,t}.$$

$Y^{EG^{\text{net}}}_{f,t}$ is the aggregate supply for consumption C_t, corresponding to the aggregate production of fancy goods $Y_{f,t}$ and $Y^{ET}_{f,t}$ in autarky and trade.

2.6.2 Equilibrium and Growth Dynamics

To $Y^{EG^{\text{net}}}_{f,t}$ comparable to the production function of the fancy-good sector in autarky and trade, the productivity term $F^{EG}_t = \frac{\theta}{1-\theta} \cdot Q_t$ is used:

$$Y^{EG^{\text{net}}}_{f,t} = F^{EG}_t \cdot n^{EG}_{f,t}, \tag{2.43}$$

where F^{EG}_t represents the technological progress in the model. Referring to the aggregate production of fancy goods in autarky $Y_{f,t} = F \cdot n_{f,t}$ in Eq. (1.6), the equilibrium and dynamics in growth can follow Eq. (1.11) in Proposition 1 and Eq. (1.12) in Proposition 2, while replacing F with F^{EG}_t. This leads to the following two parallel propositions to describe the European economy in growth.

PROPOSITION 1″ (Equilibrium of the European Economy in the Growth Model)**.** *In the growth model, for any generation t in Europe, given the share of high-taste individuals q^{EG}_t and the relative taste level of high-taste individuals α^{EG}_t, the unique equilibrium share of labor in the fancy-good sector is*

$$n^{EG^*}_{f,t} = N^{EG}_f\left(\alpha^{EG}_t,\ q^{EG}_t,\ F^{EG}_t\ ;\ \gamma,\ k\right) \tag{2.44}$$
$$\textit{with} \quad \gamma > 0 \quad \textit{and} \quad k > 0.$$

In addition, it must hold that

$$\frac{\partial n^{EG^*}_{f,t}}{\partial \alpha^{EG}_t} > 0 \quad \textit{and} \quad \frac{\partial n^{EG^*}_{f,t}}{\partial q^{EG}_t} > 0.$$

Proof. See the proof of Proposition 1 in Appendix A.2. $F^{EG}_t = \frac{\theta}{1-\theta} \cdot Q_t$ monotonically increases as the engine of growth, so it does not affect the conclusion here. □

PROPOSITION 2″ (Taste Transmission Process in the Growth Model)**.** *In the growth equilibrium, the share of high-taste individuals of generation $t+1$ depends on the demand side variables of generation t (the share of high-taste individuals q_t^{EG} and the relative taste level of high-taste individuals α_t^{EG}) which are taken as given by generation t:*

$$q_{t+1}^{EG} = Q^{EG}\left(\alpha_t^{EG},\ q_t^{EG},\ F_t^{EG}\ ;\ \gamma,\ k\right) \tag{2.45}$$
$$\textit{with} \quad \gamma > 0 \quad \textit{and} \quad k > 0.$$

In addition, it must hold that

$$\frac{\partial q_{t+1}^{EG}}{\partial \alpha_t^{EG}} > 0, \quad \frac{\partial q_{t+1}^{EG}}{\partial q_t^{EG}} > 0, \quad \textit{and} \quad \frac{\partial^2 q_{t+1}^{EG}}{\partial {q_t^{EG}}^2} > 0.$$

Proof. See the proof of Proposition 2 in Appendix A.3. $F_t^{EG} = \frac{\theta}{1-\theta} \cdot Q_t$ monotonically increases as the engine of growth, so it does not affect the conclusion here. □

Additionally, Assumption 1″ is required for the evolution of the relative taste level of high-taste individuals in growth α_t^{EG}, corresponding to Assumption 1 and Assumption 1′. The expression of the upper bound $\overline{\alpha^{EG}}$ is similar to the expression of $\overline{\alpha}$ derived in Appendix A.4, but F has to be replaced with F_t^{EG}.

ASSUMPTION 1″ (Taste Upgrading in the Growth Model)**.** *The relative taste level of high-taste individuals evolves according to the process*

$$\alpha_{t+1}^{EG} = \alpha_t^{EG} + \lambda \cdot n_{s,t}^{EG*} \cdot q_t^{EG} \cdot \frac{\overline{\alpha^{EG}} - \alpha_t^{EG}}{\overline{\alpha^{EG}}}, \quad \lambda > 0.$$

Although the equilibrium and dynamics in growth are comparable to those in the baseline autarky model in Chapter 1, the variable F_t^{EG} adds new elements to the system. Appendix B.3.3 shows $\frac{\partial n_{f,t}{}^*}{\partial F} > 0$ and $\frac{\partial q_{t+1}}{\partial F} > 0$ in the autarky equilibrium, indicating that in the growth equilibrium, $n_{f,t}^{EG*}$ and q_{t+1}^{EG} will eventually explode due to the continuously growing technological progress F_t^{EG}. Moreover, following similar procedures in Appendix A.4 for the upper bound $\overline{\alpha}$ in autarky, the upper bound $\overline{\alpha^{EG}}$ in growth can be derived as

$$\overline{\alpha^{EG}} = 1 + \frac{4k}{\gamma \cdot F_t^{EG} - 2k\,(\gamma+1)}.$$

Affected by the variable F_t^{EG}, the upper bound $\overline{\alpha^{EG}}$ is not static anymore, which requires an additional assumption.

In the expressions of $n_{f,t}{}^{*}$, q_{t+1}, and $\overline{\alpha}$ specified by Appendix A.2, Appendix A.3 and Appendix A.4, the parameters k and F can cancel each other out in a linear manner. Correspondingly, if k proportionally changes with F_t^{EG} in the growth equilibrium, it can offset the growth effects of F_t^{EG} on $n_{f,t}^{EG*}$ and q_{t+1}^{EG}, thereby preventing the dynamic system from exploding. Likewise, it can also keep the upper bound $\overline{\alpha^{EG}}$ constant. For the specific proportional relationship between k and F_t^{EG}, it is proposed to equalize the upper bound $\overline{\alpha^{EG}}$ and $\overline{\alpha}$, which makes the autarky and growth equilibrium comparable.

ASSUMPTION 3 (Equivalence between Upper Bounds)**.** *Assume* $\overline{\alpha^{EG}} = \overline{\alpha}$*.*

Thus, with the parameter k replaced with the variable k_t^{EG} in the growth model, it holds that

$$\overline{\alpha^{EG}} = 1 + \frac{4k_t^{EG}}{\gamma \cdot F_t^{EG} - 2k_t^{EG}\,(\gamma+1)} = 1 + \frac{4k}{\gamma \cdot F - 2k\,(\gamma+1)} = \overline{\alpha},$$

which can be rearranged into

$$k_t^{EG} = \frac{\gamma \cdot C}{2\,(\gamma \cdot C + C + 2)} \cdot F_t^{EG}, \tag{2.46}$$

where $C = \frac{2k(\beta+1)}{\gamma \cdot F - 2k(\gamma+1)}$ is a constant parameter based on the model setup. Eq. (2.46) makes $n_{f,t}^{EG*}$ in Eq. (2.44) and q_{t+1}^{EG} in Eq. (2.45) independent of F_t^{EG} and k_t^{EG} at the same time, leading to the simplified dynamic system

$$\begin{cases} q_t^{EG} = Q^{EG}\left(\alpha_{t-1}^{EG},\, q_{t-1}^{EG},\, ;\, \gamma,\, C\right) \\ \alpha_t^{EG} = \Lambda^{EG}\left(\alpha_{t-1}^{EG},\, q_{t-1}^{EG}\, ;\, \gamma,\, \lambda,\, \overline{\alpha^{EG}},\, C\right). \end{cases} \tag{2.47}$$

The pattern of the development also follows the same procedures in Figure 1.2.

PROPOSITION 3" (Dynamic Evolution in the Growth Model)**.** *Based on the dynamic system* *in Eq.* (2.47) *and starting from the initial conditions q_0 and α_0, the dynamic evolution proceeds in line with the same phases summarized in Proposition 3*

Proof. See the proof of Proposition 3. □

2.6.3 Balanced Growth Path

When trade stops at generation t, Europeans begin to produce fancy goods with the initial constant productivity F, so the technology term $Q_t = \frac{\theta}{1-\theta} \cdot F_t^{EG}$ is at the initial level $\frac{\theta}{1-\theta} \cdot F$. However, the productivity in the fancy-good sector has to increase to F_t^{ET} to reach equilibrium, as described in Proposition 6. Therefore,

$$\frac{\theta}{1-\theta} \cdot \overline{Q_t} = F_t^{ET}$$

is defined as the technology frontier.

Based on related literature (see, e.g., Acemoglu *et al.*, 2006), it is assumed that Q_t grows according to

$$Q_{t+1} = g_t \left[\eta \left(\overline{Q_t} - Q_t \right) + Q_t \right], \tag{2.48}$$

where the distance to the frontier $\left(\overline{Q_t} - Q_t \right)$ functions as the original motivation for growth which inspires imitation. The technology level of the previous generation lays a foundation for innovation. The parameter η stands for the importance of imitation compared to innovation before reaching the frontier. In the beginning, when $Q_t = \frac{\theta}{1-\theta} \cdot F$ is low, growth mostly comes from imitation $\left(\overline{Q_t} - Q_t \right)$. After Q_t reaches the frontier $\overline{Q_t}$, innovation becomes the only source of growth. The specific growth pattern is endogenously derived within the dynamic system in the following.

ASSUMPTION 4 (Endogenous Growth)**.** *Assume that the growth function is*

$$g_t = \frac{\alpha_t^{EG} \cdot q_t^{EG} \cdot Z_t}{Q_t}.$$

The growth rate depends positively on the investment in research Z_t, the share of high-taste individuals q_t^{EG}, and the relative taste level of high-taste individuals α_t^{EG}. Similar to the argument of Nelson and Phelps (1966) about human capital, taste is not a factor in production, but it promotes technology adoption and innovation. Meanwhile, g_t negatively depends on the quality of intermediate goods Q_t because the investment in R&D gets less effective with higher quality (Acemoglu, 2009). The free-entry condition $Z_t = \theta \cdot Q_t \cdot n_{f,t}^{EG}$ simplifies the growth function as

$$g_t = \frac{\alpha_t^{EG} \cdot q_t^{EG} \cdot \theta \cdot Q_t \cdot n_{f,t}^{EG}}{Q_t} = \theta \cdot \alpha_t^{EG} \cdot q_t^{EG} \cdot n_{f,t}^{EG}, \tag{2.49}$$

which is endogenized within the dynamic system.

As the technological progress starts, the quality of intermediate goods will advance perpetually through Eq. (2.48). As soon as Q_t reaches the technology frontier $\overline{Q_t}$, the imitation term $\left(\overline{Q_t} - Q_t\right)$ will permanently vanish, and the growth pattern becomes

$$Q_{t+1} = g_t \cdot Q_t = \theta \cdot \alpha_t^{EG} \cdot q_t^{EG} \cdot n_{f,t}^{EG} \cdot Q_t. \tag{2.48'}$$

The growth factor g_t is propelled by the dynamics of taste until the upper bound $\overline{\alpha^{EG}}$ is reached at $q_t^{EG} = 1$. Simultaneously, the equilibrium share of labor in the fancy-good sector $n_{f,t}^{EG*}$ also reaches its maximum $\overline{n_f^{EG*}}$, and g_t converges to a constant:[11]

$$g^* = \theta \cdot \overline{\alpha^{EG}} \cdot \overline{n_f^{EG*}}. \tag{2.49'}$$

Ultimately, the fancy-good sector grows at a constant rate $(g^* - 1)$.

The technological growth of one sector exerts influences on the aggregate income of the economy. The production function of the basic-good sector

$$Y_{b,t}^{EG} = B\left(1 - n_{f,t}^{EG}\right)^{\beta}, \quad 0 < \beta < 1 \tag{2.50}$$

remains unchanged, so the aggregate income of the economy is calculated as

$$Y_t^{EG} = P_{b,t}^{EG} \cdot Y_{b,t}^{EG} + P_{f,t}^{EG} \cdot Y_{f,t}^{EG\,\text{net}}.$$

[11] With $q_t^{EG} = 1$ and $\alpha_t^{EG} = \overline{\alpha^{EG}} = 1 + \frac{4k}{\gamma \cdot F - 2k(\gamma+1)}$, the equilibrium share of labor in the fancy-good sector reaches its upper bound $\overline{n_f^{EG*}} = \frac{\gamma \cdot F + 2k(\gamma+1)}{2\gamma \cdot F}$.

The normalization $P_{b,t}^{EG} = \delta \cdot F_t^{EG}$ is implemented to reflect the growth effects of the fancy-good sector on the aggregate income:

$$Y_t^{EG} = \delta \cdot B \cdot F_t^{EG} \left(1 - n_{f,t}^{EG*}\right)^{\beta - 1}. \tag{2.51}$$

When the growth factor g_t converges to a constant g^* (or the technological progress $F_t^{EG} = \frac{\theta}{1-\theta} \cdot Q_t$ has a constant growth rate), the economy will be on a balanced growth path.

2.7 Simulation

This section provides a quantitative analysis to study the dynamic systems of the three modeled stages of the economic development: autarky in Eq. (1.14), trade in Eq. (2.37), and growth in Eq. (2.47). Below we give a brief description of the calibrated parameters for the simulation, which is also summarized in Table B.1 in Appendix B.5. Following Cervellati and Sunde (2015), the length of one generation is set to 20 years and the simulation starts from year 0. In compliance with history, it is assumed that the period of trade starts from 1580 in the model, and lasts until 1820 when the endogenous economic growth begins.

2.7.1 Taste

The dynamics of taste is reflected by the dynamics of the share of high-taste individuals and of their relative taste level in the three modeled cases: q_t, q_t^{ET}, and q_t^{EG}; α_t, α_t^{ET}, and α_t^{EG}. Based on some exogenously set parameters, the remaining parameters are solved from the model.

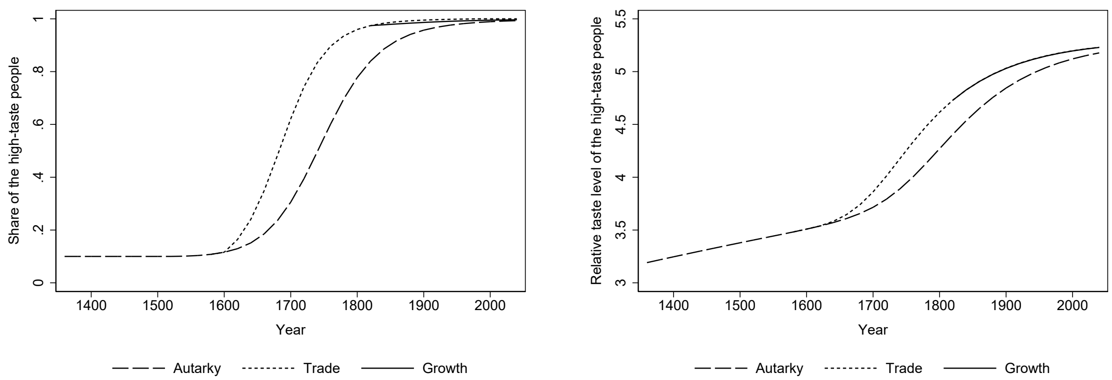
Firstly, the values of some parameters are set exogeneously according to literature and rationality. $\lambda = 0.95$ ensures that the consumer revolution (a substantial increase in the share of high-taste individuals) happens during the early modern period. Productivity parameters of all sectors in Europe $F = B = S = 15$ follow the initial level of TFP in Cervellati and Sunde (2015). In Asia, $F^A = 20$ is set for the advantage in producing fancy goods, but $B^A = 15$ is the same as the productivity in the basic-good sector of the European economy.

The parameter for altruism $\gamma = 9$ also follows Cervellati and Sunde (2015). The lower bound of q_t is set to $\underline{q} = 0.05$. In addition, the iceberg trade cost is set to $\tau = 1.1$.

Secondly, Eq. (A.3) in Appendix A.4 delivers $k = 6.45$ based on $\underline{q} = 0.05$, $F = 15$, and $\gamma = 9$. These values can be used to compute $\underline{\alpha} = 1.19$ using Eq. (A.4). Afterwards, $\overline{\alpha} = 5.30$ is determined according to Eq. (A.2), and the upper bound in growth is fixed to $\overline{\alpha^{EG}} = \overline{\alpha} = 5.30$ based on Assumption 3. Because of Eq. (2.42), the upper bound in trade is also fixed to $\overline{\alpha^{ET}} = \overline{\alpha} = 5.30$, which pins downs the parameter $\alpha^A = 0.63$ in Eq. (B.5).

In terms of the initial conditions, the share of high-taste individuals starts from $q_0 = 0.1$. In additional to the constraint $\alpha_0 > \underline{\alpha} = 1.19$, α_0 should ensure that the corresponding initial equilibrium share of labor in the fancy-good sector $n_{f,0}{}^* = N_f\,(\alpha_0,\ q_0\ ;\ \gamma,\ k,\ F)$ is positive. The condition $\alpha_0 > 1.46$ is required for $n_{f,0}{}^* > 0$. Therefore, $\alpha_0 = 1.5$ is the point where the dynamic starts.

Figure 2.6 shows the simulation results based on these parameter values. Figure 2.6(a) displays the long-run trajectory of the share of high-taste individuals in three different cases: autarky (q_t), trade (q_t^{ET}), and growth (q_t^{EG}). This share remains at the initial level $q_0 = 0.1$ until the early modern time when the consumer revolution happened in Europe. The enhancing effects of intercontinental trade from Corollary 2 lead to a faster and earlier transition compared to a scenario without trade. It is noted that at the beginning of the growth period, the curve for growth is slightly lower than the curve for trade, as the domestic productivity level is still low, which retards the dynamics of taste. Figure 2.6(b) reveals that the relative taste level of high-taste individuals keeps increasing as a result of the taste upgrading assumed in Assumption 1, Assumption 1′, and Assumption 1″. After a stable growth pattern a drastic boost occurs contemporary with the transition of q_t, and the enhancing effects of intercontinental trade are also visible.



(a) Share of High-taste Individuals q_t

(b) Relative Taste Level of High-taste Individuals α_t

Figure 2.6: *Simulation of Taste*

2.7.2 Aggregate Income

This section describes the time series of the resulting aggregate income from the model, and compares it to data for the United Kingdom.[12] The United Kingdom experienced the three stages of the economic development featured by the model: from the craze on fashion towards imitation, and then to industrialization ultimately. Therefore, we use the United Kingdom as a representative example for the simulation.

Besides the parameters and the initial conditions already determined before, $\beta = 0.6$ reflects the decreasing returns in the basic-good sector. In addition, $\eta = 5$ in Eq. (2.48) is exogenously set, which weights imitation five times compared to innovation before technology reaches the frontier. The normalization parameter $\delta = 3.41$ is solved by matching real data of GDP per capita in 1820.[13] Parameter θ affects the growth function g_t, and it is solved by matching the balanced growth path

$$g^* = \theta \cdot \overline{\alpha^{EG}} \cdot \overline{n_{f,t}^{EG*}} = \theta \left(1 + \frac{2k\,(\beta+1)}{\gamma \cdot F - 2k\,(\gamma+1)}\right) \left(\frac{\gamma \cdot F + 2k \cdot \beta\,(\gamma+1)}{\gamma \cdot F\,(\beta+1)}\right)$$

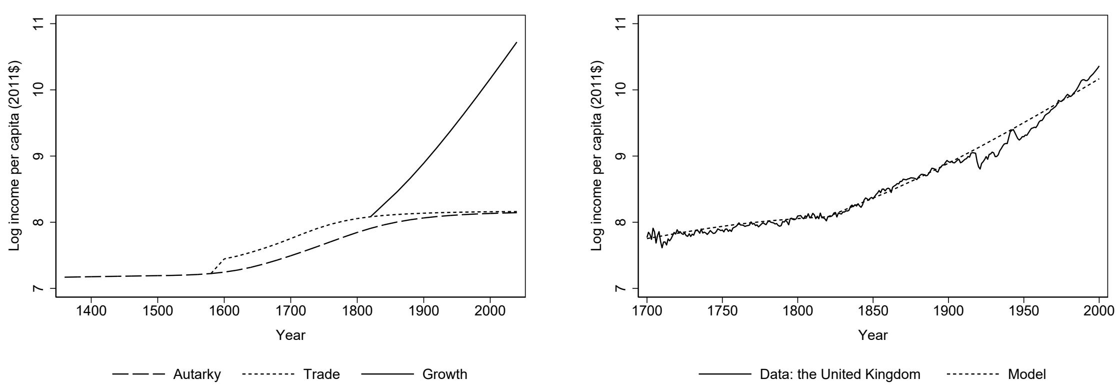
to the data of the growth rate. Following Cervellati and Sunde (2015) who use the average

[12]Data are taken from the Maddison Project Database 2018. See Bolt *et al.* (2018).

[13]1820 is the year when growth starts in the model, so matching the 1820 data can improve the model performance for the transition.

growth rate over the period 1995–2010 as the balanced growth path in the example of Sweden, the United Kingdom shows an average annual growth rate of 1.58%. This implies a growth factor of $g^* = 1.37$ on the balanced growth path for one generation of twenty years, which leads to $\theta = 0.26$.

Figure 2.7(a) plots the simulated log GDP per capita of the United Kingdom from 1400 to 2000. As summarized in Corollary 1 and Corollary 1′, the aggregate income is increased by the dynamics of taste during the period of the consumer revolution, and the enhancing effect of intercontinental trade is also prominent. Nevertheless, Figure 2.7(a) also indicates the limited potential of income growth in the absence of the technological progress. Thanks to the dynamics of the demand, industrialization is stimulated and the economic "take-off" finally commences. Figure 2.7(b) compares the simulation results from the model and the historical data of the United Kingdom, covering the period 1700–2000 as 1700 is the earliest year when data are available. Even though they are matched by construction for the year 1820, the model performs well for the entire 300 years.



(a) Simulation Results

(b) Comparison

Figure 2.7: *Log GDP per capita of the United Kingdom*

Sources: Maddison Project Database 2018, see Bolt *et al.* (2018)

2.8 Conclusion

From a global perspective, the consumer revolution in the early modern Europe was closely related to the Eurasian trade following the Voyages of Discovery because many fancy goods in European households actually had an eastern origin. Therefore, the model in this chapter includes the Asian economy as well, and mathematically presents how the enhancing effects of intercontinental trade enables an earlier and faster transition. Intercontinental trade upgrades taste, thus raising the consumer demand to a higher level compared to the baseline autarky model in Chapter 1. Consequently, the productivity in the fancy-good sector is urged to increase as a response to the extra demand, to keep equilibrium when trade ends. This naturally leads to an endogenous growth pattern formulated in the last part of the framework.

After the theoretical model, some illustrative simulations are implemented to numerically present the equilibrium dynamics. The predicted income per capita matches and real data of the United Kingdom, showing that the proposed model performs well.

Chapter 3

Are Millennials Spoiled Kids? Age and Generation Effects on Luxury Expenditure

3.1 Introduction

Since the end of the Great Recession in 2009, the American luxury market has grown dramatically (Panteva, 2011; Rubin, 2011). Millennials—those born between 1981 and 1996—are considered as not only the main contributor to this resurgence (Lafayette, 2011; Jay, 2012; Giovannini *et al.*, 2015), but also the target of the luxury market in the future. On one hand, Millennials emerge as a distinct generation with unprecedented population size, extraordinary expenditure power, and a special preference for luxury shopping.[1] On the other hand, it has also been documented extensively that younger consumers typically spend more on luxury compared to older ones.[2] Hence, it remains unclear whether the different

[1] Fry (2020) reports that Millennials have overtaken their boomer parents and became America's largest generation in 2019. Fromm and Garton (2013) compare the purchasing power of Millennials with previous generations. Moreover, Halpert (2012) and Giovannini *et al.* (2015) illustrate Millennials' unparalleled preferences for shopping, especially luxury items.

[2] For example, Danziger (2015) finds that among all affluents, younger people consistently buy more luxury goods, and Nye (2011) argues that new generations always have the most substantial influences on all markets.

consumption pattern of Millennials comes from their younger age, or can be attributed to a generation effect.

In this chapter, I address this issue by decomposing age and generation effects on luxury expenditure, to explore whether Millennials behave differently from their predecessors. Specifically, I take the following two steps: First, I estimate age and generation effects based on multiple regression models. Second, I adopt a supervised machine learning approach to pin down the variation in luxury expenditure, which can be explained by age and generation differences. For this purpose, data from the US Consumer Expenditure Survey (CE) 2000–2018 is used. I combine the generational segmentation defined by the Pew Research Center and McCrindle (2007), leading to four generations based on their birth years: Builders (1906–1945), Baby Boomers (1946–1964), Generation X (1965–1980), and Millennials or Generation Y (1981–1996).[3]

Luxury is frequently studied in the literature, but it has never been empirically defined from theories. To achieve this, I follow the microeconomic definition of luxury as having a total expenditure elasticity larger than one. I estimate the elasticity of each individual expenditure category in the data, and classify expenditure categories into luxury goods and necessity goods based on the elasticity values. As a result, luxury expenditure is defined as the sum of expenditures over all categories with elasticities larger than one.

To give an overview of luxury expenditure patterns, descriptive age profiles and time trends of the economically defined luxury expenditure are presented. Over the life cycle, the average luxury expenditure is "hump" shaped, peaking at middle adulthood, while the average share of luxury expenditure is declining, especially at young age. Across time, both the level and the share of luxury expenditure had been declining from the first few years of the sample period until 2014 and then started recovering, which can be explained by the persistent influences of the Great Recession. This time trend is similar across all generations.

Although generation-specific age profiles show lower luxury expenditure of younger

[3]See the website *https://web.archive.org/web/20170216215337/http://www.pewresearch.org/methodology/demographic-research/definitions/* (accessed 9 September 2021) and Dimock (2019) for details on the generational segmentation.

generations conditional on age, the pure descriptives do not account for the composition of generations in terms of other demographic characteristics such as education level or gender. Therefore, I conduct a regression analysis to detect the variation resulting from age and generation effects, based on full sets of dummies, while controlling for a host of other demographic variables. It is well known that, without parametric restrictions, period, age, and generation effects are collinear and thus not separately identified. The standard practice in the consumption literature assumes that the period effect captures business cycles (Aguiar and Hurst, 2013), so I follow Dohmen *et al.* (2017) and use the GDP growth as a proxy for the period effect.

I find that age and generation effects work in opposite directions: luxury expenditure decreases over the lifetime, yet older generations tend to consume more at the same age, in terms of both expenditure level and share. Millennials actually spend about 8% less on luxury than Generations X conditional on age and other controls, and their share is around 1.5% less than the share of Generation X. Relative to Baby Boomers and Builders, these differences are even larger.

As age and time period might affect different generations non-uniformly, I integrate interaction terms to account for such heterogeneous effects. Following Fitzenberger *et al.* (2021), I conduct several sensitivity tests to decide which interaction terms should be included in the ideal model. The estimated coefficients show that the main results still remain. Furthermore, the last question about the main specification is if the results are only driven by certain goods categories. The results from specific categories show that there are some deviations from the overall generation and age effects, but Millennials spend less on the majority of individual luxury categories.

Three concerns about the identification are challenging the main findings. First of all, if different generations do not perceive and define luxury in the same way, the employed overall classification will not match the definition of individual generations. Second, it is difficult to compare temporally separated generations due to the lack of overlaps of age ranges in the sample. For example, just comparing Millennials to Baby Boomers based on the main specification is insufficient because the consumption behavior of the latter at younger age was not observed in the survey, and vice versa. Third, age and generation are not treated in symmetric ways. While age is represented by a full set of individual dummies, a generation is a collection of cohorts. Thus, the results can be contaminated by mixing generation and age group effects.

To solve these issues, I show that the results are robust to some alternative model specifications. First, I estimate elasticities using samples of each generation, and derive corresponding luxury definitions. With a generation-specific classification, the results are still qualitatively stable, though the magnitudes of the effects are smaller.[4] Second, I always use data of two temporally neighboring generations within the common age range, and run multiple regressions to complete the comparisons. The direction of the generation effect remains unchanged, as younger generations always consume less luxury. As for the third concern, when grouping individual age dummies or using cohort dummies as proxies for generations, the same luxury expenditure pattern prevails.

So far, every regression analysis is based on a linear model with strict assumptions on functional forms and sample distributions. However, demographic variables are highly interactive and non-linear, which could lead to oversimplified and inaccurate results. In order to investigate how age and generation affect luxury expenditure in fully flexible models, a machine learning technique based on deep learning is employed. It is able to automatically search for the optimal non-linearities and interactions, according to patterns in the data. For this purpose, I use multiple supervised neural networks and explain details on the model training process, where the best models are selected via their validation performance.[5] Using the best models, counterfactual predictions by imposing different age and generation information are carried out.[6] In this way, the predicted results show the

[4]It is expected that the effects are weaker because the generation-specific definitions of luxury are not representative of all samples. See Section 3.6.1 for further details.

[5]Validation performance indicates a model's capability to generalize to new samples from the same distribution. Note that these samples are not used during training to search for the optimal non-linearities and interactions.

[6]See Section 3.7 for details.

variation in luxury expenditure that can be only explained by age and generation differences. For both the level and the share of luxury expenditure, the results support the patterns uncovered by the linear regression models.

All results are based on the definition of luxury from economic theory, which might not necessarily correspond with the definition of luxury from common sense that can be found in related research. Thus, I compare the luxury categories in this chapter to luxury classified by Paulin and Riordon (1998) according to their subjective perspectives as an example. The two sets of categories are different, notwithstanding several overlaps. For the overlapping categories the evidence on each category shows a similar generation effect as described above, i.e., that Millennials consume less luxury. In addition, luxury is frequently mixed up with conspicuous consumption, so I also discuss literature on conspicuous consumption for comparison. It turns out that conspicuous consumption contains quite different expenditure categories, though some goods indeed belong to both. The resulting effects of household characteristics from the overlapping categories are consistent and complementary to different findings in the literature.

My results challenge the stereotyped impression of Millennials as the (potential) growth engine of luxury industries (see, e.g., Lafayette, 2011; Panteva, 2011; Rubin, 2011; Halpert, 2012; Jay, 2012; Danziger, 2015; Giovannini *et al.*, 2015) because the pure generation effect reveals their sobriety from luxury. The conventional idea of Millennials' purchasing power actually comes from a pure age effect that leads to monotonically decreasing luxury expenditure over the life cycle. Furthermore, I provide quantitative evidence on the argument of age as an essential predictor of consumer behaviors (see, e.g., Kapferer and Bastien, 2009; Nye, 2011; Halpert, 2012; Danziger, 2015).

This chapter also makes several contributions to the existing literature: Firstly, luxury is a novel topic of economic research on consumer expenditure. Some of the standard literature focuses on (non-)durable expenditure (see, e.g., Fernández-Villaverde and Krueger, 2007; Aguiar and Hurst, 2013), while others only take selected categories into consideration. For instance, Blundell *et al.* (1994) choose seven broad commodities including food, alcohol, fuel, clothing, transport, services, and other goods. Moreover, alcohol consumption, tourism behavior, and medical expenditure have also been investigated (see, e.g., Aristei *et al.*, 2008; Bernini and Cracolici, 2015; Banks *et al.*, 2019). One of the closely related topics is conspicuous consumption studied by, e.g., Charles *et al.* (2009), Heffetz (2011), Friehe and Mechtel (2014), and Heffetz (2018). However, as shown in Section 3.8.1, luxury and visibility are essentially not equivalent to each other.

Secondly, I use a theory-based classification to define luxury. The lack of awareness of luxury in the literature might be due to the difficulties in empirically defining it in a quantitative way. Business research often uses questionnaires to examine how consumers perceive luxury as an abstract concept, without specifying the exact categories (see, e.g., Amatulli *et al.*, 2015; Giovannini *et al.*, 2015; Kapferer and Michaut, 2019). Paulin and Riordon (1998) are an exception as they show a list of luxury goods, but their classification is founded on their subjective common sense and thus lacks academic objectivity. In this chapter, I refer to a microeconomic definition of luxury as being highly elastic, and derive specific luxury categories based on estimated total expenditure elasticities.

Thirdly, this chapter introduces the methodology of decomposing age and generation effects to research on luxury. The segmentation of the market by both age and generation has been conceptually pointed out, but it has never been quantitatively analyzed, especially in the context of luxury.[7] Cross-generational studies on this usually depend on one-time market surveys which do not allow for disentangling age and generation effects because of the lack of information on the dynamic aging process. For example, Kapferer and Michaut (2019) recruit 3217 luxury buyers between the age 18 and 75 to see how different generations define luxury, but the generational grouping is solely based on age. A similar approach is taken by Eastman and Liu (2012) in analyzing the impact of generational cohorts on status consumption, where the 220 adult consumers in the sample are divided into three

[7]For example, McCrindle (2007) thinks age alone is inadequate to segment the market because today's teenagers are not comparable to Generation X in the 1980s or to Baby Boomers in the 1960s. In addition, Millennials who are possessed of wealth are not following generations that became affluent before (Danziger, 2015).

generations according to age: Baby Boomers, Generation X, and Millennials. Although Gurău (2012) conducts a life-stage analysis of Generation X and Millennial consumers, the age effect is not directly or systematically examined.[8] With data collected across multiple years, household expenditure surveys work better in this scenario, but little research using such data could strategically achieve that goal. Norum (2003) only employs data from the 1998 Consumer Expenditure Survey (CE) of the US, thus still measuring age based on generational definitions. Paulin and Riordon (1998) investigate income and expenditure patterns of people from age 18 to 29 using data from the CE program in three periods, 1972–1973, 1984–1985, and 1994–1995, while only focusing on Baby Boomers and Generation X. To estimate age and generation effects simultaneously, I exploit the dynamics of the long-term data from the CE program, which persistently keeps track of consumers of all generations.

Finally, this chapter provides an example of using machine learning techniques in empirical economic estimations. While most traditional econometric approaches are based on specific functional forms that require multiple statistical assumptions, machine learning techniques flexibly search for the optimal models that ideally fit data. In my case, this works especially well since demographic variables are highly interactive and non-linear. This advantage has been noticed and is utilized increasingly among economists (see, e.g., Varian, 2014; Mullainathan and Spiess, 2017; Athey, 2018; Athey and Imbens, 2019). However, as machine learning mainly deals with prediction instead of estimation, and consequently, the applications of machine learning techniques have been mostly restricted to the financial market where prediction is the major issue (see, e.g., Gu *et al.*, 2020; Peng *et al.*, 2021; Nosratabadi *et al.*, 2020). Nevertheless, I trace the desired age and generation effects while still making use of the advantages of a flexible model, that does not require a fixed functional form. Hence, by providing new and powerful tools, machine learning shows a significant potential for future research in economics.

[8] Millennials are divided into three categories here: college students, young single professionals, and young married professionals. Generation X are divided into two categories: single professional adults and married professional adults.

The remainder of this chapter is structured as follows: Section 3.2 introduces the generational segmentation and the data. Section 3.3 classifies the expenditure categories in the CE program into luxury and necessity, based on estimated total expenditure elasticities. Section 3.4 presents the sample selection and descriptives. The regression analysis is described in Section 3.5 for the main specification and Section 3.6 for the robustness of the regression results. Section 3.7 confirms the main results using supervised neural networks. Finally, Section 3.8 discusses the results and intuition, and Section 3.9 concludes.

3.2 Setting and Data

This section introduces the generational segmentation and the data set used in this chapter. The definition and main characteristics of each generation are explained. Afterwards, I briefly introduce the data structure of the US Consumer Expenditure Survey (CE) and how the used samples are selected.

3.2.1 Generational Segmentation

Although the concept of generation does not have a clear origin, the generation-based demographic segmentation has been widely used in the social science literature since Strauss and Howe (1991) developed the Strauss–Howe generational theory (Chaney *et al.*, 2017). From this perspective, people in the US are divided into different generations based on demographics, political events, and economic environment. These factors are especially important during their coming-of-age years. As a results, each generation develops heterogeneous preferences and behaviors accordingly.

There are no clear, universally defined thresholds of generational segments except for the definition of Baby Boomers.[9] This chapter refers to the generational segments developed by the Pew Research Center (a non-partisan fact tank that provides information on the

[9]See, e.g., Norum (2003) for a list of different cutoff points in the literature.

US social and demographic trends), which is summarized in Table 3.1.[10] The US Census Bureau calls individuals born from 1946 to 1964 "Baby Boomers" because of the drastically rising birth rate during this post-war period (Colby and Ortman, 2014). The predecessors of Baby Boomers, born from 1928 to 1945 during the Great Depression and World War II, are defined as the "Silent Generation". They are the children of the "Greatest Generation" who played a vital role in dealing with such destructive economic and political events. Following Baby Boomers, the period of "Generation X" lasted until 1980. Afterwards, the generation of "Millennials" started, whose oldest members reached young adulthood in the new millennium. The Pew Research Center defines 1996 as the last birth year of Millennials to separate them from the following "Generation Z". Compared to Millennials, Generation Z did not experience key social events such as the 9/11 terrorist attacks and the 2008 Obama election during their formative years (Dimock, 2019).

Table 3.1: *Generational Segments*

	Birth Year	Age in 2021
The Greatest Generation	1902–1927	94–119
The Silent Generation	1928–1945	76–93
Baby Boomers	1946–1964	57–75
Generation X	1965–1980	41–56
Generation Y (Millennials)	1981–1996	25–40
Generation Z	From 1997	Younger than 25

Sources: The Pew Research Center, available at *https://web.archive.org/web/20170216215337/http://www.pewresearch.org/methodology/demographic-research/definitions/* (accessed 9 September 2021); Dimock (2019)

People from the same generation have common value systems, attitudes and behaviors because they share life stages through the same macro environment (Howe and Strauss, 2000; McCrindle, 2007). There is a general consensus that the external events during the late adolescence or early adulthood—the coming-of-age period—have the deepest influences on economic and political beliefs. For example, Giuliano and Spilimbergo (2014) empirically

[10] Also see *https://web.archive.org/web/20170216215337/http://www.pewresearch.org/methodology/demographic-research/definitions/* (accessed 9 September 2021) for the segments of the Pew Research Center.

prove this psychological theory by showing evidence that an economic recession during these impressionable years significantly shapes preferences for redistribution. To investigate these key political, economic and social factors experienced by each generation when coming of age, the Pew Research Center conducted a survey called "Americans Name the 10 Most Significant Historic Events of Their Lifetimes", and Table C.1 shows that the list varies across generations. In the following, I summarize how generations are shaped by the environment during their formative years.

The Greatest Generation was working during the Great Depression, a harsh economic time, thus being indoctrinated with conservative values of financial security. As the main participants of World War II, they also experienced the extreme political turmoil, where they developed the ability to delay gratification (Schewe *et al.*, 2000). Influenced by the economic hardship and wartime experiences, the Greatest Generation has been willing to sacrifice personal satisfaction for the sake of a better society. This is reflected in the Inaugural Address of John F. Kennedy in 1961, "ask not what your country can do for you—ask what you can do for your country" (Norum, 2003). Consequently, fighting for the country rather than personal fame or recognition became a standard, and the Greatest Generation achieved significant accomplishments, such as the Interstate Highway System and Medicare program (Brokaw, 1998).

The Silent Generation experienced a relatively long time of economic growth and social stability. Economically, they hold less conservative attitudes towards saving and spending (Schewe *et al.*, 2000). Nevertheless, when coming of age after the World War II, they continuously worked in a new social order and never had the motivation or courage to change it. That is also the origin of the "silent" label (Howe, 2014). Located between the Greatest Generation who had been fighting and sacrificing, and Baby Boomers who created shock waves afterwards, the Silent Generation stayed in a difficult situation like a sandwich (Howe, 2014), therefore refraining from individual expression (Schewe *et al.*, 2000). Due to their large population size, Baby Boomers had been dominating all aspects of the American society (Schewe *et al.*, 2000). Opposite to the war years, their period was symbolized by the unmatched economic prosperity, ample educational opportunities, and major technological advancements (Strauss and Howe, 1991; McCrindle, 2007). Growing up in such a booming environment, Baby Boomers value independence and individualism (Eastman and Liu, 2012), so they attach more importance to personal achievements than contribution to the society (Smith *et al.*, 1997). In contrast to previous generations that were characterized by humility and modesty, they started defying established social orders; for this reason, Russell (1993) called them "free agents". At the same time, full employment encouraged and fostered Baby Boomers' financial confidence and consequent spending habits (Eastman and Liu, 2012). Therefore, austerity was left behind and "buy now, pay later" became their new consumption philosophy instead (Schewe *et al.*, 2000).

Generation X grew up in a less optimal environment created by the individualism and the self-fulfillment of their Baby Boomer parents who shifted the focus of the society from children to adults (Howe and Strauss, 1993). The increasing divorce rate and female labor force participation of Baby Boomers left Generation X unsupervised after school, originating the "latchkey generation" label (Shamma, 2011; Blakemore, 2015). When Generation X was coming of age, the economic recession in the 1980s made them conscious and pessimistic (Eastman and Liu, 2012). Meanwhile, turbulent political conditions caused their uncertainty and disillusionment (Smith *et al.*, 1997). All of these unfortunate experiences negatively shaped Generation X as aimless, bleak, and cynical (Paulin and Riordon, 1998), portrayed later by Richard Link in the 1990 American comedy-drama film *Slackers*.

By the end of the economic recession and political instabilities experienced by Generation X, Millennials appeared on the scene. Living through the era of digital revolution, globalization, and environmentalism (Schewe *et al.*, 2000; McCrindle, 2007), Millennials are always considered as distinct from previous generations in every aspect, which is discussed in more details in the following.

3.2.2 Millennials

Millennials have been attracting attention due to their distinguishability and uniqueness. Two most distinct features are a higher relative education level (Frey, 2018) and the familiarity with new technology (Valentine and Powers, 2013). Demographically, the Pew Research Center estimated that in 2019, Millennials (with a population of 72.1 million) had passed Baby Boomers (with a population of 71.6 million) and become the largest living adult generation in the US, thanks to the dynamics of mortality and immigration (Fry, 2020). As a generation with a higher racial and ethnic diversity, Millennials might serve as a demographic "bridge" in America's future (Fromm and Garton, 2013; Frey, 2018).

The stereotype of Millennials is formed by the fact that Millennials grew up in a time of accumulated materialism (Valentine and Powers, 2013) and are well protected by the society and governmental safety regulations (Tucker, 2006). As a "spoiled" generation, Millennials are too impatient to delay gratification, indicating their possible active participation in the luxury market. However, such a modern environment could shape Millennials in an opposite manner. Exposed to explosive amounts of information and massive technological innovation, Millennials actually developed sophistication and suspicion (Valentine and Powers, 2013). For example, Martin and Turley (2004) find that Millennials are objective, rational, and goal-oriented during a mall excursion, and they emphasize functional values instead of being motivated by hedonism or marketing tricks.

At the same time, the new era of Millennials is also full of unpredictability. First of all, the expected gains from greater educational achievements have been counteracted by the accompanying decreasing returns due to an overproduction of advanced degrees (Emmons *et al.*, 2019). Since 2000, the college wage premium first started flattening and then disappearing (see, e.g., Beaudry *et al.*, 2014; Valletta, 2018; Ashworth and Ransom, 2019). Secondly Millennials were impacted most negatively from the Great Recession. They were benefiting the least from the recovery (Smith, 2012), and are facing a worse situation in the labor market compared to Baby Boomers and Generation X when they were young (Frey, 2018). By examining the effects of the Great Recession on wealth accumulation, Gale *et al.*

(2020) show similar problems: notwithstanding the temporary wealth decline of all age groups, Millennials have become poorer relative to older generations. Furthermore, the large number of Millennials results in fierce competition for jobs (Zeihan, 2016). At last, the new trends of artificial intelligence and robotics generate not only new opportunities but also challenges (Zao-Sanders and Palmer, 2019).

Shaped by these revolutionary external events, Millennials have been evolving differently from their predecessors, reflected in a unique way of thinking and consuming. Millennials might strongly stimulate the American economy (Noble *et al.*, 2009) when reaching their peak earning and spending years, especially given their large number. It is therefore important to understand how their spending pattern differs from previous generations, both from a marketing and a broader economic perspective.

3.2.3 Data

I use data from the US Consumer Expenditure Survey (CE). Carried out by the US Bureau of Labor Statistics (BLS), the CE is a program to collect data of household expenditures on goods and services in the US, where basic information on economic and demographic characteristics is also included. The CE program consists of two separate surveys using different samples: 1) the Quarterly Interview Survey contains data on large and recurring expenditures during the three months prior to the interview, and 2) the Diary Survey is designed for small and frequent purchases for a consecutive period of two weeks. In this chapter, I only use the Quarterly Interview Survey due to its higher data quality.[11]

The Quarterly Interview Survey is a short, rotating panel survey in which approximately 6000 interviews are conducted during each calendar quarter. Each household is interviewed every three months over four consecutive quarters, and is supposed to recall expenditures during the past three months.[12] All households that complete the fourth interview or

[11] See Bee *et al.* (2012) for the detailed discussion about this issue.

[12] Before 2015, a preliminary bounding interview was included to minimize telescoping errors. Because of its ineffectiveness and cost, it was stopped at the beginning of 2015 (Elkin, 2012). Data from these interviews are not used in this chapter.

preliminarily leave the survey, are dropped from the sample and replaced. Although each household can provide data for a maximum of one year, I treat records of each interview independently. I do not report the sum of expenditures across all interviews of one household because the following reasons distort these results: less than 50% of all households complete four surveys; and fully participating households tend to be older, richer, and more likely to own their homes.

The data set consists of various files that report expenditure information in different levels of detail since the end of 1979, and data from the FMLI files from 2000 to 2018 are used. These FMLI files from the Quarterly Interview Survey provide summary level expenditures and other household characteristics. Since 2000, the questionnaire design and expenditure categorization have been consistent, meaning that the consumption bundle always stays identical. Besides, Millennials are also included in the samples of each year from 2000 to 2018. I aggregate specific expenditure categories in the FMLI files into 32 categories, and Table C.2 reports the details.[13] Besides expenditure, I also take data on the household characteristics and the total amount of household income after taxes in the last 12 months from the FMLI files.[14] All expenditure and income data are deflated to 2007 dollars using the Consumer Price Index (CPI). Household characteristics of each record include demographic information of household head (e.g., age, gender, race, marital status and education), household structure (e.g., household size and number of adults), urban residence, information on metropolitan statistical area, region, and interview quarter. Note that redundant variables from the survey are excluded. For instance, the number of children in a household is excluded, as it can be directly inferred from the household size and the

[13]The FMLI files also report aggregated expenditure categories, but they are too broadly defined and the heterogeneity among individual categories might already average out. For example, *shelter*, *utilities, fuels and public services*, *household operations*, and *house furnishings and equipment* are all included in a single category called *total housing outlays*.

[14]Complete income reports after taxes were the only source of published income data before 2004, afterwards the CE program started to impute missing values. Estimation of personal taxes was introduced in the second quarter of 2013, which has been collected instead of reported tax values. As a result, missing incomes are used before 2004, imputed or collected income values are used for the years 2004–2013, and imputed or collected income data are combined with estimated taxes after 2013.

number of adults. The pooled sample contains 526828 observations.

3.3 Defining Luxury Expenditure

First, I determine which of the 32 categories listed in the left column of Table C.2 can be treated as luxury. The microeconomic definition of luxury says that luxury expenditure rises by more than one percent with an increase in total expenditure of one percent. Based on this definition, I estimate the total expenditure elasticity of each category and determine whether it should be treated as luxury or necessity by comparing the elasticity to one. Concerning measurement errors and extreme values in the data, I drop households with negative expenditures in any category from the full sample. Furthermore, households in the top or bottom one percent of the total expenditure distribution within each year are removed. I do not consider specific generations or age ranges for the elasticity estimation, since the definition of luxury should represent the perception of luxury within the whole population.

Following the approach of Heffetz (2004, 2011, 2018), I conduct a non-parametric estimation using the prepared sample. To be specific, I start with estimating the expenditure of each category as a function of total expenditure at 101 total expenditure points, using the weighted local linear regression with a quartic kernel developed by Fan (1992). Next, gradients between pairs of neighboring points are computed, and 100 local expenditure elasticities are derived from these gradients. Finally, the average elasticity of all households is obtained from the local elasticities weighted by the number of households located in each of the 100 intervals. This is repeated for all 32 expenditure categories.

For a stable and reliable measure of luxury, the estimation is executed using data of different time periods: 2000–2009, 2010–2018, and 2000–2018. Because the perception of luxury depends on subjective preferences that typically do not change too frequently, I consider the total expenditure elasticities as relatively stable across time. However, averages across the entire 19-year sample period might cover some important deviations (i.e., when estimated over different periods, the elasticities can fluctuate around one for some categories), and hence the finial classification could be imprecise. Therefore, I also separately estimate elasticities during the 2000s and the 2010s, besides the whole sample period. Only categories with elasticities consistently larger than one in any period are defined as luxury.

The estimation results are shown in Figure 3.1, where one is indicated by a vertical line as the elasticity threshold. The elasticity-based luxury definition above leads to 15 categories of luxury goods.

- *household operations*
- *house furnishings and equipment*
- *clothing for adults*
- *vehicle purchases*
- *other vehicle expenditures*[15]
- *public and other transportation*
- *fees and admissions*
- *pets, toys and playground equipment*
- *recreational vehicles*
- *miscellaneous entertainment outlays*
- *education*
- *cash contribution*
- *retirement, pensions, social security*
- *life and other personal insurance*
- *miscellaneous outlays*[16]

After this, the two categories, *retirement, pensions, social security* and *life and other insurance* are excluded because they belong to the consumption transferred into the future. As a result, the remaining 13 are defined as luxury and boldfaced in Figure 3.1. Thus, luxury expenditure is the sum of expenditures over these categories in the following analysis.

[15] *Other vehicle expenditures* include vehicle rental, leases, licenses, and other charges. See Table C.2 for details.

[16] *Miscellaneous outlays* specifically include checking account fees and other bank service charges, credit card memberships, accounting fees, funerals, union dues, etc. See Table C.2 for details.

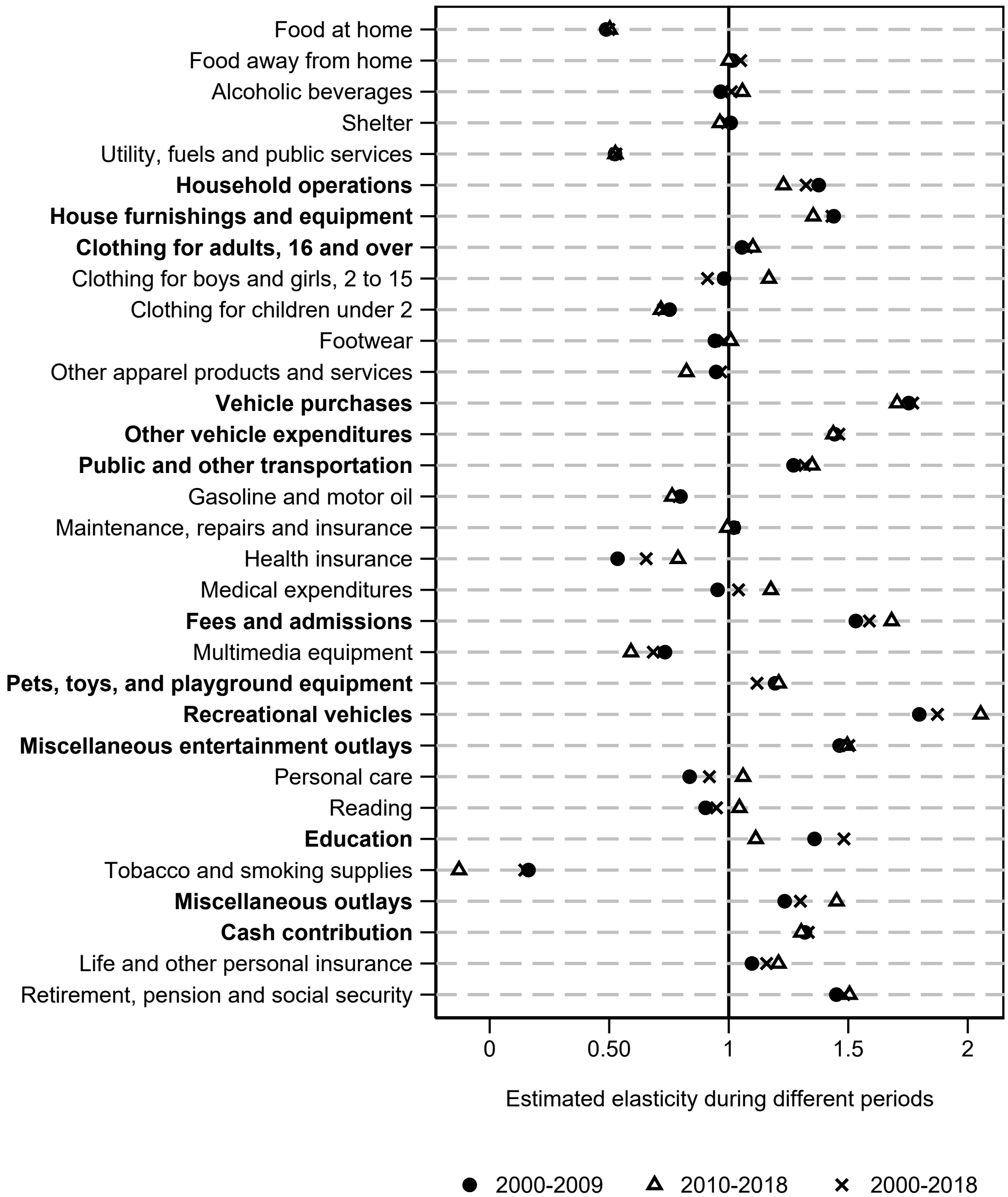


Figure 3.1: *Total Expenditure Elasticity*

Notes: This figure reports the estimated total expenditure elasticities of the 32 categories listed in the left column of Table C.2. To keep the results consistent and stable across different time periods, the same estimation procedure is conducted. The 13 resulting luxury categories are the boldfaced.

Arguments whether some categories really belong to luxury might arise here, since the estimation results are not necessarily in line with every personal opinion. For instance, it is debatable whether education should be treated as investment or expenditure. The methods of financing education also involve complex financial issues that are not homogeneous across households or generations. For simplicity and objectivity, here I mainly rely on the economic definition of luxury instead of arguing in detail about the rationale behind it. I also show the results from individual categories in Section 3.5.5. For categories that are agreeably considered as "classic" luxury, results are consistent with the main findings, as discussed in Section 3.8.1.

3.4 Descriptives

In this section, I summarize some descriptive statistics after refining the pooled sample with 526828 observations. Then, I graph overall and generation-specific sample means over the life cycle and across time to show patterns of luxury expenditure.

3.4.1 Sample Selection and Summary Statistics

Several steps are taken to refine the pooled sample for the following analysis.[17] First, I exclude Generation Z from the sample since there are only few observations and members from this generation have not completed their education yet, which might distort their expenditure structure. Next, I only keep households whose heads are younger than 81 as only few old households were surveyed.[18] Furthermore, households whose heads are younger than 21 are excluded since in the US they do not have access to some expenditure categories like alcoholic beverages, tobacco, or smoking supplies.[19] On top of that, I drop

[17] Instead of the trimmed sample from the elasticity estimation in Section 3.3, I start with the full sample of 526828 observations again here.

[18] There are consistently more than 3000 observations for each age lower than 81, but for households older than 80, the number of observations fluctuates between 4972 and 0.

[19] The lower age bound 21 also rules out most members of Generation Z.

households with negative expenditure in any category and households with negative income (before or after taxes) from the sample to account for measurement errors. For the data before 2004, I drop incomplete income reports.[20] Finally, to mitigate the impacts of extreme values, I drop households in the top or bottom one percent of the total expenditure and income (before or after taxes) distribution within each year. The resulting sample contains 443497 observations after the selection process.

Generation is created as a categorical variable based on the birth year of household heads. I combine the two oldest generations, the Greatest Generation and the Silent Generation, together into one single generation in the main specification, since Millennials are the focus of this chapter and less data of old generations are included in the survey. McCrindle (2007) calls this combined generation "Builders" because they have transformed an agrarian economy into an industrialized one by building the infrastructure and organizations of the new post-war society. Figure 3.2 displays the size of each generation in the sample across time: overall there are 51797 observations from Millennials, 132364 from Generation X, 174083 from Baby Boomers, and 85253 from Builders.

Table 3.2 lists summary statistics for the refined sample, where both the level and the share of luxury expenditure are the main dependent variables for the analysis in the following. On average, households spend $2591.56 per quarter (in 2007 dollars) on luxury, accounting for around 18.3% of their total expenditure. Millennials exhibit the lowest expenditure on luxury in terms of absolute level probably because Millennials are just at the beginning of their career path and receive relatively low income. Builders have the second lowest level of luxury expenditure, and they have the lowest total expenditure level, followed by Millennials. However, Millennials on average have the largest share of luxury expenditure among all generations, which matches the established social impression of Millennials as influential luxury consumers. Nevertheless, the average picture is not yet enough for this conclusion, as it is also related to age.

Regarding demographics, the average age in the sample is 48.5, which is driven by the

[20]See Footnote 14 for detailed information on this.

Table 3.2: *Summary Statistics*

Dependent variables	N	Mean	SD	Min	Max
Luxury expenditure (overall)	443497	2591.56	3425.37	0	42948.56
Millennials	51797	2126.42	2812.12	0	39564.71
Generation X	132364	2727.53	3214.43	0	40640.74
Baby Boomers	174083	2825.22	3653.39	0	40824.00
Builders	85253	2185.93	3535.53	0	42948.56
Share of luxury expenditure (overall)	443497	0.183	0.141	0	0.989
Millennials	51797	0.188	0.148	0	0.989
Generation X	132364	0.186	0.134	0	0.959
Baby Boomers	174083	0.181	0.137	0	0.976
Builders	85253	0.178	0.153	0	0.944
Income and total expenditure	N	Mean	SD	Min	Max
Income after taxes	443249	56637.61	45088.50	831.48	310994.20
Total expenditure	443497	11615.09	7624.98	1501.62	51922.45
Millennials	51797	9564.92	5807.89	1507.52	51754.86
Generation X	132364	12426.74	7430.92	1511.90	51827.42
Baby Boomers	174083	12699.76	8205.20	1501.62	51922.45
Builders	85253	9385.70	6914.06	1517.80	51794.45
Demographics of household head	N	Mean	SD	Min	Max
Age	443497	48.460	15.469	21	80
Male	443497	0.487	0.500	0	1
Married	443497	0.545	0.498	0	1
Below 9th grade	443497	0.048	0.213	0	1
High school, no diploma	443497	0.083	0.276	0	1
High school graduate	443497	0.461	0.498	0	1
College graduate	443497	0.299	0.458	0	1
Masters degree and above	443497	0.109	0.312	0	1
White	443497	0.815	0.388	0	1
Black	443497	0.119	0.324	0	1
Native American	443497	0.006	0.078	0	1
Asian or Pacific Islander	443497	0.049	0.216	0	1
Other races	443497	0.011	0.104	0	1
Household size	N	Mean	SD	Min	Max
Number of household members	443497	2.590	1.507	1	21
Number of adults	443497	1.985	0.926	1	13
Household scale (equivalence)	443497	1.992	0.899	1	12.6
Household location	N	Mean	SD	Min	Max
Urban	443497	0.933	0.251	0	1
Metropolitan statistical area	443497	0.871	0.336	0	1
Northeast	438897	0.177	0.382	0	1
Midwest	438897	0.224	0.417	0	1
South	438897	0.355	0.479	0	1
West	438897	0.243	0.429	0	1
Interview quarter	N	Mean	SD	Min	Max
Quarter 1	443497	0.245	0.430	0	1
Quarter 2	443497	0.254	0.436	0	1
Quarter 3	443497	0.251	0.433	0	1
Quarter 4	443497	0.250	0.433	0	1

Notes: This table reports summary statistics of the refined sample (including 443497 observations) for the descriptives and regression analysis. Different numbers of observations come from missing values of corresponding variables. Expenditure data are quarterly-based, while income after taxes is measured as the total amount of household income after taxes in the last 12 months.

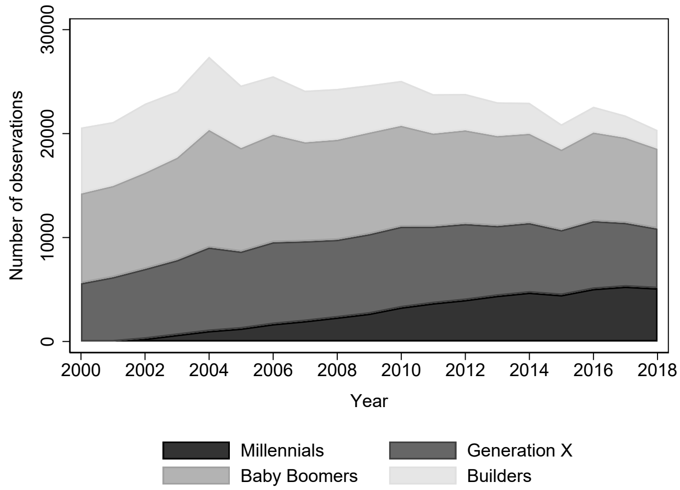


Figure 3.2: *The Size of Each Generation in the Sample 2000–2018*

Notes: This figure reports the size of each generation across time in the refined sample (including 443497 observations) for the analysis. 1906 is the earliest birth year of Builders in the refined sample, which is different from the earliest birth year of the Greatest Generation (1902) defined in Table 3.1. The age range of each generation in the sample is: Millennials (21–37), Generation X (21–53), Baby Boomers (36–72), and Builders (55–80). The number of observations of each generation in the sample is: Millennials (51797), Generation X (132364), Baby Boomers (174083), and Builders (85253)

Sources: Own illustration based on the Consumer Expenditure Survey (CE) 2000–2018

fact that Baby Boomers and Generation X are overrepresented in the survey.[21] Slightly more than half of household heads are women, and households with married heads make up 54.5%. The largest group of household heads (46.1%) are high school graduates, and 81.5% of the household heads are Whites. The spatial distribution of households is uneven as most of them are located in urban and metropolitan statistical areas, and the largest number of surveys happened in the South region of the US. The surveys are distributed almost uniformly across the four calendar quarters.

Due to the economies of scale in consumption, household sizes should be adjusted. Different choices of scales are discussed in the literature, all of which have advantages and drawbacks (see, e.g., Fernández-Villaverde and Krueger, 2007; Aguiar and Hurst, 2013). In the main specification, I use the “OECD equivalence scale”, also called “Oxford scale”,

[21]See Figure 3.2 for the size of each generation in the sample. The average ages are: Millennials 27.0, Generation X 36.7, Baby Boomers 53.2, and Builders 70.0.

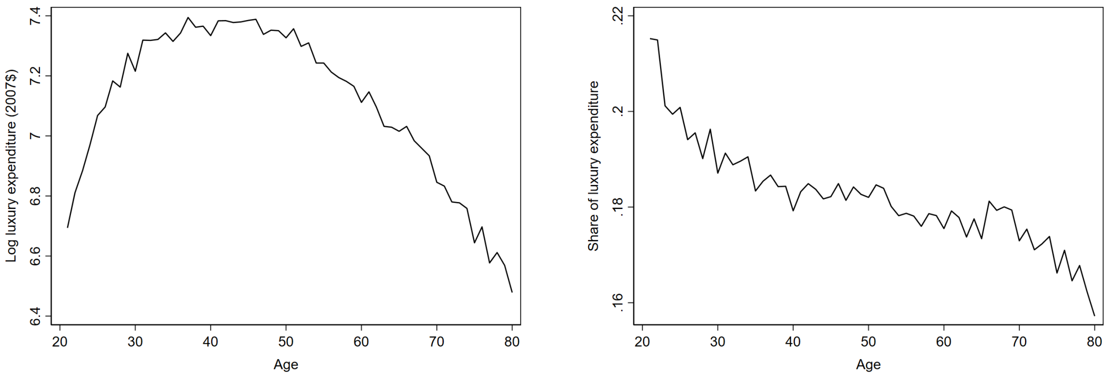
which assigns a value of 1 to the first household member, a value of 0.7 to each additional adult, and 0.5 to each child. This scale reduces the average household size from 2.59 to 1.99. Alternatively, the "OECD-modified scale" and the "Square root scale" are mainly employed in robustness checks, but deliver almost identical results compared to main specification.[22]

3.4.2 Age Profiles

To present the average share and log level of luxury expenditure by age, I pool observations of all sample years and calculate the averages conditional on age. Figure 3.3 shows the resulting age profiles. On average, the luxury expenditure level over the life cycle is characterized by a "hump" peaking around age 40 in Figure 3.3(a), corresponding to the dynamics of earning years. Nonetheless, Figure 3.3(b) reveals a monotonic decline of the share of luxury expenditure over the life cycle. After falling drastically from about 21.5% at age 21 to 18% at age 40, it stays on a stable decrease until another sharp drop at age 70. The key insight from Figure 3.3 is that age is an active factor which affects luxury expenditure in terms of both level and share, and that young people exhibit a large amount of luxury consumption. Although Millennials are the youngest generation in the sample, only the mean consumption by age is displayed. So the specific behaviors of Millennials are not immediately clear from these averages, as the expenditure of Generation X at the same age is also included.

As the generation heterogeneity behind Figure 3.3 is still hidden, I provide further information on the evolution of average luxury expenditure for each generation in Figure 3.4. Each line represents the expenditure behavior of a specific generation over the 19-year sample period. Different generations are observed through different life stages, with overlaps among age brackets which can be used for comparing neighboring generations. The vertical distance between lines implies the existence of the generation effect, although it

[22]The "OECD-modified scale" assigns a value of 1 to the household head, a value of 0.5 to each additional adult and 0.3 to each child. The "Square root scale" uses the square root of the total number of household members. See *http://www.oecd.org/economy/growth/OECD-Note-EquivalenceScales.pdf* (accessed 9 September 2021) for an overview of all scales.



(a) Log Level

(b) Share

Figure 3.3: *Luxury Expenditure by Age*

Notes: All values are in US 2007 dollars. Both figures plot means at each age from 21 to 80. Figure 3.3(a) shows the log level of luxury expenditure, and Figure 3.3(b) shows the share of luxury expenditure.

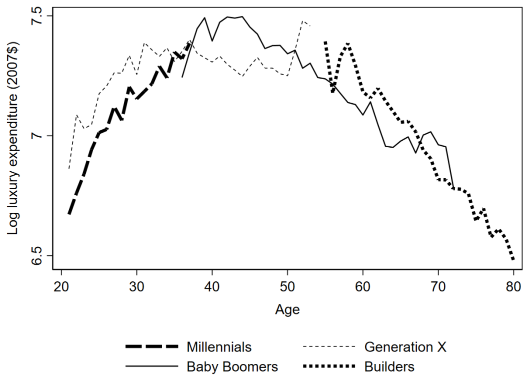
Sources: Own illustration based on the Consumer Expenditure Survey (CE) 2000–2018

is still contaminated by other effects here. The overall "hump-shaped" expenditure levels and declining expenditure shares still remain, while differences between generations are obvious as well. At the same age, younger generations tend to spend less on luxury in terms of both expenditure level and share. Figure 3.4(b) shows that the differences are especially substantial in expenditure share. Even though the data might contain some amount of noise, Millennials have been consistently consuming less luxury than Generation X at any given age from 21 to 37. This is the entire available age range of Millennials in the data.

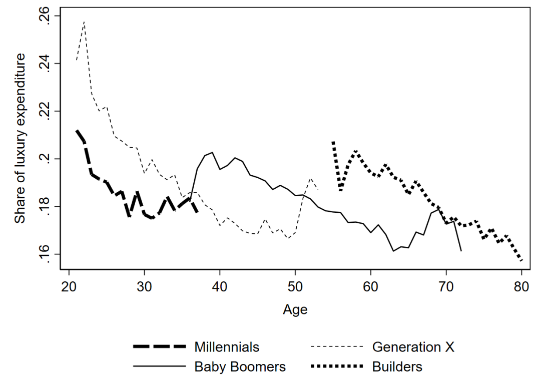
However, these average expenditure patterns can not tell to what extent the results are driven by differences in the demographic composition between generations, such as education levels or household size. To isolate the generation effect from such compositional effects, I will turn to a regression analysis in Section 3.5.

3.4.3 Time Trends

Next, I examine luxury expenditure across time to have an overall perception of the period effect. Figure 3.5 presents the results. Clearly, the level and the share of luxury expenditure follow the same time trend, declining from the early 2000s until 2014 and then starting



(a) Log Level



(b) Share

Figure 3.4: *Generation Specific Luxury Expenditure by Age*

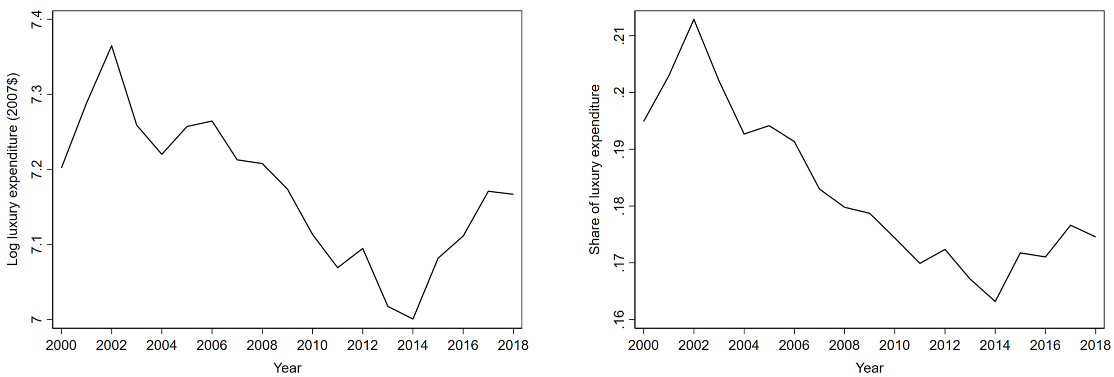
Notes: All values are in US 2007 dollars. Both figures plot means at each age from 21 to 80 for every generation. Figure 3.4(a) shows the log level of luxury expenditure, and Figure 3.4(b) shows the share of luxury expenditure.

Sources: Own illustration based on the Consumer Expenditure Survey (CE) 2000–2018

to recover. The lowest expenditure in 2014 reflects the long-term influences of the Great Recession.

Subsequently, the generation-specific time trends are analyzed and Figure 3.6 shows the resulting expenditure level and share. Generation X and Baby Boomers have the highest absolute luxury expenditure level. These generations are still closer to their peak earning ages and thus have the highest income and total expenditure (see Table 3.2), which is closely linked to high luxury expenditures. Around 2008, when most Baby Boomers gradually approach retirement, Generation X naturally replaces them as the leading luxury purchaser. In Figure 3.6(a), Millennials diverge from other generations as their expenditure level continuously increases across time, consistent with the perception that Millennials are major contributors in the luxury market. The generation differences in Figure 3.6(b) reflect the average statistics in Table 3.2, where Millennials consistently have the largest luxury expenditure share from 2000 to 2018.

An important feature of Figure 3.6 is that luxury expenditure trends are synchronized among all generations to some degree, implying that every generation faces a similar



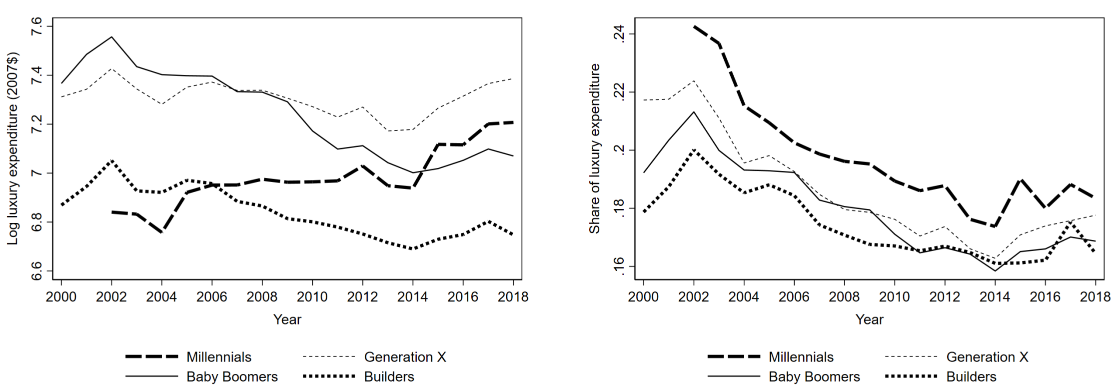
(a) Log Level

(b) Share

Figure 3.5: *Luxury Expenditure by Year*

Notes: All values are in US 2007 dollars. Both figures plot means in each year from 2000 to 2018. Figure 3.5(a) shows the log level of luxury expenditure, and Figure 3.5(b) shows the share of luxury expenditure.

Sources: Own illustration based on the Consumer Expenditure Survey (CE) 2000–2018



(a) Log Level

(b) Share

Figure 3.6: *Generation Specific Luxury Expenditure by Year*

Notes: All values are in US 2007 dollars. Both figures plot means in each year from 2000 to 2018 for each generation. Figure 3.6(a) shows the log level of luxury expenditure, and Figure 3.6(b) shows the share of luxury expenditure.

Sources: Own illustration based on the Consumer Expenditure Survey (CE) 2000–2018 period effect. This synchronization empirically supports the separability of the period effect from the generation effect. This is the base for my main specification, whereas additional identifications present heterogeneous effects.

3.5 Regression Analysis

In the following, I present econometric models that identify the age effect and the generation effect, and I quantitatively measure them. After discussing multiple identifications, I analyze the individual categories to show how the overall results are driven by specific luxury goods.

3.5.1 Identification Strategy

The main specification is constructed as

$$L_{i,t} = \alpha_0 + \boldsymbol{\beta_a} \boldsymbol{D^a_{i,t}} + \boldsymbol{\beta_g} \boldsymbol{D^g_i} + \alpha_1 \text{Period}_t + \alpha_2 \ln\left(\text{Income}\right)_{i,t} + \boldsymbol{\beta_h} \boldsymbol{X_{i,t}} + \varepsilon_{i,t}, \tag{3.1}$$

where $L_{i,t}$ is either the log level of luxury expenditure or the share of luxury expenditure of household i during the last 3 months in year t. I take an age-dummy vector $\boldsymbol{D^a_{i,t}}$ for every age from 21 to 80, with age 40 as the base group. Likewise, $\boldsymbol{D^g_i}$ is a vector of generation dummies for Millennials, Baby Boomers, and Builders, where Generation X is the base group.

Period$_t$ stands for the 5-year lagged GDP growth rate as a proxy for the period effect. With age and generation dummies, an additional time control will induce a collinearity problem because age can be computed from calendar time and birth year which is inferred from the generation. To avoid this, I use a proxy variable approach suggested by Dohmen *et al.* (2017), which substitutes the period effect with the GDP growth rate that captures the cyclical pattern of expenditure variations across time.[23] To account for the enduring influences of the economy on luxury expenditure (like the long-lasting consequences of the

[23]The standard approach developed by Deaton (1997) in consumption literature assumes that the time effect captures the cyclical fluctuations (Aguiar and Hurst, 2013). See Section 3.6.2 for robustness checks that this method delivers similar results to the main findings.

Great Recession shown in Figure 3.5) the lag of the GDP growth rate should be considered. In Table C.3, multiple lag period lengths, from one to six years of lag, are scrutinized to find the most suitable proxy variable.[24] It turns out that 5-year lagged GDP growth rate results in the highest correlation with luxury expenditure level and share. To further corroborate this approach, Figure C.1 plots both 5-year lagged GDP growth rate and average luxury expenditure across time. It can be seen that the cyclical patterns of luxury expenditure can be epitomized by the GDP growth to some degree.

Finally, $\ln(\text{Income})_{i,t}$ is the log of the total amount of household income after taxes in the last 12 months. $\boldsymbol{X_{i,t}}$ is a control variable vector of the household characteristics specified in Table 3.2, including household demographics, size, location, and information on the interview quarter. This choice follows the selection of controls in related literature (see, e.g., Charles *et al.*, 2009; Friehe and Mechtel, 2014).

The main specification is built on the separability assumption which states that there are no interactions among control variables. The descriptive time trends from Section 3.4.3 empirically support that the period effect is separable from the generation effect. Thus it is additionally assumed, that there are no interaction terms between age and generation dummies in Eq. (3.1). In this way the age and generation effect are explored separately here, but more general specifications are discussed in the following.

3.5.2 Main Results

Estimation results are presented in Table 3.3. To start with, I create a naive regression model to investigate generational variations of luxury expenditure without accounting for age, using generation dummies, the 5-year lagged GDP growth rate as a proxy for the period effect, and income. Next, I additionally include age dummies as the baseline model which shows the preliminary pure generation effect independent of age. Furthermore, I run the preferred regression including full controls for household characteristics $\boldsymbol{X_{i,t}}$.

[24] Data on GDP growth rates are taken from the World Bank, available at *https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?end=2019&locations=US&start=1961* (accessed 9 September 2021).

Table 3.3: *Main Results*

	Log luxury expenditure			Share of luxury expenditure		
	(1)	(2)	(3)	(4)	(5)	(6)
Millennials	0.0545***	-0.0735***	-0.0872***	0.0180***	-0.0139***	-0.0156***
	(0.0087)	(0.0110)	(0.0109)	(0.0010)	(0.0013)	(0.0012)
Baby Boomers	-0.0533***	0.0780***	0.0939***	-0.0054***	0.0136***	0.0145***
	(0.0062)	(0.0099)	(0.0098)	(0.0007)	(0.0011)	(0.0011)
Builders	-0.1019***	0.1350***	0.1887***	0.0044***	0.0286***	0.0322***
	(0.0083)	(0.0167)	(0.0164)	(0.0009)	(0.0018)	(0.0018)
ln(Income)	0.8016***	0.8066***	0.6409***	0.0331***	0.0352***	0.0273***
	(0.0035)	(0.0037)	(0.0042)	(0.0003)	(0.0003)	(0.0004)
Household scale (equivalence)			0.0568***			-0.0031***
			(0.0058)			(0.0006)
Number of adults			-0.0177***			-0.0025***
			(0.0055)			(0.0006)
Male			-0.0182***			-0.0014**
			(0.0054)			(0.0006)
Married			0.2594***			0.0149***
			(0.0067)			(0.0007)
Below 9th grade			-0.4844***			-0.0318***
			(0.0148)			(0.0014)
High school, no diploma			-0.3767***			-0.0281***
			(0.0114)			(0.0010)
College graduate			0.2415***			0.0162***
			(0.0062)			(0.0007)
Masters degree and above			0.4004***			0.0286***
			(0.0085)			(0.0010)
Black			-0.1588***			-0.0118***
			(0.0090)			(0.0009)
Native American			-0.0980***			0.0013
			(0.0360)			(0.0036)
Asian or Pacific Islander			-0.2095***			-0.0145***
			(0.0128)			(0.0014)
Other races			0.0280			0.0035
			(0.0232)			(0.0026)
Urban			-0.0256*			-0.0031*
			(0.0145)			(0.0016)
Metropolitan statistical area			0.0517***			-0.0104***
			(0.0114)			(0.0012)
Period	✓	✓	✓	✓	✓	✓
Age		✓	✓		✓	✓
Region			✓			✓
Quarter			✓			✓
Observations	426498	426498	422145	443249	443249	438658
R^2	0.2499	0.2521	0.2854	0.0456	0.0529	0.0721

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. While related work that uses short-term data usually reports standard errors at state level, for the reasons mentioned in Footnote 25, I cluster standard errors at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. High school graduate is the base group of education, and White is the base group of race.

Column (1) and (4) display the results of the naive model, for both the log and the share of luxury expenditure as dependent variables, respectively. Without controlling for age, the estimated coefficients on generation dummies are decreasing (except for the expenditure share of Builders), which coincides with the established impression that Millennials have a high spending power in the luxury market. However, in the baseline model including age dummies, the generation effect immediately switches direction as shown in Column (2) and (5). Earlier born generations tend to consume more luxury, conditional on age, time period, and income level. This finding is further confirmed by the preferred regressions in Column (3) and (6) which additionally control for household characteristics.[25] In all specifications with age controls, the generation effect is solid and significant, and the estimator magnitudes are relatively stable. The pure generation effect from the regression corresponds to the overview of generation specific age profiles in Figure 3.4: younger generations actually spend less on luxury.[26]

Millennials are consuming the least amount of luxury in terms of both level and share. Quantitatively, Column (2) shows that Millennials spend 7.35% less than Generation X on luxury, accounting for age, income, and time period. This number increases to 8.72% in Column (3) when household characteristics are additionally considered. Based on the average luxury expenditure of Generation X, i.e., $2727.53 per quarter in Table 3.2, the estimation leads to generation differences from $200 to $238 per quarter. At the same time, the share of luxury expenditure of Millennials is around 1.50% less with respect to Generation X as displayed in Column (5) and (6). Given that the average share of luxury expenditure of Gen-

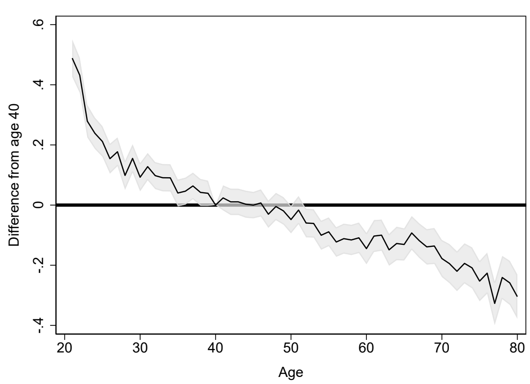
[25]In the preferred specification, the region (Northeast/Midwest/South/West) rather than the specific state is controlled due to two reasons. First of all, the sample period is too long to rule out the considerable influences from large-scale migrations across states. Therefore, the state fixed effect is obscured in the sample as expenditure preferences geographically move along with the people. However, the region fixed effect is comparatively stable because of larger areas and fewer transitions. Secondly, there is a significant amount of missing state information in the data. For the same reasons, I cluster standard errors at household level, while related work that uses short-term data usually reports standard errors at state level. Nevertheless, I also investigate the inclusion of both region and state fixed effects in Table C.5. The resulting coefficients barely change as displayed in Column (2) and (4).

[26]All results in this chapter are unweighted. Nevertheless, Table C.5 reports results considering frequency weights, according to the size of each generation in the sample, as shown in Figure 3.2 and Section 3.4.1.

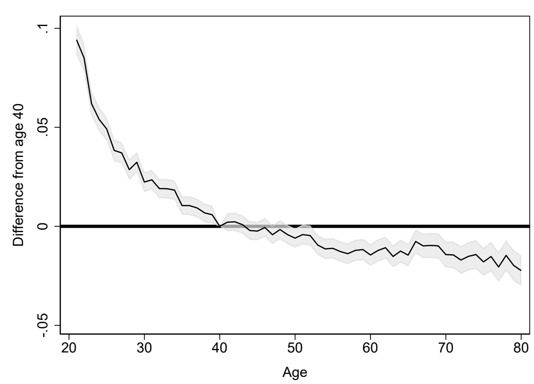
eration X in the sample is only 18.6% from Table 3.2, the generation difference is not trivial. Considering the monotonic increase of luxury expenditure across generations, Millennials behave even more conservatively when compared with Baby Boomers or Builders.

The effects of household characteristics are quite intuitive as well. Conditional on the same household size, the negative effect of the number of adults implies the existence of altruism, as parents are more likely to purchase luxury for their children. Referring to education, the estimation suggests a positive correlation between luxury expenditure and education level, so luxury might actually require a certain amount of knowledge.

Figure 3.7 portrays the age effect on luxury expenditure based on the preferred model in Column (3) and (6). The solid lines plot the coefficients on estimated age dummies where shaded areas indicate 95% confidence intervals. The horizontal zero lines mark the reference age 40. Conditional on other variables, luxury expenditure monotonically decreases over the life cycle, with respect to both the level and the share, meaning that the interests in luxury decrease with age. The received idea of Millennials' high luxury expenditure seems to arise from their young age, which is unrelated to the effect of their generation identity.



(a) Log Level



(b) Share

Figure 3.7: *Main Results: Age Effect on Luxury Expenditure*

Notes: Both figures show the estimated coefficients on age dummies from Column (3) and (6) in Table 3.3, including 95% confidence intervals. Figure 3.7(a) shows the effect on the log level of luxury expenditure, and Figure 3.7(b) shows the effect on the share of luxury expenditure. Coefficients are relative to the horizontal zero lines, which correspond to the reference age 40.

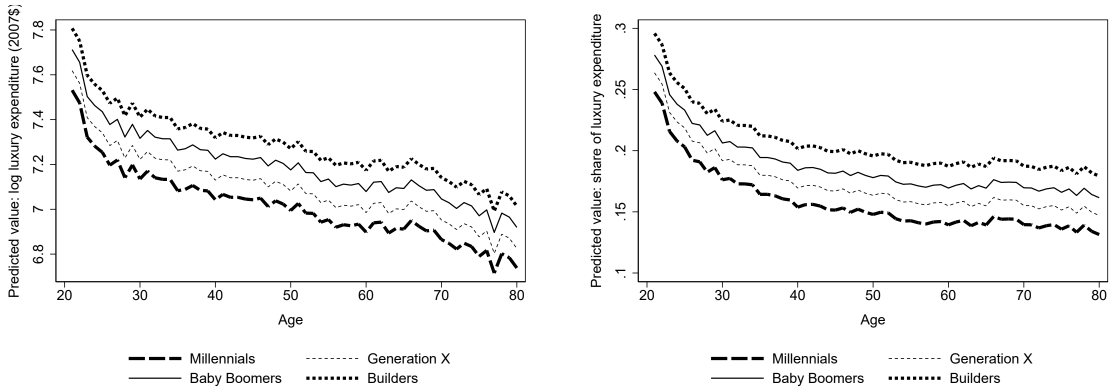
3.5.3 Counterfactual Predictions

Next, I construct counterfactual age profiles of luxury expenditure for all generations based on the regression results. The estimators from the preferred model in Column (3) and (6) in Table 3.3 are used to predict the dependent variables. Instead of using samples from a specific generation g, I calculate the means over the entire data set.[27] Specifically, for generation g at age a, the predicted values represent the average luxury expenditure of all households, assuming they were treated as generation g at age a. The life-cycle luxury expenditure is predicted after repeating this process for every generation at every age from 21 to 80. In this way, each control variable value in the entire data set is used, so the obtained counterfactual patterns exactly delineate pure age and generation effects conditional on all other controls.

Figure 3.8 plots the resulting predictions for all generations, with log level in Figure 3.8(a) and share in Figure 3.8(b), where vertical distances between lines indicate generation differences at the same age. When comparing these predictions to real values in Figure 3.4, the expenditure shares in Figure 3.8(b) match well with Figure 3.4(b). However, the predicted expenditure level in Figure 3.8(a) completely diverges from the "hump" shaped age profile in Figure 3.4(a) which is caused by aggregate effects. Figure 3.8 works as a visual representation of the main findings: Firstly, the decreasing life-cycle luxury expenditure for every generation is predicted from the model. Secondly, younger generations spend less on luxury than older generations, so Millennials have been consuming the least at all ages between 21 and 80.

Additionally, Figure 3.8 graphically explains how the stereotype might have emerged: Currently Millennials are still in their early life stages. When comparing Millennials to other generations who are older now, without considering potential future expenditures of Millennials, it is easy to mistakenly accredit a high luxury consumption to them. Similarly, it

[27] When only samples of individual generations are used to predict the life-cycle expenditure, two problems occur: First, values of other control variables vary across generations, which contaminates the predictions by introducing other effects not caused by age or generation differences. Second, values of other control variables of each generation remain in a limited range over the life cycle, which is not very realistic.



(a) Log Level (b) Share

Figure 3.8: *Main Results: Predicted Generation Specific Luxury Expenditure by Age*

Notes: All values are in US 2007 dollars. Both figures plot predicted means at each age from 21 to 80 for every generation, using the estimated coefficients on age dummies from Column (3) and (6) in Table 3.3. Figure 3.8(a) shows the log level of luxury expenditure, and Figure 3.8(b) shows the share of luxury expenditure. Predictions are always conducted using the whole data set to pin down pure age and generation effects conditional on all other controls.

is often overlooked how seniors behaved when they were young. This analysis fills the gap by predicting that Millennials will follow their own age profiles which shows a generally lower luxury expenditure down to their 70s and 80s. In a nutshell, it is important to focus on the same life stages when examining the generation effect, in order to isolate it from the age effect.

3.5.4 Heterogeneous Effects

The main regression model is based on the separability assumption, which does not contain any interaction terms. However, age and time period influence different generations heterogeneously, therefore questioning the uniformity of life-cycle patterns and time trends across generations. Following Fitzenberger *et al.* (2021), I develop more general models that feature multiple interaction terms between generation dummies and age or period controls.

In Appendix C.2, I find that the period effect is separable, while the generation effect can not be disentangled from the age effect. Details on the performed extensive procedures of regression and sensitivity tests are elucidated there as well. I adjust the main specification to allow for non-uniform trends due to the entanglements between the generation and age effects. This conduces to the ideal regression model

$$L_{i,t} = \alpha_0 + \boldsymbol{\beta_{g,a} D^g_{i,t} \cdot D^a_{i,t}} + \alpha_1 \text{Period}_t + \alpha_2 \ln \left(\text{Income}\right)_{i,t} + \boldsymbol{\beta_h X_{i,t}} + \varepsilon_{i,t}. \tag{3.2}$$

Instead of the individual age effect $\boldsymbol{\beta_a D^a_{i,t}}$ and generation effect $\boldsymbol{\beta_g D^g_i}$, it includes interaction terms $\boldsymbol{\beta_{g,a} D^g_{i,t} \cdot D^a_{i,t}}$, while other controls remain unchanged.

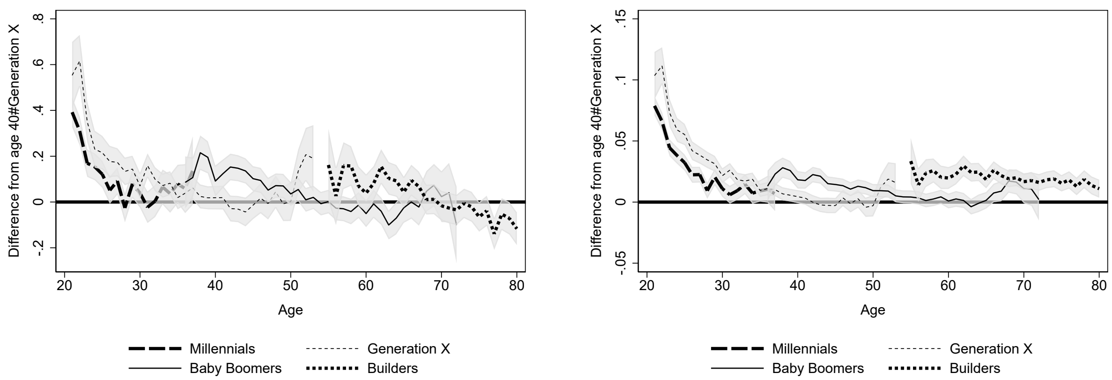
Figure 3.9 shows the generation specific age effect on luxury expenditure by visualizing the estimated coefficients $\hat{\boldsymbol{\beta}}_{\boldsymbol{g,a}}$. The declining life-cycle pattern still follows the main age effect in Figure 3.7, and differences among generations are also consistent with the generation effect in Table 3.3. The coefficient estimation for the interaction terms is only possible at valid combinations of generation and age. As a result, Figure 3.9 only displays coefficients for observed age ranges in the data. Despite this incompleteness, similar patterns to the main results in Table 3.3 can be found here: the generation effect gives rise to less luxury expenditure of Millennials with respect to all preceding generations at the same age. Even though there are minor fluctuations, e.g., a slightly increasing trend for old Millennials, these deviations are not significant, so the main findings remain. For completeness, I visualize age and generation effects in Figure C.2 in Appendix C.1, by conducting the counterfactual analysis as explained in Section 3.5.3 with the interaction-based ideal model.

3.5.5 Evidence on Specific Categories

In this section, I analyze the individual categories of luxury goods to identify the heterogeneous patterns behind the main results. For the 13 different expenditure categories of luxury goods according to the classification in Section 3.3, I aggregate several closely related ones.[28] Table C.4 reports the summary statistics of the resulting 9 categories.

I run the regression based on the preferred model as described above for each of the 9 categories, and present the results in Table 3.4. The generation effects are mostly

[28]The combined category "*vehicles*" includes *vehicle purchases* and *other vehicle expenditures*. Moreover, *fees and admissions*, *pets, toys and playground equipment*, *recreational vehicles*, and *miscellaneous entertainment outlays* are combined into one single category called "*entertainment*".



(a) Log Level

(b) Share

Figure 3.9: *Heterogeneous Effects: Generation Specific Age Effect on Luxury Expenditure*

Notes: Both figures show the estimated coefficients on the interaction terms in Eq. (3.2), including 95% confidence intervals. Figure 3.9(a) shows the effect on the log level of luxury expenditure, and Figure 3.9(b) shows the effect on the share of luxury expenditure. Coefficients are relative to the horizontal zero lines, which correspond to the 40-year-old Generation X.

heterogeneous in terms of both magnitudes and significance levels, but still monotonic and significant apart from certain outliers. Millennials tend to spend significantly less on the majority of the categories except for *household operations* and *education*. The expenditure gaps for *clothing for adults*, *vehicles*, and *public and other transportation* in Column (4) and (5) are also relatively large compared to the main results. Across all generations, I find the highest coefficient differences when estimating the effects on *clothing for adults* in Column (3), on which Builders spend 62% more than Generation X. For *household operations* and *education*, Column (1) and (7) are outliers, as they have an opposite generation effect that is mostly significant. So younger generations are obviously showing more interests in these categories. In addition, for *cash contribution* and *miscellaneous outlays* in Column (8) and (9), the estimates are also monotonic across generations, but barely significant, and also economically weak.

The age effect presented in Figure C.3, is also non-uniform among categories. While older generations tend to spend less on *household operations* overall, there is an increasing trend over the life cycle. Furthermore, age profiles of expenditures on *cash contribution* and *miscellaneous outlays* diverge from the decreasing age effect in the main results in

Table 3.4: *Results from Specific Categories*

	Log luxury expenditure								
	Household operations	House furnishings and equipment	Clothing for adults	Vehicles	Public and other transportation	Entertainment	Education	Cash contribution	Miscellaneous outlays
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Millennials	0.1959***	-0.0319**	-0.2867***	-0.1900***	-0.1384***	-0.0389***	0.1190***	-0.0190	-0.0529***
	(0.0142)	(0.0147)	(0.0114)	(0.0193)	(0.0217)	(0.0122)	(0.0325)	(0.0241)	(0.0190)
Baby Boomers	-0.2051***	0.0600***	0.2742***	0.0994***	0.0105	0.0248**	-0.0331	0.0195	0.0027
	(0.0111)	(0.0131)	(0.0104)	(0.0179)	(0.0197)	(0.0114)	(0.0269)	(0.0185)	(0.0169)
Builders	-0.4324***	0.1370***	0.6169***	0.1603***	0.0799**	0.0689***	-0.2285***	0.0435	0.0491*
	(0.0172)	(0.0212)	(0.0170)	(0.0300)	(0.0326)	(0.0196)	(0.0591)	(0.0274)	(0.0275)
ln(Income)	0.3593***	0.3984***	0.3583***	0.4225***	0.3810***	0.4745***	0.3603***	0.4286***	0.2930***
	(0.0043)	(0.0053)	(0.0043)	(0.0072)	(0.0073)	(0.0049)	(0.0119)	(0.0069)	(0.0070)
Period	✓	✓	✓	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓	✓	✓	✓
Household characteristics	✓	✓	✓	✓	✓	✓	✓	✓	✓
Observations	302213	249698	249599	273465	93028	298734	67974	214811	183118
R^2	0.1438	0.0748	0.1428	0.0868	0.1197	0.1729	0.1563	0.1028	0.0460

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months.

Figure 3.7. The declining age profile in the main results is mostly driven by the categories in Figure C.3(b), especially by the strong decreasing trends for *vehicles* and *clothing for adults*. The age effect of these two categories is even strong enough to hide the remaining divergent age profiles. The cyclical age effect on *education* might be caused by expenditures on personal education until about age 30, and education costs for offspring from age 45 to 65.

3.6 Robustness

Several robustness checks are conducted in this section to look at the stability of the main results. I begin with alternative model specifications concerning a generation-specific classification style. Afterwards the generation effect within the same age range is discussed, and the symmetric treatment of age and generation is analyzed. Finally, I investigate if the results are affected by changes to the control variables other than the age and generation dummies.

3.6.1 Alternative Model Specifications

Generation Specific Definition of Luxury Expenditure Categories. As individual generations may perceive and define luxury differently, the elasticity estimation based on the overall sample might not fit all individual generations alike. Therefore, I estimate elasticities only using data of each generation following the same procedures in Section 3.3. An empirical problem is that there are not enough observations of expenditures of a single generation at the top and bottom of the distribution. This can lead to empty observation ranges between some of the 101 total expenditure points when estimating. To solve this, outlier households of each generation are trimmed in a similar way as the sample selection procedure in Section 3.3. That means, I exclude households in the top or bottom one percent of the total expenditure distribution for each generation. Besides, generation-specific elasticities are only estimated for the whole sample period from 2000 to 2018. Because generation-specific luxury definitions might vary heterogeneously across time, an average of the full period works best as it treats generations equally.[29]

The estimated elasticities using such generation-specific sub-samples are shown in Figure C.4. Compared to the full estimation in Figure 3.1, the results are less stable due to larger standard errors. Based on the same threshold, a generation defines a category as a luxury good if the estimated elasticity is higher than one. For comparison, the overall classification is shown by the boldfaced category names in Figure C.4. The generation-specific classification indeed differs, but most of the luxury categories defined by the overall sample are consistent throughout every generation. Millennials have the most parsimonious selection of luxury. For example, they do not consider *education* and *clothing for adults* as luxury. Moreover, the estimated elasticity of *recreational vehicles* using the sample of Millennials is substantially negative. This is either caused by distorted results from a large amount of zero expenditures, or by lacking interests in recreational vehicle consumption from households with high total expenditure. In contrast, Builders and Baby Boomers view notably more categories as luxury.

I use the classification defined by each generation to construct the dependent variables and run the regression based on the preferred model in Eq. (3.1) including full controls. The results in Table 3.5 show that the generation effect is qualitatively stable and statistically significant. In comparison with the main results in Table 3.3 the effect is weakened, since individual definitions of luxury can not represent all households in the sample here. This finding also confirms that even with some misclassifications due to measurement errors, the main results could still be qualitatively robust.

Common Age Range. As each generation is only observed through certain life stages during the sample period from 2000 to 2018, households of different generations do not share common age ranges in the data. As a result, the generation effect conditional on age is

[29] As an example, Millennials had been gradually coming of age from 2000 to 2018, so their perception of luxury was less stable compared to Baby Boomers during the same period. The estimation based on the whole sample period could average out the instabilities across time to some extent.

Table 3.5: *Robustness: Generation Specific Definition of Luxury*

	Log luxury expenditure			
	Millennials	Generation X	Baby Boomers	Builders
	(1)	(2)	(3)	(4)
Millennials	-0.0537***	-0.0098	-0.0200**	-0.0176**
	(0.0109)	(0.0089)	(0.0086)	(0.0080)
Baby Boomers	0.0731***	0.0425***	0.0514***	0.0507***
	(0.0098)	(0.0083)	(0.0080)	(0.0075)
Builders	0.1648***	0.1238***	0.1381***	0.1188***
	(0.0161)	(0.0139)	(0.0136)	(0.0127)
ln(Income)	0.6272***	0.6015***	0.5961***	0.5697***
	(0.0041)	(0.0037)	(0.0036)	(0.0034)
Period	✓	✓	✓	✓
Age	✓	✓	✓	✓
Household characteristics	✓	✓	✓	✓
Observations	422529	432265	434048	434796
R^2	0.2791	0.3315	0.3394	0.3504
	Share of luxury expenditure			
	Millennials	Generation X	Baby Boomers	Builders
	(1)	(2)	(3)	(4)
Millennials	-0.0097***	-0.0054***	-0.0073***	-0.0073***
	(0.0012)	(0.0013)	(0.0013)	(0.0014)
Baby Boomers	0.0105***	0.0099***	0.0121***	0.0121***
	(0.0010)	(0.0011)	(0.0012)	(0.0012)
Builders	0.0290***	0.0311***	0.0348***	0.0326***
	(0.0018)	(0.0019)	(0.0020)	(0.0020)
ln(Income)	0.0261***	0.0293***	0.0304***	0.0286***
	(0.0004)	(0.0005)	(0.0005)	(0.0005)
Period	✓	✓	✓	✓
Age	✓	✓	✓	✓
Household characteristics	✓	✓	✓	✓
Observations	438658	438658	438658	438658
R^2	0.0723	0.0834	0.0827	0.0781

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. The dependent variables are either the log or the share of luxury expenditure defined by each generation, according to the estimated total expenditure elasticities using the sample of each generation in Figure C.4.

imprecise.[30] Therefore, I run the same regression for groups of two neighboring generations at once, and just focus on households within their overlapping age range.

Table 3.6 shows the generation effect for the resulting three groups. Specifically, I compare Millennials and Generation X from age 21 to 37, Generation X and Baby Boomers from age 36 to 53, and Baby Boomers and Builders from age 55 to 72. Each column presents results from one group, where the older generation always acts as a reference. The negative and significant coefficients on all generation dummies imply the robustness of the main results: conditional on the same age, younger generations consume less luxury. Furthermore, the magnitudes of the coefficients are similar to the magnitudes of the main estimates as well: Millennials have about 8% less luxury expenditure than Generation X, and the difference in the share is about 1.5%. Hence, the lack of common age ranges among multiple generations in the data does not impact the generation effect.

Symmetric Treatment of Age and Generation. A generation is a collection of cohorts, but age is taken as individual dummies in the regression, so the results might be coincidental because of such an asymmetric treatment of generation and age. To ensure that the generation effect is not only a broad age group effect, I use cohort as a proxy for generation. With cohorts defined by their specific birth year and age dummies controlled individually, I can confirm whether the overall cohort trend follows the monotonic generation effect from the main results in Table 3.3.

Figure 3.10 plots the continuous cohort effect with 1960 as the reference birth year. The results are consistent when using either the log level or the share of luxury expenditure as the dependent variable, and also quantitatively comparable to the generation differences in the main results in Table 3.3. Conditional on age, younger cohorts spend monotonically less on luxury. The behaviors of the oldest cohorts (born in the 1920s) and the youngest cohorts (born in the 1990s) are fluctuating, but these parts are not significant enough to affect the

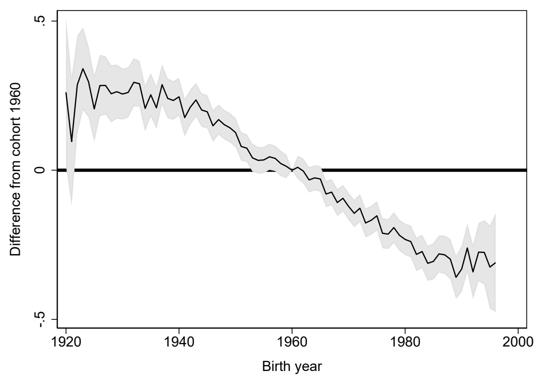
[30] For example, Builders are tracked from the age 55, while Generation X is only featured until age 53. The youngest Builders were born in 1945 and 55 years old in 2000, while the oldest members of Generation X were born in 1965 and only 53 years old in 2018.

Table 3.6: *Robustness: Common Age Range*

	Log luxury expenditure		
	Millennials & Generation X 21-37	Generation X & Baby Boomers 36-53	Baby Boomers & Builders 55-72
	(1)	(2)	(3)
Millennials	-0.0796***		
	(0.0115)		
Generation X		-0.0896***	
		(0.0102)	
Baby Boomers			-0.1020***
			(0.0133)
ln(Income)	0.5882***	0.7302***	0.6100***
	(0.0076)	(0.0072)	(0.0078)
Period	✓	✓	✓
Age	✓	✓	✓
Household characteristics	✓	✓	✓
Observations	119607	157620	119759
R^2	0.2317	0.3103	0.2806
	Share of luxury expenditure		
	Millennials & Generation X 21-37	Generation X & Baby Boomers 36-53	Baby Boomers & Builders 55-72
	(1)	(2)	(3)
Millennials	-0.0146***		
	(0.0013)		
Generation X		-0.0143***	
		(0.0011)	
Baby Boomers			-0.0184***
			(0.0014)
ln(Income)	0.0184***	0.0333***	0.0284***
	(0.0008)	(0.0007)	(0.0007)
Period	✓	✓	✓
Age	✓	✓	✓
Household characteristics	✓	✓	✓
Observations	123806	162682	124983
R^2	0.0563	0.0828	0.0750

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. The older generation is taken as the reference for each group of two neighboring generations. Period stands for the 5-year lagged GDP growth rate as the proxy for period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months.

overall results. The behaviors of cohorts in between are more stable. Likewise, Figure 3.11 plots the age effect in the same way as the main results in Figure 3.7. Conditional on cohorts and other controls, the same age effect persists as a declining life-cycle luxury expenditure as well as similar estimator magnitudes are visible.



(a) Log Level

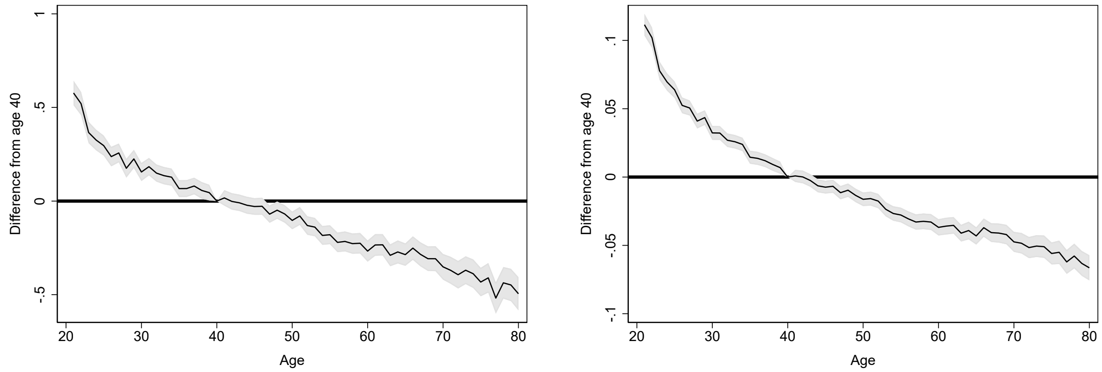
(b) Share

Figure 3.10: *Controlling for Birth Year: Generation Effect on Luxury Expenditure*

Notes: Both figures show the estimated coefficients on cohort dummies, including 95% confidence intervals. Figure 3.10(a) shows the effect on the log level of luxury expenditure, and Figure 3.10(b) shows the effect on the share of luxury expenditure. Each cohort is defined by the specific birth year, and coefficients are relative to the horizontal zero lines, which correspond to the reference cohort 1960.

Furthermore, this strategy based on the cohort fixed effect also speaks to the concern about the size of each generation in the data. As shown in Figure 3.2, the two middle generations, Baby Boomers and Generation X are slightly overrepresented in the sample. In addition to the results from the weighted regression in Table C.5, this approach of controlling for cohorts provides further evidence. When generations are equally disaggregated into cohorts in Figure 3.10, the original generation effect is replicated by differences among cohorts, even within a generation. Thereby, the relative size of each generation does not influence the main findings.

To further confirm that the asymmetric treatment of age and generation does not change the results, an alternative approach is used. I keep the generation dummies from the main identification, but aggregate age into groups. Figure C.5 and Figure C.6 in Appendix C.1



(a) Log Level

(b) Share

Figure 3.11: *Controlling for Birth Year: Age Effect on Luxury Expenditure*

Notes: Both figures show the estimated coefficients on age dummies, including 95% confidence intervals. Figure 3.11(a) shows the effect on the log level of luxury expenditure, and Figure 3.11(b) shows the effect on the share of luxury expenditure. Coefficients are relative to the horizontal zero lines, which correspond to the reference age 40.

present consistent evidence of monotonic age group and generation effects in this setting.[31]

3.6.2 Adjustment of Controls

In the following, four concerns require adjustments of control variables: 1) the quality of the CE income data is low, 2) different household scales can be used, 3) the generational segmentation might be too broad, and 4) other solutions to the collinearity problem are possible. In this section, I show that changes to the control variables to account for these concerns do not lead to different results from the main findings.

Instrument Variable Estimation. The first concern comes from the fact that income data of the CE program are of poor quality, especially at the beginning of the sample years when income data only depends on the reports. The permanent income hypothesis states that the total expenditure could be a proxy for income, and the data quality of the total expenditure is much higher. However, Charles *et al.* (2009) point out two possible problems of this

[31] As reported by Figure C.6, the generation differences decay conditional on the age group, but still remain significant.

proxy variable approach: endogeneity and measurement errors in the total expenditure data.[32] Luckily, a solution is provided there as well: controlling for the total expenditure and using income as an instrument variable (IV). Following the same identification of the preferred model, I use both the IV approach and a simple OLS estimation while controlling for the total expenditure. It can be seen from Table C.8 that generation effects are similar to the main results, while the coefficient magnitudes from the OLS estimation in Column (1) and (4) are slightly lower. Additionally, all values of R^2 in Table C.8 increase substantially compared to main results, since the total expenditure is explaining most of the variations and does trigger the endogeneity problem.

Different Household Scales. Secondly, I check if the results stay identical when different household scales are applied. Aguiar and Hurst (2013) argue that results based on the consumer expenditure survey are usually sensitive to the choice of household scales, both across and within categories. For instance, teenagers and babies are both counted as children but might not deserve the same weights. Another example is that the economies of scale in *education* should be weaker than the economies of scale in *household operations*. Thus, I replace the "OECD equivalence scale" used in the main specification with the "OECD-modified scale" and the "Squared root" scale respectively.[33] I find that the generation effect in Table C.9 is essentially replicating the main results.

Additional Generational Segmentation. Thirdly, I rely on an additional disaggregated generational segmentation. In the main specification, I combine the Greatest Generation and the Silent Generation and name them "Builders", therefore dividing households in the sample into four generations. Here, I separate the oldest two generations like they are originally defined in Table 3.1.

[32] All expenditure categories are jointly determined in a consumption model, which makes the total expenditure endogenous in the regression with any category as the dependent variable. Next, measurement errors in any of the categories could contaminate the total expenditure, which is the sum of expenditures on all individual categories in the original data of the CE program.

[33] See Section 3.4.1 and Footnote 22 for details.

Besides, I follow Kapferer and Michaut (2019) by dividing Millennials into two subgroups because of the concerns that they might be lacking homogeneity due to a too wide definition. I run the alternative regression model with six generations: the Greatest Generation (1902–1927), the Silent Generation (1928–1949), Baby Boomers (1946–1964), Generation X (1965–1980), Millennials I (1981–1989), and Millennials II (1990–1996). Column (1) and (3) of Table C.10 present the results, where Generation X is still taken as the base group. The estimated coefficients on the new generation dummies are consistent with the main results in Table 3.3. In addition, the estimators of the two Millennial subgroups are similar, and the Greatest Generation does not behave too differently from the Silent Generation either, suggesting that aggregated setting in the main specification is actually reasonable.

An Alternative Solution to the Collinearity Problem. Lastly, I use an different approach to solve the collinearity problem. I follow the standard normalization of Deaton (1997) who uses the period effect for cyclical fluctuations. Thus, the period effect is restricted to an average of zero over the sample period and is orthogonal to a linear time trend, such that all growth of luxury expenditure is only attributed to age and generation effects. Specifically, I use year dummies instead of the 5-year lagged GDP growth rate as the proxy, and drop the first two years in the regression.[34] Column (2) and (4) of Table C.10 show the estimated coefficients. The resulting generation effect, albeit quantitatively weaker, still corroborates the earlier findings.

3.7 Model Flexibility using Machine Learning

In spite of the robust findings, the linear model might be too restrictive as demographic variables are usually highly non-linear and interactive. In this section, I use supervised neural networks as a flexible, non-linear machine learning technique to investigate the effects of age and generation.

[34] The coefficients on the first two year dummies can be recovered from the period effect due to the restrictions on the zero average and orthogonality.

3.7.1 The Benefits of Machine Learning

When interaction terms are added to the model in Eq. (3.2), the heterogeneous age effect across generations is revealed by the regression results in Figure 3.9. But are there other interactions? Clearly, a fixed linear model with certain manually defined interaction terms might be far from capturing the true variable relationships. Because demographic characteristics are typically strongly intertwined, such variable relationships could be fairly complicated. To this end, machine learning is liberated from the constraints imposed in the linear model, as non-linearities and interactions are integrated and optimized by design. Machine learning typically works better on big data, so the large sample size in this chapter provides the ideal setting for machine learning algorithms to learn even intricate patterns.

However, estimating age and generation effects using machine learning is not straightforward. There are no individual coefficients like $\hat{\beta}$ that exactly measure the desired marginal effects, when the model gets complicated. Here, I provide a solution to estimate these effects based on the counterfactual predictions in Figure 3.8, which work as the visual representation of the age and generation effects. Specifically, I derive suitable machine learning models from a standard training process, and conduct predictions using the whole data set. By only manipulating age and generation information while keeping all other variables untouched, the averages of the predicted output values pin down the differences between each combination of age and generation.

3.7.2 Neural Network Training

In this chapter, I train standard *fully connected neural networks*, the basic idea of which is briefly introduced in Appendix C.3.1. The model training and results prediction process is implemented in the `scikit-learn` library in Python.

To start with, the activation function and hyperparameters are selected (for details, see Appendix C.3.3) to compare different network architectures in the following. The exact structure of the neural network, specifically the number of layers and number of nodes per layer, plays a particularly crucial role in the convergence process and the final prediction performance. Farrell *et al.* (2021) already summarize how this issue is discussed in the literature, and find that there are no agreed optimal choices, as the models are data-driven. Therefore, following the normal machine learning procedure of grid search, I check different combinations of the number of layers and nodes to determine the most suitable models.

I randomly split the whole data set in two parts: 70% are used as the training set to optimize the model, and the remaining 30% are used as a testing set to validate the model performance.[35] For that, I input data from the testing set into the trained models to get predicted output variables. The predicted results are compared to the real data, and a goodness of fit (R^2) determines the best models. As the model training only utilizes information in the training set, the out-of-sample performances on the testing set show how well the trained models generalize and capture the real patterns.

I implement the following steps to search for the best neural network structure: To make the results from neural network comparable to the linear model, the input variables are identical to the independent variables in the preferred model from the OLS regression. The log level and the share of luxury expenditure are separately used as outputs. Besides transforming all categorical variables into 0-1 dummies, I use a min-max normalization for the continuous input variables in the training set as

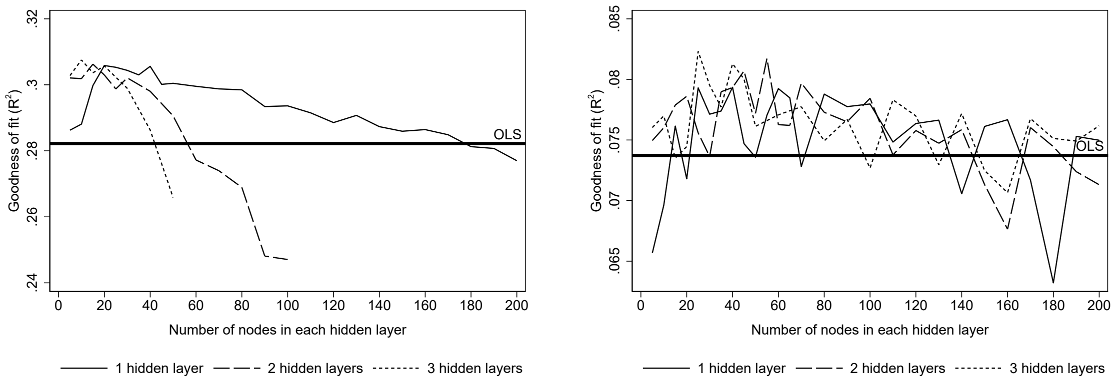
$$\widetilde{X}_i = \frac{X_i - \min(X_i)}{\max(X_i) - \min(X_i)}.$$

As a result, all inputs range from 0 to 1 to even out contributions from variables with different scales in the training process. Likewise, I also normalize the variables in the testing set with the scale statistics from the training set, to prevent an information leak from the testing set. I train models with one, two, or three hidden layers, while trying different numbers of nodes from 5 to 200 in steps of 10 to find a rough optimum. Afterwards, this optimum is refined in a second round with smaller steps of 5 around it. For models with more than one layer, the number of nodes per hidden layer is kept identical for simplicity.

[35]The training process basically estimates weights $\boldsymbol{w}$ and biases $\boldsymbol{b}$ of the model based on a mean squared error loss function as explained in more detail in Appendix C.3.3.

Figure 3.12 shows the performance of all trained models on the testing set during the grid search, by plotting the goodness of fit (R^2) of these predictions from different models. The horizontal lines represent the goodness of fit of the OLS out-of-sample predictions. For that the same procedures including data set splitting, model training, and testing are adopted for comparable results. Intuitively, a very simple neural network with few nodes does not learn complex relationships in the data very well. Using a more complex structure, the network fits the training data better. However, at some point the trained model moves towards overfitting by learning too complex structures from the training data (essentially corresponding to noises instead of meaningful patterns). This leads to incrementally worse prediction performances on the testing set, when the model fits the training data well but fails to generalize. Figure 3.12 clearly shows this process: In the beginning, the goodness of fit on the testing set increases with the number of nodes per hidden layer, and then starts to decrease with additional nodes after reaching an optimum. With too many nodes, the neural network even works worse than the simple OLS. The results regarding expenditure share are less stable, but the general trend is still clear. Figure 3.12(a) also compares the different numbers of hidden layers in the models. As each additional layer accelerates the complexity, models with more hidden layers exhibit this overfitting problem earlier and more strongly.

Overall, the relatively low R^2 for all neural networks means that the fit is far from perfect. One reason might be that expenditure as a subjective human behavior can not be predicted accurately by simple demographic and economic variables. Nonetheless, the focus of this chapter is not a precise reproduction of the output variables, but the luxury expenditure differences among different generations, even just qualitatively. In this sense, neural networks are able to deliver the desired results with more realistic, flexible interactions between variables.



(a) Log Level

(b) Share

Figure 3.12: *Neural Network Model Selection: Testing the Goodness of Fit*

Notes: Both figures plot the goodness of fit of predictions (R^2) on the testing set for different network architectures (with a different numbers of layers and nodes). Figure 3.12(a) shows the results of the log level of luxury expenditure, and Figure 3.12(b) shows the results of the share of luxury expenditure. The goodness of fit of the OLS regression is calculated in the same way as the neural network predictions and is marked by the horizontal lines.

3.7.3 Age and Generation Effects from Neural Networks

I consider the goodness of fit shown in Figure 3.12 to determine the best models with the optimal number of nodes. Note that using the CE data set, neural networks with multiple hidden layers are not substantially better than the simple single-layer network, despite significant additional computation costs. This observation corresponds to the *universal approximation theorem* with bounded number of hidden layers, proved by Hornik *et al.* (1989), stating that even a neural network with a single hidden layer can be a universal approximator given a sufficient number of nodes. In my case, with a single hidden layer, the optimal number of nodes is 20 for the luxury expenditure level and 40 for the luxury expenditure share as the output variables.

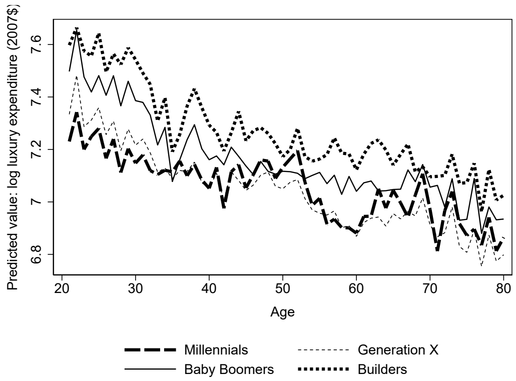
The next step is to derive age and generation effects through prediction of these optimal models based on neural networks. For that, I use counterfactual predictions in a similar way as described in Section 3.5.3. The log level and the share of luxury expenditure of generation g at age a is predicted as follows: I use the whole data set and treat all households as generation g aged a, before processing it with the best trained models. Then, the average of the results are stored as counterfactual predictions of the level and the share of luxury expenditure for this generation g at age a. This procedure is repeated for every generation and age. As a consequence, values of other control variables in the data set equally influence every prediction, meaning only differences due to age and generation remain.

Figure 3.13 plots the final results predicted using the model with different architectures. There is a clear declining trend of luxury expenditure over the life cycle for all generations, with later born generations consuming less. For one hidden layer, the differences in expenditure level in Figure 3.13(a) between Millennials and Generation X start to fluctuate at age 30, but Millennials still consistently have a lower expenditure share. Therefore, the averages of predictions from models with one hidden layer are essentially not too different from the smoother counterfactual results based on simple linear models. The results from the best trained models with two and three hidden layers are presented below in Figure 3.13. The general findings also remain consistent here, although the specific predictions slightly vary depending on the different neural network structures. With additional hidden layers, it also becomes more prominent that Millennials have a lower luxury expenditure level than Generation X. For the expenditure share, the difference across generations is stable and consistently monotonic for every network architecture.

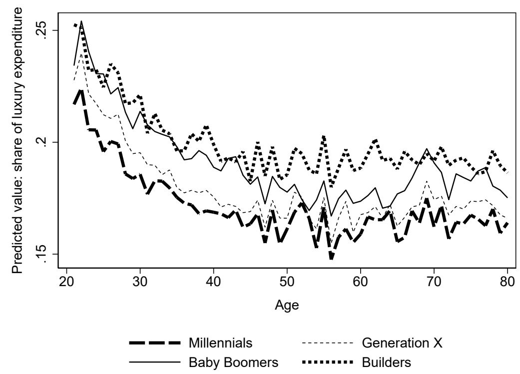
Overall, the predictions from the main results with separable age and generation effects in Figure 3.8 are already disclosing the general trend, and might be preferable to more complex models due to Occam's razor. Instead of oversimplifying the relationships between variables, a linear regression model seems to be sufficiently intricate to arrive at the same conclusions from the main findings.

3.8 Discussion

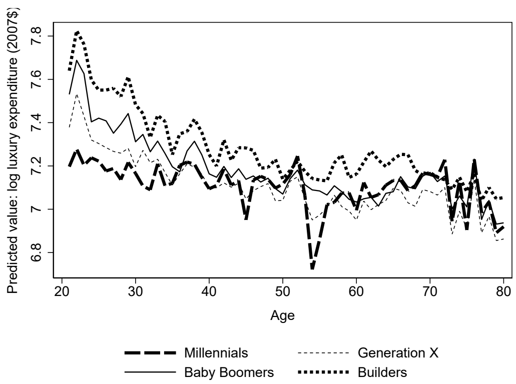
Categories of luxury goods defined by elasticity might not necessarily coincide with various subjective luxury definitions from individuals. In this section, I compare the luxury categories in this chapter to these "classic" luxury goods using evidence on specific categories from Section 3.5.5. In addition, I relate my results based on such evidence to the studies of



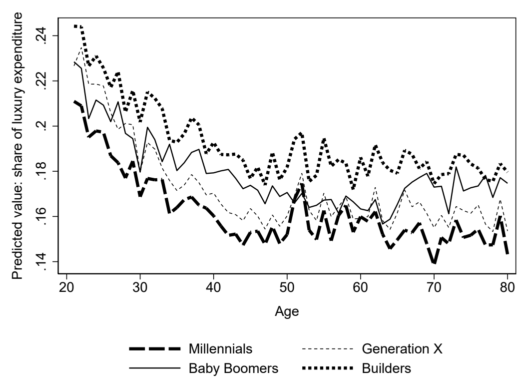
(a) One Layer: Log Level



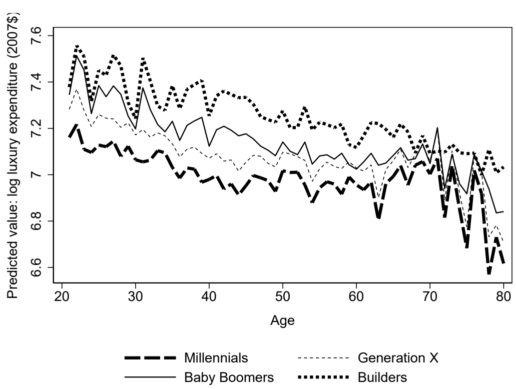
(b) One Layer: Share



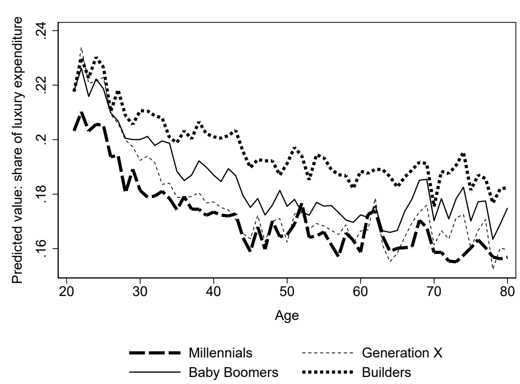
(c) Two Layers: Log Level



(d) Two Layers: Share



(e) Three Layers: Log Level



(f) Three Layers: Share

Figure 3.13: *Neural Network: Predicted Generation Specific Luxury Expenditure by Age*

Notes: All values are in US 2007 dollars. All figures plot predicted means at each age from 21 to 80 for every generation. Each figure uses the best neural network model for the given number of layers, with the log level of luxury expenditure or the share of luxury expenditure as the output variable. The optimal numbers of nodes per hidden layer for the log level of luxury expenditure are: one layer (20), two layers (15), and three layers (10). The optimal numbers of nodes per hidden layer for the share of luxury expenditure are: one layer (40), two layers (55), and three layers (15).

conspicuous consumption in the literature. Finally, I discuss the intuition behind the main findings in this chapter.

3.8.1 Comparison with "Classic" Luxury and Conspicuous Consumption

To start with, I examine how luxury goods defined by elasticity differ from the "classic" luxury goods that are categorized based on intuitive criteria from common sense. Table 3.7 compares the 13 categories defined in Section 3.3 to luxury as described by Paulin and Riordon (1998). Based on their personal point of view, they propose to divide the expenditure categories in the CE data into basic goods and services vs. luxury goods (which mainly feature recreation related expenditures). Overlaps do exist to some degree, as *entertainment*, *vehicles*, and *transportation* are considered to be luxury by both classification styles. However, others like *household operations*, *house furnishings and equipment*, *clothing for adults*, *education*, *cash contribution*, and *miscellaneous outlays*, does not count as luxury without economic measurements. In addition, *food away from home* actually does not pass the elasticity threshold although Paulin and Riordon (1998) count it towards "classic" luxury.

Afterwards, I investigate the effects on economically defined luxury categories that also belong to "classic" luxury. To be specific, I check the generation effect from those categories in Table 3.4. From every individual category, *entertainment*, *vehicles* and *transportation* are also considered as luxury by Paulin and Riordon (1998). On all three of them, the generation effect holds and indicates less expenditures for Millennials. Thus, my findings based on the luxury categories as classified in Section 3.3 are representative enough to apply to "classic" luxury. This provides clear evidence against the argument that Millennials are a growth engine of luxury industries.

Another related concept is conspicuous consumption, first introduced by Veblen (1899). The Veblen effect refers to the observation that people buy visible goods to signal wealth, for example jewelry, cars, etc. Typically, this is achieved through expensiveness, suggesting an upward-sloping demand curve (see, e.g., Leibenstein, 1950; Bagwell and Bernheim, 1996). Empirical research that focuses on conspicuous consumption has a very similar selection

Table 3.7: *Luxury Defined by Elasticity and Related Categories*

Luxury defined by elasticity	"Classic" luxury	Visible (conspicuous) goods
Household operations	Paulin and Riordon (1998)	Charles *et al.* (2009)
House furnishings and equipment	*Food away from home*	*Clothing/jewelry*
Clothing for adults, 16 and over	*Entertainment*	*Personal care*
Vehicle purchases	*Reading*	*Vehicles*
Other vehicle expenditures	*Lodging except for shelter*	
Public and other transportation	*Vehicles*	Heffetz (2011)
Fees and admissions	*Transportation*	(Top lists based on visibility index)
Pets, toys, and playground equipment		*Cigarettes*
Recreational vehicles		*Cars*
Miscellaneous entertainment outlays		*Clothes, jewelry*
Education		*Furniture, appliances*
Miscellaneous outlays		*Recreational equipment*
Cash contribution		
		Friehe and Mechtel (2014)
		Motor vehicles
		Shoes, apparel (adults, children, babies)
		Jewelry, watches, headpieces
		Skin and body care
		Dental treatments, protheses
		Furniture, Household appliances
		Phones, TVs, Radio sets, Cameras

Notes: This table lists: 1) luxury goods defined by the elasticity measurement in this chapter, 2) categories that are arbitrarily considered as luxury based on common sense ("classic" luxury), and 3) visible goods defined in the literature based on the conspicuous consumption theory (Veblen, 1899). For 3), Heffetz (2011) develops the visibility index for each category based on surveys, and here I only show the 10 goods with the highest visibility indices. Friehe and Mechtel (2014) extend the existing definitions of conspicuous consumption (from Charles *et al.*, 2009; Heffetz, 2011) by adding some categories that are usually noticed within closer social groups such as colleagues and friends.

of visible goods, by either surveys or simple introspection. For example, the categories from Charles *et al.* (2009), Heffetz (2011), and Friehe and Mechtel (2014) are shown in the last column of Table 3.7. The former two also use the CE data, while categories from the latter are based on German income and expenditure samples. From these classifications, it is clear that conspicuous expenditure and luxury are different concepts only sharing few overlapping categories, and neither is a subset of the other.

Results from these overlapping categories (that are luxury and conspicuous) also correspond to findings in the literature. Charles *et al.* (2009) show that Blacks spend more on visible goods, i.e., *clothing/jewelry*, *personal care* and *vehicles*, compared to Whites conditional on other controls. As *clothing for adults* and *vehicles* are also luxury goods according to the total expenditure elasticity, the race fixed effect in the full regression table Table C.6 confirms this finding.

The main results in Section 3.5.2 already discussed the positive correlation between luxury expenditure and the education level, which is further confirmed by the results from individual categories (except for *vehicles*) as shown in Table C.6 and Table C.7. This correlation to some extent contradicts the results from Friehe and Mechtel (2014), who find that households with higher education level tend to spend less on visible goods. Based on results from overlapping categories, this contradiction can be explained by the higher education level of new generations.[36] This means, the negative education effect found by Friehe and Mechtel (2014) results from the omission of generation dummies.

3.8.2 What Do We Learn?

Several theories from both economic and sociological perspectives might explain the main findings. Firstly, Millennials have been facing many obstacles in the current economic environment as introduced in Section 3.2.2. Compared to preceding generations, Millennials have been benefiting the least and suffering the most in the macro business cycles (see, e.g., Smith, 2012; Gale *et al.*, 2020). This situation is additionally deteriorating because of the increasing peer competition (see, e.g., Emmons *et al.*, 2019; Zeihan, 2016). Unsurprisingly, Millennials are struggling with crises like unemployment, financial difficulties, etc. (Halpert, 2012). As a consequence, they have been postponing marriage, housing, and fertility plans, let alone a luxury lifestyle (Danziger, 2015).

Secondly, few luxury purchases of Millennials correspond to the statement of McCrindle (2007) who calls Millennials “new puritans”: having grown bored of prepackaged spiels,

[36] *Household furnishings and equipment* and *clothing* are overlapping categories between the luxury definition in this chapter and the definition of visible goods from Friehe and Mechtel (2014).

Millennials see through all the contrived messages, so they become more circumspect and critical when being marketed. Therefore, contrary to the stereotype of being spoiled and consumption-oriented, Millennials are more likely to be objectively rather than socially motivated to spend money (Martin and Turley, 2004). In addition, my results also support some arguments in the literature on older generations. For example, Paulin and Riordon (1998) show that members of Generation X consume less luxury goods and more necessities compared to Baby Boomers. They are more disillusioned and skeptical due to both economic and societal uncertainty during their formative years, opposite to Baby Boomers who stress self-achievement and personal success (Eastman and Liu, 2012).

3.9 Conclusion

Having grown up in a time of prosperity and materialism, Millennials are stereotyped as a protected and indulged generation with an unprecedented appetite for luxury. However, cross-sectional observations of a high expenditure on luxury alone do not necessarily support this view, as they confound age with generation effects. This chapter separately identifies age and generation effects on luxury expenditure from a panel of consumption expenditures in the US.

First, I classify expenditure categories in the Consumer Expenditure Survey of the US into luxury and necessity based on the economic definition of luxury as having total expenditure elasticity higher than one. Next, a descriptive average expenditure on luxury over the life cycle and across time is shown. Following that, I extend the methodology of decomposing age, generation, and period effects to luxury expenditure, and also account for heterogeneous effects via interaction terms. To further strengthen the results, I use neural networks as a state-of-the-art machine learning technique, to derive more flexible and non-linear models. Finally, I compare the results with related topics of conspicuous consumption and "classic" luxury as subjectively defined in the literature, and discuss the general intuition behind the main findings.

The linear regression results show a decreasing trend of luxury expenditure over the life cycle for all generations, while the generation effect works oppositely: younger generations tend to consume less luxury than older generations conditional on age. Quantitatively, Millennials spend around 8% less on luxury than Generation X, 17% less than Baby Boomers, and 26% less than Builders. The results remain robust to alternative model specifications and adjustment of controls. Moreover, the models trained from neural networks exhibit the same patterns across generations and over the life cycle. Therefore, Millennials are conveying attitudes of abstinence, consciousness, and rationality, instead of acting as an indulged generation. Their substantial expenditure power on luxury is actually the result of a strongly predominating age effect.

This distinct finding refreshes the conventional point of view, and provides novel challenges to luxury marketers who target Millennials as well. As America's largest generation, Millennials have been gradually prevailing over the market. Nevertheless, Millennials' lack of interests in luxury may suggest a potential crisis in this industry, especially as they age. Therefore, comprehending more unbiased information from surface phenomena is essential for better strategies in the future, and more efforts are needed to conduct deeper market research on long-run demographics.

As for future research direction, it would be interesting to investigate data from other countries, to see if this is an international phenomenon. Furthermore, collecting panel data specifically in the luxury market might provide additional insights on the luxury expenditure of different generations.

Chapter 4

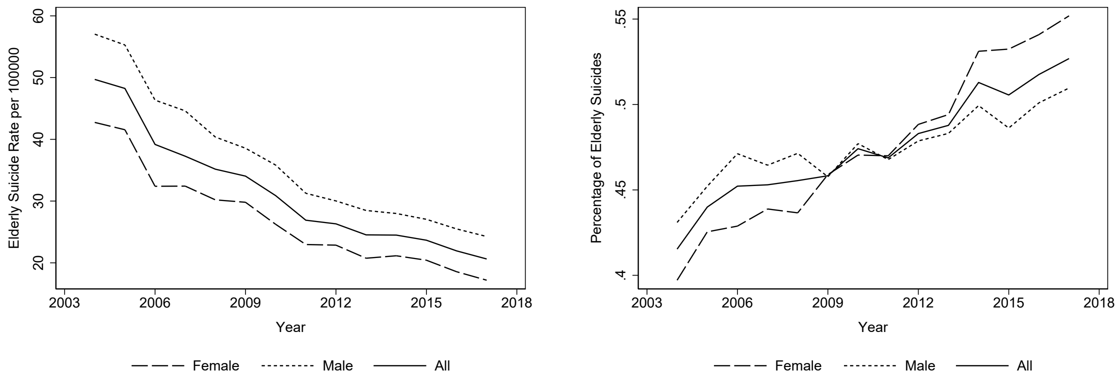
Restrictive Fertility Policy and Elderly Suicides: Evidence from China[1]

4.1 Introduction

Suicide is one of the leading causes of death in China, especially among the elderly, with mortality from suicide being 2.75-7 times higher for the population aged 60 and older in comparison to the general population (Lien *et al.*, 2018). Although suicides among the elderly show a downward trend, the share of suicides committed by the elderly is sharply increasing, especially among women, as shown in Figure 4.1.

With unparalleled economic development on the one hand, and profound social changes and a rapidly aging population on the other, this observation has shifted the focus of recent research to the reasons for the suicide rates among the elderly in China, which are exceptional in international comparison. An increasing body of empirical research has isolated several salient risk factors, including, most prominently, economic living conditions, with suicides among the elderly with low incomes, low education and living in rural areas being significantly more frequent. These findings are consistent with an economic perspective that views suicide as the behavioral reaction to discounted future utility reaching

[1]This chapter is joint work with Uwe Sunde.



(a) Suicides among Elderly

(b) Percentage of Suicides by Elderly

Figure 4.1: *Suicides among the Elderly in China*

Sources: Own illustration of data from the Chinese Disease Surveillance Points (DSP), see Section 4.2.1 for details

a finite lower bound (Hamermesh and Soss, 1974). However, this rationale does not readily explain the systematic differences by sex. Moreover, among the most frequently mentioned protective factors for elderly suicides are the family environment and companionship with children and kin. A candidate explanation for these patterns is that children and family structures are important factors for old age support in a country with limited public pension coverage. Empirical research has indeed shown that financial dependence and the lack of access to state pension schemes has a detrimental effect on life satisfaction and mental health of the elderly (see, e.g., Abruquah *et al.*, 2019). In this context, exposure to China's restrictive fertility policies in the past might have contributed to exacerbating this effect. The policy-induced decline in fertility not only accelerated population aging, but also might have contributed to mental health problems, particularly among women, and more precarious living conditions in old age for the most affected generations, who had fewer offspring to care for them, and a higher risk of no support in the case of premature death of their only child.[2] Although the exposure to restrictive fertility policy has been conjectured to influence elderly suicides in China before, direct evidence for such a link is still missing.

[2]See, e.g.,Yu (2014) or a recent discussion by Shi (2021).

In this chapter, we investigate the hypothesis that the exposure to China's fertility policies is one of the factors contributing to the dynamics and patterns of elderly suicides in China. Starting in 1969, China implemented policies to control fertility, first in terms of a "Later, Longer, Fewer" policy (aiming at marriages at a later age, longer intervals between births, and fewer children per couple in total) and since 1979 in terms of the "One Child Policy" (for details, see, e.g., Whyte *et al.*, 2015). The hypothesis of this chapter is motivated by the observation that China's "Later, Longer, Fewer" fertility policy strongly affected fertility, even more than the "One Child Policy". Figure 4.2 illustrates this by showing the average fertility dynamics in China in relation to the implementation dates of the "Later, Longer, Fewer" (LLF) fertility policies starting in 1969, and of the "One Child Policy" (OCP) starting in 1979 (see also Chen and Huang, 2020, for causal evidence on this point). Moreover, people who were affected by the LLF policy in 1970s are increasingly representing the majority of the elderly population above 60 years of age.

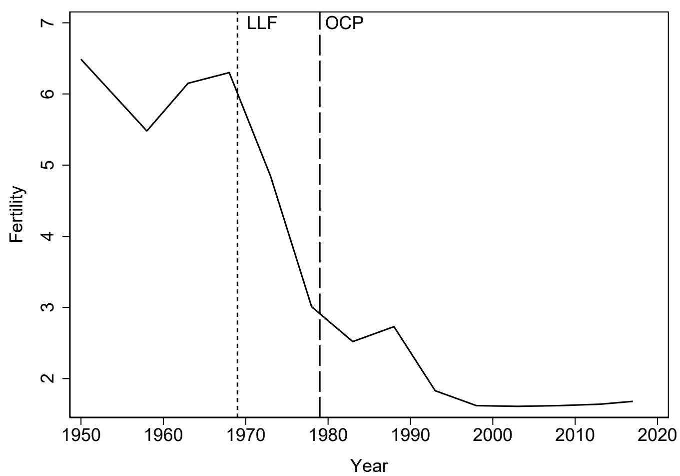


Figure 4.2: *The Dynamics of Fertility and Fertility Policies in China*

Sources: Own illustration of data from Macrotrends, available at *https://www.macrotrends.net/countries/CHN/china/fertility-rate* (accessed 9 September 2021)

To investigate whether the exposure to the LLF policy influences suicides among the elderly, we apply an identification strategy that exploits quasi-random variation in the timing of the implementation of the fertility policies across Chinese provinces. This variation implies that individuals experienced a differential exposure to the fertility policies depending on their year of birth, their region of residence, and their living environment in terms of an urban or rural context. Identification is thus based on variation in exposure across birth cohorts, time and space.

The findings show that a greater exposure to the fertility policy is associated with higher suicide rates. This finding emerges on top of sex-related differences, lower suicides in urban environments, and a declining time trend in suicides, all of which are replicated in our analysis. In addition, we find that the effect is mainly driven by individuals in urban areas, and by cohorts born in the period 1930–1957. Robustness checks using placebos in the policy implementation reveal that the effect is identified by the combination of variation in the policy implementation across cohorts, space, and time.

This chapter contributes to the literature in several dimensions. Recent reviews of the evidence on causal and protective factors of suicides or suicide ideation by the elderly find an important influences of sex, age, and the urban/rural divide, as well as of physical and mental health and of the social, cultural, and family context (Dong *et al.*, 2015; Li and Katikireddi, 2019; Yu *et al.*, 2021). Our findings replicate these patterns while adopting a cohort perspective and add evidence for a factor that has been conjectured repeatedly to play a role in this context, namely the exposure to restrictive fertility policies.

A stylized fact emerging from the existing literature is that the number of children seems to affect the prevalence of suicide ideation, especially among the elderly living in rural areas, and thereby contribute to the rural/urban divide in suicides (Wei *et al.*, 2018). In a recent study that complements ours, Fang *et al.* (2021) focus on the role of family companionship for elderly suicides and exploit high-frequency variation in suicides at a highly disaggregated level using the Chinese Lunar New Year, when families traditionally have reunions, as a social experiment. Their results suggest that suicides decline significantly during the festivities related to the Chinese Lunar New Year, but increase significantly in the subsequent two months. Existing studies also repeatedly conjectured that, among recent developments such as economic reform and cultural change, also the restrictive fertility policies of the

1970s and 1980s may have contributed to the recent suicide dynamics among the elderly (see, e.g., Li *et al.*, 2009; Wang *et al.*, 2014; Liu *et al.*, 2015; Zhou *et al.*, 2019). However, causal evidence for an effect of fertility policies on elderly suicide rates is still lacking. The present chapter contributes novel evidence that is consistent with this long-standing conjecture.

With its focus on the long-term consequences of fertility policies on elderly suicides, our analysis contributes to earlier work on the effect of fertility policies on health in old age (e.g., Islam and Smyth, 2015) and complements recent findings of negative long-term consequences of China's fertility policies on parental mental health that uses a similar identification strategy (Chen and Fang, 2021).

The remainder of the chapter is structured as follows. Section 4.2 presents the data and methodology, Section 4.3 contains the results, and Section 4.4 provides a brief discussion.

4.2 Empirical Strategy

4.2.1 Data on Suicides

There are two sources of publicly available data on suicides in China. One is provided by the Ministry of Health's Vital Registration (MOH-VR) System, the other is provided by the Chinese Disease Surveillance Points (DSP) System of the Chinese Center for Disease Control and Prevention (CCDC). In the publicly available statistic, the MOH-VR system reports suicide information only at the aggregate (country) level, while the data from the DSP system includes information about the region (east/central/west).

The DSP system was implemented in 1978 with a pilot study conducted in Beijing, to collect data on births, causes of death, and the incidence of infectious diseases. This data only became nationally representative in 1990, when the Chinese Academy of Preventive Medicine revised and expanded the system to 145 geographic locations across the country (Yang *et al.*, 2005). By 2004, DSP had been expanded further to include 161 geographic locations across 31 provinces, covering 6% of the population (Liu *et al.*, 2016). In 2013, the government merged the information of the MOH-VR and DSP into an integrated national mortality surveillance system, which comprises 605 surveillance points, covering 323.8 million people, 24.3% of the total population (Liu *et al.*, 2016). Since this, the data from the two sources are identical (Sha *et al.*, 2018).

In the publicly available data set, the DSP system reports suicide rate (per 100000 people) and the number of suicides based on the sample, by sex, quinquennial age group, living environment (rural/urban), and region (east/central/west). To obtain continuous observations across age and cohorts, we assign the same suicide information to observations of ages within the same quinquennial age group.[3]

In the empirical analysis, we use data for the period 2004 to 2017. We focus on elderly suicides by restricting attention to suicides among individuals aged 60 and older.

4.2.2 Measuring the Exposure to Fertility Policies

The identification approach makes use of variation in the (latent) exposure to the fertility policies across birth cohorts, space, and time. In particular, the "Later, Longer, Fewer" (LLF) policy has been implemented at different points in time in different provinces. Our measure of policy exposure makes use of the implementation year of this policy by the Family Planning Leading Group as the starting point of fertility policies in each province. This approach follows work by Chen and Huang (2020), who have documented that the exposure indeed affected fertility dynamics.[4]

Concretely, we construct the measure of policy exposure for birth cohort c in province p and urban/rural area u, as

$$\text{PolExp}_{p,u,c} = \sum_{a=15}^{49} \left\{ \text{AFR}_{p,u}\left(a\right) \cdot I\left[c + a > T_p\right] \right\} \tag{4.1}$$

with T_p denoting the implementation year of the LLF policy by the Family Planning Leading Group in province p, $I\left[c + a > T_p\right]$ denoting a binary indicator function that equals one if

[3]For example, we consider people aged 60–64 to reflect the same suicide rate without distinguishing suicide rates of, e.g., individuals aged 61 and 62.

[4]See Chen and Fang (2021, p. 7) and Chen and Huang (2020, p. 993) for the specific implementation year in each province.

the policy came into effect in the year when birth cohort c reached age a and zero otherwise, and $\text{AFR}_{p,u}(a)$ denoting the age-specific fertility rates of province p and urban/rural area u in 1969, prior to the fertility policies. The data on age-specific fertility rates in a province, distinguishing between urban and rural areas, is taken from Coale and Chen (1987). Since it is well known that suicide rates differ strongly between rural and urban areas (Dong *et al.*, 2015; Li and Katikireddi, 2019), the analysis explicitly accounts for this rural-urban divide. In this sense, this measure extends the related measure of exposure to fertility policies used by Chen and Fang (2021); Chen and Huang (2020).[5]

Since DSP only reports suicide data at the level of regions and distinguishing between urban/rural areas, for each cohort c, we adjust the measure of fertility policy exposure at the level of province$\times$urban location and derive the weighted average for each region$\times$urban area using sample weights in Coale and Chen (1987). Concretely, for cohort c in region r and urban/rural area u, the modified formula of policy exposure is given by

$$\text{PolExp}_{r,u,c} = \frac{\sum_{p \in r} W_{p,u} \cdot \text{PolExp}_{p,u,c}}{\sum_{p \in r} W_{p,u}} \tag{4.2}$$

where $\text{PolExp}_{p,u,c}$ represents policy exposure at the level of province p and urban/rural area u for cohort c, and $W_{p,u}$ denote the population weights of a province p and urban/rural area u within a given region r. The age-specific fertility rate is only available for quinquennial age groups, so we assign the same value of fertility to all ages within a given quinquennial age group. Moreover, the same age-specific fertility rate is assigned to both sexes.

The empirical analysis is based on data for the period 2004–2017 and focuses on suicides among the elderly aged 60 and older.[6] This implies that the youngest cohort in the sample

[5]The measure of exposure to fertility policies by Chen and Fang (2021); Chen and Huang (2020) is given by

$$\text{PolExp}_{p,c} = \sum_{a=15}^{49} \left\{ \text{AFR}_p(a) \cdot \left[c + a > T_p \right] \right\}$$

with T_p and $I\left[c + a > T_p\right]$ as described in the text, and $\text{AFR}_p(a)$ denoting the age-specific fertility rate of province p in 1969, prior to the fertility policies. The strict inequality reflects the assumption that the policy has a visible effect on fertility roughly after one year, accounting for conception and pregnancy.

[6]Information on suicides is reported in quinquennial brackets and the oldest age group observed is aged 85 and above in the data, which we label as individuals aged 85–89 for consistency.

was of age 60 in 2017, and hence was a member of the birth cohort born in 1957. We focus attention on cohorts that were actually affected by the LLF policies during their fecund ages. As the policies were implemented across the country between 1969 and 1975, we drop cohorts born before 1930 since they were essentially not affected by the policy as they had already completed their fecundity when the policies were first implemented.[7] Therefore, the oldest age group considered in our sample, the cohort born in 1930, was aged 87 in 2017, the last year of observation in our data. Figure 4.3 plots the average exposure to the LLF policy in the estimation sample.

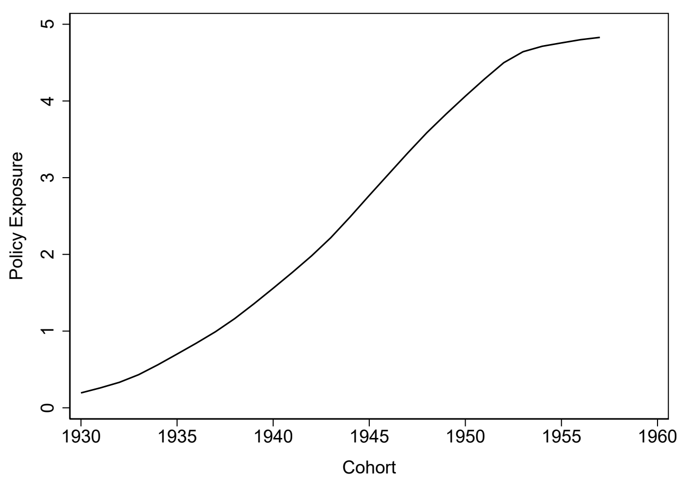


Figure 4.3: *Average Exposure to LLF Policies Across Birth Cohorts*

Notes: This is calculated as the mean exposure of all regions based on Eq. (4.2) for each cohort.

4.2.3 Empirical Methodology

Since an analysis of the role of family environment and companionship with children and kin is prevented by data availability, we investigate the hypothesis that exposure to the LLF policy affects suicide rates of the elderly by estimating the effect using a reduced-form

[7]For instance, members of the cohort born in 1925 were already 44 years old in 1969, so their fertility was practically not affected by the policy.

approach. The empirical framework is given by

$$\text{ESR}_{r,u,c,s,a,t} = \alpha + \beta \text{PolExp}_{r,u,c} + I_s + \text{Age}_a + \text{Time}_t + \text{Cohort}_c + \epsilon_{r,u,c,s,a,t}. \tag{4.3}$$

The dependent variable $\text{ESR}_{r,u,c,s,a,t}$ represents the elderly suicide rate of cohort c. The explanatory variable of main interest is the exposure to the LLF policy, $\text{PolExp}_{r,u,c}$ as in Eq. (4.2), of cohort c in region r and urban/rural location u. Additional control variables include an indicator for sex I_s (distinguishing females and males), and a full set of dummies for quinquennial age groups, denoted by Age_a. Period trends are accounted for by a linear time trend or time dummies, Time_t, and Cohort_c reflects dummies accounting for heterogeneity across birth cohorts (years).[8] The error term ϵ allows for clustering at region$\times$cohort level.

The coefficient of interest is the effect of fertility polices on the elderly suicide rate, β. Identification and consistent estimation of this coefficient requires exogeneity of the exposure to the LLF policy conditional on the controls in the specification. In order to keep as much variation as possible, the baseline specification does not control for year and cohort dummies, or for region or urban/rural areas, but extended specifications also account for these factors. Moreover, in robustness checks below we show results for effect heterogeneity along these dimensions.

With the specification of the empirical model in Eq. (4.3), the identifying variation in policy exposure as defined in Eq. (4.1) comes from three dimensions: time, space, and cohort. With T_p denoting the year in which the policy was implemented in a particular province p, individuals belonging to a given birth cohort in a province in which the policy was implemented earlier experienced a greater exposure to this policy than members of the same birth cohort in a province in which the policy was implemented later. Moreover, with variation in fertility $\text{AFR}_{p,u}(a)$ across space (provinces and urban/rural areas), individuals belonging to a given birth cohort in a province/area with a relatively high fertility prior to

[8]Note that, due to the semi-parametric specification, patterns across age groups, time and cohorts are identified from non-linearities in the respective dimensions.

the initial policy implementation in 1969 were more intensively affected by fertility policies than members of the same birth cohort in a province/area with low pre-implementation fertility. Finally, within a given province/area, $c + a$ reflects variation across cohorts, since later-born cohorts were younger when the policy was implemented and, as a consequence, their fertility was exposed to more restrictions by the policy than the fertility of older cohorts who were closer to completing their fecund period of life.

The validity of this approach of measuring the exposure to LLF policies has been documented previously. In particular, Chen and Huang (2020) show evidence for a causal effect of variation in policy exposure on fertility rates. Moreover, previous work found no significant correlation between the timing of the implementation of LLF policies by the Family Planning Leading Group and provincial characteristics prior to the implementation in 1969 (Chen and Huang, 2020; Chen and Fang, 2021). This suggests that the variation in policy exposure is plausibly exogenous in the present context. In addition, the reduced-form approach implicitly assumes that the exposure to LLF policies and the elderly suicide rates apply adequately to the resident population in a given province$\times$urban location. The link between exposure, fertility, and suicide rates might be weakened by systematic internal migration patterns. However, internal migration in China was in fact heavily restricted until the late 1980s through the *hukou* system.[9] This implies that for a given age cohort residing in a given location, the policy exposure was entirely determined by the timing of the policy implementation. Since the late 1980s, restrictions on internal migration were relaxed, which allowed for work-related migration of young individuals from rural areas to urban areas. However, as a result of the *hukou* system, most work migrants eventually return to their home towns (Wang *et al.*, 2017). Hence, internal migration is unlikely to attenuate the link between exposure to the LLF policy and elderly suicides, supporting the implicit identification assumption.

[9]The *hukou* system refers to the local registration status of a household, which determines access to food rations, housing, health care, pension benefits or schools (Wang *et al.*, 2017).

4.3 Results

4.3.1 Main Results

Table 4.1 presents the baseline results for the effect of exposure to the LLF policy on suicide rates among the elderly (aged 60 and older) in China during the period 2004–2017. The table contains results for different specifications of the empirical model in Eq. (4.3). In particular, the baseline specification in Column (1) includes controls for sex, a linear time trend and a full set of dummies for quinquennial age groups. Alternative specifications include year fixed effects instead of a linear time trend (Column (2)), year fixed effects and a linear cohort trend (Column (3)), or a full set of cohort dummies (Column (4)).

Table 4.1: *Policy Exposure and Elderly Suicides: Baseline Results*

	Suicide rate			
	(1)	(2)	(3)	(4)
Policy exposure	7.2573***	7.2883***	7.8664***	7.4684***
	(0.8106)	(0.8103)	(0.9060)	(0.8510)
Male	10.0919***	10.0919***	10.0919***	10.0919***
	(0.7295)	(0.7307)	(0.7308)	(0.7335)
Time trend	-3.2176***			
	(0.3433)			
Cohort trend			-1.1961***	
			(0.2393)	
Age group	✓	✓	✓	✓
Year		✓	✓	✓
Cohort				✓
Observations	3612	3612	3612	3612
R^2	0.4197	0.4242	0.4293	0.4418

Notes:: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. This table shows OLS estimates. Standard errors (in parentheses) are clustered at region×cohort level. Policy Exposure refers to exposure to LLF policy, see texts for details. Age group: full set of dummies for quinquennial age groups (reference group: 70–74); Year: full set of year dummies (reference year: 2004); Cohort: full set of cohort dummies (reference cohort: 1950).

The main finding that emerges regardless of the exact specification is that a greater exposure to the LLF policy is associated with a significantly higher suicide rate among the elderly. The coefficient estimate is similar across all specifications, suggesting that confounders such as non-linear trends or cohort patterns that differ systematically from age patterns are unlikely to drive the main finding. Quantitatively, the estimates imply that the increased exposure to the fertility policy between cohorts born in 1930 and 1957 accounts for an increase in the suicide rate of about 35 per 100000, which is sizable.[10]

In addition, the estimation results provide evidence for a significantly elevated suicide rate among elderly men, and a declining time trend in suicides, as well as systematic patterns across ages (with suicide rates increasing among older age groups) and cohorts (with suicide rates being significantly higher among older birth cohorts than among younger ones).[11]

4.3.2 Robustness

Accounting for Regional Differences. Additional robustness checks reveal that the main results are robust to adding a full set of region dummies to account for systematic differences in elderly suicide patterns across East/Central/West Chinese regions. In particular, accounting for region-specific differences delivers qualitatively and quantitatively very similar estimates for the coefficient of interest.[12] However, this specification is very taxing in light of the identifying variation.

Effect Heterogeneity. In additional analysis, we also explore the possibility of heterogeneous effects across different dimensions. In particular, we investigate whether the effect of policy exposure exhibits heterogeneity between suicides of men and women, across the urban/rural divide, across regions, and across different cohorts. Heterogeneity is identified by ways of interaction terms with policy exposure. Table 4.2 shows the corresponding results.

Column (1) of Table 4.2 shows the estimation results for an extended version of the

[10]The cohort born in 1930 exhibited almost no exposure, while the cohort 1955 exhibited an exposure of close to 5, see Figure 4.3. With a coefficient estimate of approximately 7, this implies a total increase of 35, which is close to the mean in Figure 4.1(a).

[11]Figure D.1 in Appendix D shows the coefficient estimates for the age group dummies and cohort dummies corresponding to Column (4) of Table 4.1.

[12]See Table D.1 in Appendix D for details.

Table 4.2: *Heterogeneous Effects by Sex, Area, and Cohort*

	Suicide rate							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy exposure	8.1342***	8.3452***	0.6187	-1.1667	3.8093***	3.9580***	4.3053***	2.2413***
	(0.8851)	(0.8930)	(0.7909)	(1.4072)	(1.0276)	(1.0824)	(0.3975)	(0.1364)
Male	13.4447***	13.4447***	10.0919***	10.0919***	10.0919***	10.0919***	7.7027***	3.0329***
	(1.1419)	(1.1482)	(0.7297)	(0.7337)	(0.7299)	(0.7339)	(0.6000)	(0.1175)
Male×Policy exposure	-1.7537***	-1.7537***						
	(0.3084)	(0.3101)						
Time trend	-3.2176***		-2.5135***		-3.0991***			
	(0.3433)		(0.3669)		(0.2464)			
Urban			-27.8492***	-28.7403***				
			(3.8354)	(4.2175)				
Urban×Policy exposure			8.3732***	7.0783***				
			(1.5476)	(1.0715)				
East					-24.2223***	-24.1303***		
					(3.2660)	(2.7959)		
West					-25.2020***	-25.1498***		
					(3.3838)	(3.0064)		
East×Policy exposure					5.3100***	5.2969***		
					(0.9702)	(0.8602)		
West×Policy exposure					3.7418***	3.7146***		
					(0.9086)	(0.8287)		
Age group	✓	✓	✓	✓	✓	✓	✓	✓
Year		✓		✓		✓	✓	✓
Cohort		✓		✓		✓	✓	✓
Observations	3612	3612	3612	3612	3612	3612	5460	1848
R^2	0.4238	0.4459	0.5528	0.5738	0.5621	0.5837	0.5073	0.7660

Notes:: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. This table shows OLS estimates. Standard errors (in parentheses) are clustered at region×cohort level. Policy Exposure refers to exposure to LLF policy, see text for details. Age group: full set of dummies for quinquennial age groups (reference group: 70–74); Year: full set of year dummies (reference year: 2004); Cohort: full set of cohort dummies (reference cohort: 1950).

specification in Column (1) of Table 4.1 that accounts for heterogeneity by sex. The estimates reveal a significantly positive effect of policy exposure as in the baseline, which is quantitatively even larger. In the present specification, this coefficient refers to the effect of policy exposure on suicide rates of women. While the results reveal that the suicide rate is higher on average among men, the effect of policy exposure is significantly larger for women than for men, as indicated by the negative coefficient for the interaction term. Column (2) of Table 4.2 documents that quantitatively almost identical results are obtained for the specification with age, time, and cohort controls (corresponding to Column (4) of Table 4.1).

Column (3) of Table 4.2 presents the estimation results for an extended specification that allows for heterogeneity in the effect of policy exposure by rural/urban areas. In this specification, the effect of policy exposure is positive but insignificant in rural areas. In addition, elderly suicide rates are smaller in urban areas. However, the significant positive interaction term shows that the effect of policy exposure is significantly positive in urban areas.[13] This suggests that there is an important heterogeneity in the effect, which mainly materializes in urban areas, where lower fertility and the consequences in terms of a smaller family and reduced companionship with children and kin are felt harder, with the consequence of significantly higher suicide rates among the elderly. Similar results emerge for the specification with age, time, and cohort controls (see Column (4) of Table 4.2). In light of the rural/urban divide in economic living conditions, these findings suggest that social and psychological factors play an important role above and beyond economic factors.

Column (3) of Table 4.2 shows the estimation results when allowing for heterogeneity in the policy effect by region. The estimated main effect of policy exposure is significant and positive for the Center as reference region. While on average, elderly suicide rates are lower in the East and West compared to the center, the significant positive interaction effects with policy exposure reveal that the policy effect is even more pronounced in the East and in the West regions than in the Center.

Columns (7) and (8) of Table 4.2 present results for an extended sample that includes younger cohorts than in the baseline sample. The baseline results were based on the elderly cohorts aged 60–87 during the period 2004–2017, who were born between 1930 and 1957, for which the variation in the implementation of the LLF policy across time and space implied substantial variation in the exposure to the policy in terms of fertility. To explore the robustness of the results, we extended this sample to cohorts that were younger than 60 during the observation period 2004–2017. To make the measure of policy exposure consistent, we focus on cohorts aged 49 and above who had already completed their fecund

[13]Unreported results reveal that the effect of policy exposure is insignificant in a specification that controls for urban/rural divide but that does not account for heterogeneous effects of policy exposure across rural and urban areas.

period. Thus, the younger cohorts comprise individuals born between 1945 (who were age 59 in 2004) to 1968 (who were age 49 in 2017). Despite the overlap in birth years from 1945 to 1957 in baseline and younger cohorts, the age constraint implies that the two sub-samples are exclusive to each other.

The estimation results in Column (7) again reveal a significantly positive effect of policy exposure when including also the younger cohorts, with a slightly smaller coefficient estimate than in the baseline specification. The results in Column (8) show that, in comparison, restricting the sample to younger cohorts implies an even smaller policy effect than for the baseline cohorts. However, the total effect of the policy exposure is still positive among the younger cohorts, and about a quarter of the size of the compared to the estimate for the baseline sample for cohorts for which there is more variation in policy exposure.[14]

Placebo Test: Randomizing the Intensity of Policy Exposure. To further investigate the robustness of the result, we analyze the source of the identifying variation for our main finding by comparing the estimates obtained from the baseline model to estimates obtained with an exposure measure $\text{PolExp}_{p,u,c}$ that is constructed for placebo policies. In particular, the variation in

$$\text{PolExp}_{p,u,c} = \sum_{a=15}^{49} \left\{ \text{AFR}_{p,u}\left(a\right) \cdot I\left[c + a > T_p\right] \right\}$$

comes from three dimensions: the timing of the implementation of the policy (the implementation year T_p), space (province$\times$urban/rural divide, through $\text{AFR}_{p,u}\left(a\right)$), and birth cohorts (through c). To disentangle which dimension is crucial for the identification of the effect, we constructed alternative measures of policy exposure in which one of these three dimensions is replaced by a placebo based on randomization.

First, in order to generate a placebo regarding the time variation in exposure, we randomly assign policy implementation years to provinces. The Family Planning Leading

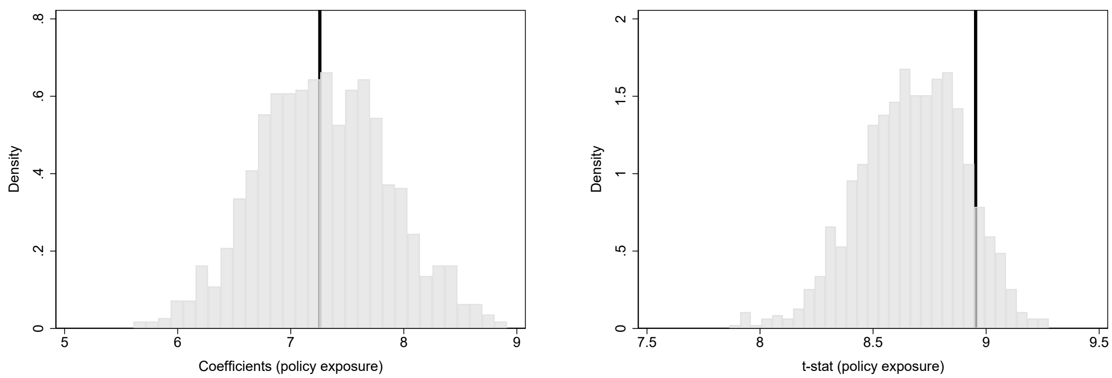
[14]Alternative specifications allowing for distinct effects of policy exposure by birth cohort in the baseline sample reveal no evidence for significant heterogeneity in the effect across cohorts, but also suggest a greater effect among older cohorts. See Figure D.2 in Appendix D. Additional unreported results also reveal that suicides in urban areas are more frequent among younger cohorts, whereas the effect of policy exposure for young cohorts in urban areas is diminished relative to older cohorts.

Group implemented the LLF policy across all provinces between 1969 to 1975. In order to have a comparable pattern of implementation overall, provinces are randomly designated as implementing the fertility policy within each year, according to the actual distribution of implementation years without replacement. This implies that, for each year from 1969 to 1975, the number of provinces that had implemented the fertility policies in the placebo exercise is the same as the number of provinces that actually implemented the fertility policies in the observed data. Using the randomized policy implementation years, we compute policy exposure $\text{PolExp}_{p,u,c}$ as in Eq. (4.1). Then, we calculate the weighted average for each region$\times$urban/rural area, $\text{PolExp}_{r,u,c}$, in the same way as for the observed data as in Eq. (4.2). We repeat the randomization for 1000 times and replicate the estimation of the specification in Column (1) of Table 4.1 for each placebo sample. Figure 4.4 shows the distribution of the resulting estimates of β and the corresponding distribution of t-statistics for the 1000 estimated placebo treatment effects. The vertical line represents the location of the baseline estimates corresponding to Column (1) of Table 4.1. The results suggest that the placebo estimates exhibit fairly similar estimation results as the baseline estimates. The likely explanation for this finding is that the variation in the timing alone is not what identifies the estimated effect in the baseline results; instead, the estimates rely on variation in the other components of the policy exposure variable $\text{PolExp}_{p,u,c}$ rather than time variation of policy implementation.[15] Very similar results are obtained when estimating the coefficient of interest with the specification with age, time, and cohort controls as in Column (4) of Table 4.1 for each placebo sample.[16]

Second, we randomize the assignment of the policy implementation across space and cohorts. In particular, after calculating $\text{PolExp}_{p,u,c}$ based on the actual policy implementation year in each province as in Eq. (4.1), we randomly assign a combination of province$\times$urban/rural area to each set of cohort-specific policy exposure measures

[15] Alternatively, averaging across provinces to obtain a measure for each region$\times$urban/rural area might wash out relevant variation.

[16] See Figure D.3 in Appendix D.



(a) Coefficient Estimates

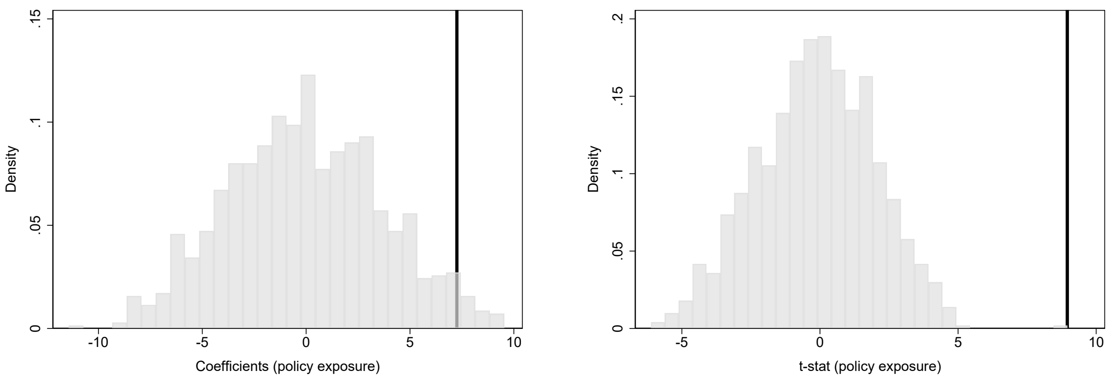
(b) Inference (t-statistics)

Figure 4.4: *Placebo: Random Implementation of Policy (Time)*

Notes: Figure 4.4(a) shows the coefficient estimates for β as in specification of Column (1) of Table 4.1. Figure 4.4(b) shows the t-values for estimates of β in Figure 4.4(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments over time. See text for details.

$\text{PolExp}_{p,u,c}$ and then, within each province×urban/rural area, randomize these measures across cohorts and then calculate weighted average $\text{PolExp}_{r,u,c}$ for each spatial entity (region×urban/rural area) as in Eq. (4.2). This randomization implies that the variation across time (policy implementation year) remains unchanged, while a placebo mapping is obtained across spatial entities (province×urban/rural area) and birth cohorts. We conduct this placebo construction for 1000 times and then re-estimate for each placebo the effect with the empirical framework in Eq. (4.3). Figure 4.5 plots the corresponding coefficient estimates and t-values. On average, the coefficient estimates are smaller compared to the baseline estimates, and often negative. Also the t-values are systematically smaller, but for some random draws, the coefficient estimates are still at the size of the baseline estimates, and significant with t-values exceeding the thresholds for conventional significance levels. This suggests that variation across space and cohorts is relevant for the identification of the effect of interest, but that randomization in these two dimensions is not enough to eliminate the effect in all cases.[17]

[17] Figure D.4 in Appendix D shows the corresponding results for the specification with age, time, and cohort controls as in Column (4) of Table 4.1. Similar results emerge when randomizing separately by cohort or space, see Figure D.5 and Figure D.6 in Appendix D



(a) Coefficient Estimates

(b) Inference (t-statistics)

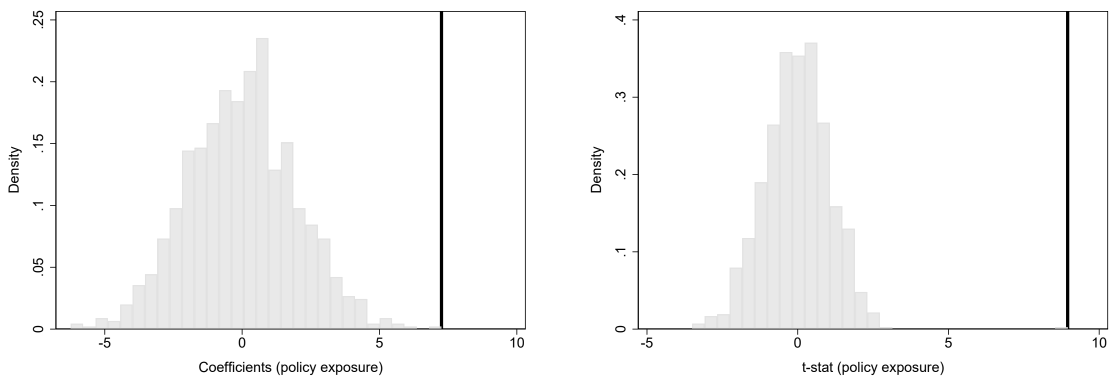
Figure 4.5: *Placebo: Random Implementation of Policy (Space and Cohorts)*

Notes: Figure 4.5(a) shows coefficient estimates for β as in specification of Column (1) of Table 4.1. Figure 4.5(b) shows t-values for estimates of β in Figure 4.5(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments across both space and cohort. See text for details.

Taken together, the randomization of the individual components of the variation in the policy exposure measure affects the results, particularly when considering variation across space and cohorts. At the same time, these exercises suggest that it is not variation in one of these dimensions of variation alone that is responsible for the identification of the effect. To document that it is the combination of the different dimensions of identifying variation, we finally present results for a placebo that combines the randomization across the different dimensions as described before. In other words, we simultaneously implement a randomized assignment of the LLF policy across space, cohorts, and time.

Specifically, we conduct a random assignment of policy implementation years for 1000 times and compute the corresponding policy exposure measure $\text{PolExp}_{p,u,c}$ as in Eq. (4.1). Afterwards, we randomly assign $\text{PolExp}_{p,u,c}$ across cohorts and spatial entities (province$\times$urban/rural areas). For each of the 1000 randomized samples, we then compute $\text{PolExp}_{r,u,c}$ as in Eq. (4.2) and regress the elderly suicide rate on the resulting weighted placebo policy exposure measure $\text{PolExp}_{r,u,c}$. Figure 4.6 shows the corresponding coefficient estimates and t-values in comparison to the baseline estimates. The results reveal that the distribution of estimates based on the placebo data are closely centered around zero.

Similarly, the distribution of the corresponding t-values is closely centered around zero, leaving hardly any significant estimates, and with sizes substantially smaller than in the baseline results.[18] This suggests that the identification of the effect of policy exposure indeed draws on the combination of three dimensions of identifying variation across time, space, and cohorts.



(a) Coefficient Estimates

(b) Inference (t-statistics)

Figure 4.6: *Placebo: Random Implementation of Policy (Space, Cohorts, and Time)*

Notes: Figure 4.6(a) shows coefficient estimates for β as in specification of Column (1) of Table 4.1. Figure 4.6(b) shows t-values for estimates of β in Figure 4.6(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments across space, cohort, and time. See text for details.

4.4 Discussion

Overall, our results show that exposure to the "Later, Longer, Fewer" campaign to reduce fertility in the 1970s continues to have persistent effects on suicide patterns among the elderly still today. This finding emerges above and beyond the well-documented time and age trends in suicide rates, and beyond systematic heterogeneity in suicides across birth cohorts. The effect exhibits some heterogeneity across men and women and varies substantially across rural and urban areas. While elderly suicide rates are generally lower in

[18] Figure D.7 in Appendix D shows the corresponding results for the specification with age, time, and cohort controls as in Column (4) of Table 4.1

urban areas, the effect of exposure to the fertility policy is larger in urban areas. Moreover, the findings suggest that younger cohorts are affected less by variation in policy exposure.

The results confirm earlier conjectures about a link between fertility, fertility policy, and suicide patterns among the elderly. Thereby, they contribute to a better understanding of the underlying causes for the notable suicide patterns among the elderly in China. The findings can also rationalize recent evidence that documents a declining trend in the absolute number of elderly suicides since the late 1990s and a convergence of the rural/urban divide that began around the same time (see, e.g., Zhong *et al.*, 2016; Sha *et al.*, 2017), since this timing coincides with the end of the fecund period of life of the last cohorts that were affected differentially by the fertility policies of the 1970s and the 1980s. While there is an ongoing debate about the prospects for a rebound of elderly suicide rates in the literature (see, e.g., Parry, 2014; Wang *et al.*, 2014; Sha *et al.*, 2017; Zhong *et al.*, 2016), our findings of a declining trend of suicides across cohorts, together with the fading out of the policy effects, particularly in urban areas, suggest that there might be opposing effects at work.

In terms of policy, the results indicate the need for reforms of the pension system for limiting suicides and suicide ideation among the elderly. While such reforms might not fully alleviate the social and psychological consequences of low fertility among the elderly, they would at least help reducing suicides driven by economic hardship.

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Appendix A

Appendix to Chapter 1

A.1 Individual Optimization Problems

For low-taste individuals, maximizing the utility function in Eq. (1.3) subject to the budget constraint in Eq. (1.1) leads to the interior solutions

$$\begin{aligned}
{b_{l,t}}^{*} &= \frac{m_t q_t \left(\alpha_t - 1\right) + kP_{f,t}\left(q_t + 1\right)}{P_{b,t} q_t \left(\gamma + 2\right)\left(\alpha_t - 1\right)};\\
{f_{l,t}}^{*} &= \frac{m_t q_t \left(\alpha_t - 1\right) + kP_{f,t}\left(q_t + 1\right)}{P_{f,t} q_t \left(\gamma + 2\right)\left(\alpha_t - 1\right)};\\
{e_{l,t}}^{*} &= \frac{\gamma m_t q_t \left(\alpha_t - 1\right) - 2kP_{f,t}\left(q_t + 1\right)}{kP_{f,t} q_t \left(\gamma + 2\right)\left(\alpha_t - 1\right)}.
\end{aligned}$$

For high-taste individuals, maximizing the utility function in Eq. (1.4) subject to the budget constraint in Eq. (1.2) leads to the interior solutions

$$\begin{aligned}
{b_{h,t}}^{*} &= \frac{m_t q_t \left(\alpha_t - 1\right) + kP_{f,t}\left(q_t + 1\right)}{P_{b,t} q_t \left(\alpha_t - 1\right)\left(\gamma\alpha_t + \alpha_t + 1\right)};\\
{f_{h,t}}^{*} &= \frac{\alpha_t \left[m_t q_t \left(\alpha_t - 1\right) + kP_{f,t}\left(q_t + 1\right)\right]}{P_{f,t} q_t \left(\alpha_t - 1\right)\left(\gamma\alpha_t + \alpha_t + 1\right)};\\
{e_{h,t}}^{*} &= \frac{\gamma\alpha_t m_t q_t \left(\alpha_t - 1\right) - kP_{f,t}\left(\alpha_t + 1\right)\left(q_t + 1\right)}{kP_{f,t} q_t \left(\alpha_t - 1\right)\left(\gamma\alpha_t + \alpha_t + 1\right)}.
\end{aligned}$$

With $\alpha_t > 1$, it must hold that

$$b_{h,t}{}^* - b_{l,t}{}^* = -\frac{(\gamma+1)\left[m_t q_t(\alpha_t - 1) + kP_{f,t}(q_t+1)\right]}{P_{b,t} q_t (\gamma+2)(\gamma\alpha_t + \alpha_t + 1)} < 0;$$
$$f_{h,t}{}^* - f_{l,t}{}^* = \frac{m_t q_t(\alpha_t - 1) + kP_{f,t}(q_t+1)}{P_{f,t} q_t (\gamma+2)(\gamma\alpha_t + \alpha_t + 1)} > 0;$$
$$e_{h,t}{}^* - e_{l,t}{}^* = \frac{\gamma\left[m_t q_t(\alpha_t - 1) + kP_{f,t}(q_t+1)\right]}{kP_{f,t} q_t (\gamma+2)(\gamma\alpha_t + \alpha_t + 1)} > 0.$$

A.2 Proof of Proposition 1

In the following, the equilibrium is derived from the fancy-good sector. The interior solutions to the consumer problems solved in Appendix A.1 express the aggregate consumption of fancy goods as

$$\begin{aligned} D_{f,t} &= q_t\left(f_{h,t}{}^* + k \cdot e_{h,t}{}^*\right) + (1-q_t)\left(f_{l,t}{}^* + k \cdot e_{l,t}{}^*\right) \\ &= \frac{m_t q_t(\gamma+1)(\alpha_t-1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_t+1]+kP_{f,t}(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]}{P_{f,t} q_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)}. \end{aligned}$$

Using the price of fancy goods $P_{f,t}$ in Eq. (1.9) and the income m_t in Eq. (1.10) the aggregate consumption of fancy goods is

$$D_{f,t} = \frac{Fq_t(\gamma+1)(\alpha_t-1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_t+1]+k(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]}{q_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)}.$$

With the market clearing condition that the aggregate demand equals the aggregate supply, $D_{f,t} = Fn_{f,t}$, the equilibrium share of labor in the fancy-good sector is

$$\begin{aligned} n_{f,t}{}^* &= \frac{Fq_t(\gamma+1)(\alpha_t-1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_t+1]+k(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]}{Fq_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)} \\ &= N_f\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right). \end{aligned}$$

To Prove $\frac{\partial n_{f,t}{}^*}{\partial \alpha_t} > 0$.

$$\frac{\partial n_{f,t}{}^*}{\partial \alpha_t} = \frac{q_t{}^2 (\gamma + 1) + \frac{k(q_t+1)\left[(\gamma\alpha_t+\alpha_t+1)^2 - q_t(\gamma+1)^2(\alpha_t-1)^2\right]}{F(\gamma+2)(\alpha_t-1)^2}}{q_t (\gamma\alpha_t + \alpha_t + 1)^2}$$

with

$$\begin{aligned} &(\gamma\alpha_t + \alpha_t + 1)^2 - q_t (\alpha_t - 1)^2 (\gamma + 1)^2 \\ =& (1 - q_t) \left[\alpha_t{}^2 (\gamma + 1)^2 + 1\right] + \gamma q_t (\gamma + 2) (\alpha_t - 1) + \alpha_t \{q_t [\gamma (\gamma + 2) + 2] + 2 (\gamma + 1)\}. \end{aligned}$$

Because of $\alpha_t > 1$, $0 < q_t < 1$, $\gamma > 0$, $k > 0$, and $F > 0$, $\frac{\partial n_{f,t}{}^*}{\partial \alpha_t} > 0$ must hold.

To Prove $\frac{\partial n_{f,t}{}^*}{\partial q_t} > 0$.

$$\frac{\partial n_{f,t}{}^*}{\partial q_t} = \frac{F q_t{}^2 (\gamma + 1) (\alpha_t - 1)^2 + k \left[q_t{}^2 (\gamma + 1) (\alpha_t - 1) + \gamma\alpha_t + \alpha_t + 1\right]}{F q_t{}^2 (\gamma + 2) (\alpha_t - 1) (\gamma\alpha_t + \alpha_t + 1).} > 0$$

holds because of $\alpha_t > 1$, $0 < q_t < 1$, $\gamma > 0$, $k > 0$, and $F > 0$.

As a result, the equilibrium share of labor in the fancy-good sector $n_{f,t}{}^*$ monotonically increases with q_t and α_t. Therefore, given q_t and α_t, the equilibrium value is unique for any generation t.

A.3 Proof of Proposition 2

The taste transmission process in equilibrium is

$$\begin{aligned} q_{t+1} &= q_t \cdot \mathbb{P}_{h,t}{}^* + (1 - q_t) \mathbb{P}_{l,t}{}^* \\ &= q_t \cdot e_{h,t}{}^* \cdot \frac{q_t}{q_t + 1} + (1 - q_t) e_{l,t}{}^* \cdot \frac{q_t}{q_t + 1}. \end{aligned}$$

The optimal cultivation effort $e_{l,t}{}^*$ and $e_{h,t}{}^*$ is derived in Appendix A.1, leading to

$$q_{t+1} = \frac{\gamma m_t q_t (\alpha_t - 1)[q_t(\alpha_t - 1) + \gamma\alpha_t + \alpha_t + 1] + k P_{f,t} (q_t + 1)[\gamma q_t(\alpha_t - 1) - 2(\gamma\alpha_t + \alpha_t + 1)]}{k P_{f,t} (\gamma + 2)(\gamma\alpha_t + \alpha_t + 1)(q_t + 1)(\alpha_t - 1)}.$$

Moreover, using the price of fancy goods $P_{f,t}$ in Eq. (1.9) and the income m_t in Eq. (1.10) the share of high-taste individuals of generation $t+1$ is

$$q_{t+1} = \frac{\gamma F q_t\left(\alpha_t-1\right)\left[q_t\left(\alpha_t-1\right)+\gamma\alpha_t+\alpha_t+1\right]+k\left(q_t+1\right)\left[\gamma q_t\left(\alpha_t-1\right)-2\left(\gamma\alpha_t+\alpha_t+1\right)\right]}{k\left(\gamma+2\right)\left(\alpha_t-1\right)\left(q_t+1\right)\left(\gamma\alpha_t+\alpha_t+1\right)}$$
$$= Q\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right).$$

To Prove $\frac{\partial q_{t+1}}{\partial \alpha_t} > 0$.

$$\frac{\partial q_{t+1}}{\partial \alpha_t} = \frac{\frac{\gamma F {q_t}^2}{k(q_t+1)} + \frac{(\gamma+1)\left\{\alpha_t[\alpha_t(\gamma+2)+\gamma q_t+4]+\gamma{\alpha_t}^2(1-q_t)+\gamma q_t(\alpha_t-1)\right\}+2}{(\gamma+2)(\alpha_t-1)^2}}{\left(\gamma\alpha_t+\alpha_t+1\right)^2} > 0$$

holds because of $\alpha_t > 1$, $0 < q_t < 1$, $\gamma > 0$, $k > 0$, and $F > 0$.

To Prove $\frac{\partial q_{t+1}}{\partial q_t} > 0$.

$$\frac{\partial q_{t+1}}{\partial q_t} = \frac{\gamma\left\{F\left[q_t\left(q_t+2\right)\left(\alpha_t-1\right)+\gamma\alpha_t+\alpha_t+1\right]+k\left(q_t+1\right)^2\right\}}{k\left(\gamma+2\right)\left(q_t+1\right)^2\left(\gamma\alpha_t+\alpha_t+1\right)} > 0$$

holds because of $\alpha_t > 1$, $0 < q_t < 1$, $\gamma > 0$, $k > 0$, and $F > 0$.

To Prove $\frac{\partial^2 q_{t+1}}{\partial {q_t}^2} < 0$.

$$\frac{\partial^2 q_{t+1}}{\partial {q_t}^2} = -\frac{2\gamma F\left(\gamma\alpha_t+2\right)}{k\left(\gamma+2\right)\left(q_t+1\right)^3\left(\gamma\alpha_t+\alpha_t+1\right)} < 0$$

holds because of $\alpha_t > 1$, $0 < q_t < 1$, $\gamma > 0$, $k > 0$, and $F > 0$.

A.4 Derivation of the Upper and Lower Bounds

α_t and q_t are bounded as $\alpha_t \in [\underline{\alpha},\ \overline{\alpha}]$ and $q_t \in \left[\underline{q},\ 1\right]$ in the model. The difference equation $q_{t+1} = Q\left(\alpha_t,\ q_t\ ;\ \gamma,\ k,\ F\right)$ is graphed as an increasing and concave curve in Figure 1.2 with q_t as the *x-axis* and q_{t+1} as the *y-axis*. It shifts upwards with increasing α_t. Since q_t denotes the share of high-taste individuals, it lies in $[0,\ 1]$. Moreover, the function Q is continuous within this range.

- $q_t = 0$ leads to
$$Q\left(\alpha_t,\ 0\ ;\ \gamma,\ k,\ F\right) = -\frac{2}{\left(\gamma+2\right)\left(\alpha_t-1\right)} < 0.$$
Note that the function Q increases with α_t in this case. Therefore, the curve always has a negative *y-intercept* which approaches zero as α_t increases.

- $q_t = 1$ leads to
$$Q\left(\alpha_t,\ 1\ ;\ \gamma,\ k,\ F\right) = \frac{\gamma F\alpha_t\left(\alpha_t-1\right)-2k\left(\alpha_t+1\right)}{2k\left(\alpha_t-1\right)\left(\gamma\alpha_t+\alpha_t+1\right)}.$$
Here, the function Q also increases with α_t. At the optimum, $Q\left(\alpha_t,\ 1\ ;\ \gamma,\ k,\ F\right) = 1$ results in
$$\frac{\gamma F\alpha_t\left(\alpha_t-1\right)-2k\left(\alpha_t+1\right)}{2k\left(\alpha_t-1\right)\left(\gamma\alpha_t+\alpha_t+1\right)} = 1 \iff \alpha_t = 1+\frac{4k}{\gamma F-2k\left(\gamma+1\right)}.$$
In addition, the condition
$$\gamma F > 2k\left(\gamma+1\right) \tag{A.1}$$
is required to ensure $\alpha_t > 1$ in this case.

Upper bound $\overline{\alpha}$. At $\alpha_t = 1+\frac{4k}{\gamma F-2k(\gamma+1)}$, the difference equation in Eq. (1.12) intersects the 45° line at $(1,\ 1)$. Accordingly, the upper bound $\overline{\alpha}$ is defined as
$$\overline{\alpha} = 1+\frac{4k}{\gamma F-2k\left(\gamma+1\right)} \quad \text{with} \quad \gamma F > 2k\left(\gamma+1\right). \tag{A.2}$$

Lower bound $\underline{q}$. Since the difference equation in Eq. (1.12) always has a negative *y-intercept*, the concavely increasing curve intersects the 45° line at $(1,\ 1)$ and $\left(\underline{q},\ \underline{q}\right)$ for $\alpha_t = \overline{\alpha}$. Here, $\underline{q} > 0$ is defined as the lower bound of q_t in the model.

The upper bound $\overline{\alpha}$ is used in the difference equation in Eq. (1.12) to solve for q_t:

$$\begin{aligned} q_{t+1} &= Q\left(\overline{\alpha},\ q_t\ ;\ \gamma,\ k,\ F\right) \\ &= \frac{\gamma F^2(\gamma+2)(1-q_t)+4k^2(\gamma+1)(q_t+1)(q_t+\gamma+1)-2Fk\left[{q_t}^2(\gamma+4)+q_t(3\gamma+2)+2(\gamma+1)^2\right]}{2k(\gamma+2)(q_t+1)[2k(\gamma+1)-F(\gamma+2)]} \\ &= q_t. \end{aligned}$$

By construction, there are two solutions, $q_t = 1$ and

$$q_t = \underline{q} = \frac{\left[\gamma F - 2k\left(\gamma+1\right)\right]\left[F\left(\gamma+2\right) - 2k\left(\gamma+1\right)\right]}{2k\left[\gamma F\left(\gamma+3\right) - 2k\left(\gamma+1\right)^2\right]}. \tag{A.3}$$

- Check if $\underline{q} > 0$:
  - $\gamma F - 2k\left(\gamma+1\right) > 0$ is the condition in Eq. (A.1);
  - $F\left(\gamma+2\right) - 2k\left(\gamma+1\right) > \gamma F - 2k\left(\gamma+1\right) > 0$ holds because of the condition in Eq. (A.1);
  - $\gamma F\left(\gamma+3\right) - 2k\left(\gamma+1\right)^2 > \gamma F\left(\gamma+1\right) - 2k\left(\gamma+1\right)^2 = \gamma F - 2k\left(\gamma+1\right) > 0$ also holds for the same reason.

  Therefore, $\underline{q} > 0$ must hold.

- Check if $\underline{q} < 1$: As mentioned above, at the upper bound $\overline{\alpha} = 1 + \frac{4k}{\gamma F - 2k(\gamma+1)}$, the indifference curve intersects the 45° line at $(1,\ 1)$ and $\left(\underline{q},\ \underline{q}\right)$, with a negative *y-intercept* at $\left(0,\ -\frac{2}{(\gamma+2)(\overline{\alpha}-1)}\right)$. If γF increases, $\overline{\alpha}$ will decrease, which moves the *y-intercept* downwards and consequently moves $\left(\underline{q},\ \underline{q}\right)$ upwards along the 45° line. Accordingly, $\underline{q}$ increases with γF until $\underline{q} = 1$, when γF also reaches its maximum

$$\max \gamma F = \frac{k\left(\gamma+2\right)\left(3\gamma+1\right) + \sqrt{k^2\left(\gamma+2\right)\left[\gamma^2\left(\gamma+8\right)+5\gamma+2\right]}}{\left(\gamma+2\right)}.$$

Therefore, the following condition ensures $0 < \underline{q} < 1$:

$$2k\left(\gamma+1\right) < \gamma F < \frac{k\left(\gamma+2\right)\left(3\gamma+1\right) + \sqrt{k^2\left(\gamma+2\right)\left[\gamma^2\left(\gamma+8\right)+5\gamma+2\right]}}{\left(\gamma+2\right).}$$

Based on the lower bound $\underline{q}$, the system starts from an initial condition $q_0 \geq \underline{q}$. For the graphical analysis in Figure 1.2, the origin is set to $(q_0,\ q_0)$. When α_t is relatively high, the curve will intersect the *y-axis* at some point $(q_0,\ q_t')$ with $q_t' > q_0$. Likewise, $(1,\ 1)$ is the only point of intersection between the curve and the 45° line for $\alpha_t = \overline{\alpha}$.

Lower bound $\underline{\alpha}$. The lower bound $\underline{\alpha}$ should keep the curve of the difference equation in Eq. (1.12) visible in the coordinate system. With $\underline{q}$ as the lower bound, this requirement is equivalent to $q_{t+1} = Q\left(\alpha_t,\ q_t\ ;\ \beta,\ \gamma,\ k,\ F\right) = \underline{q}$ with $\alpha_t = \underline{\alpha}$ and $q_t = 1$:

$$Q\left(\underline{\alpha},\ 1\ ;\ \beta,\ \gamma,\ k,\ F\right) = \frac{\gamma\underline{\alpha}F\left(\underline{\alpha}-1\right) - 2k\left(\underline{\alpha}+1\right)}{2k\left(\underline{\alpha}-1\right)\left(\gamma\underline{\alpha}+\underline{\alpha}+1\right)} = \underline{q}.$$

Using the value of $\underline{q}$ in Eq. (A.3), the solution for the lower bounds is

$$\underline{\alpha} = \frac{A + \sqrt{A^2 + B}}{2\left[\gamma F - 2k\underline{q}\left(\gamma+1\right)\right]} \tag{A.4}$$

with

$$A = \gamma F + 2k\left(1 - \gamma\underline{q}\right);$$
$$B = 8k\beta\left(1 - \underline{q}\right)\left[\gamma F - 2k\underline{q}\left(\gamma+1\right)\right].$$

- Check if $\underline{\alpha} > 1$:
  - $A > \gamma F + 2k\left(1-\gamma\right) > 0$ holds because of $0 < \underline{q} < 1$ and the condition $\gamma F > 2k\left(\gamma+1\right)$ in Eq. (A.1);
  - $B > 8k\beta\left(1-\underline{q}\right)\left[\gamma F - 2k\left(\gamma+1\right)\right] > 0$ also holds because of $0 < \underline{q} < 1$ and the condition in Eq. (A.1);
  - For the denominator, $2\left[\gamma F - 2k\underline{q}\left(\gamma+1\right)\right] > 2\left[\gamma F - 2k\left(\gamma+1\right)\right] > 0$ holds for the same reason.

Overall, it must hold that

$$\underline{\alpha} = \frac{A + \sqrt{A^2 + B}}{2\left[\gamma F - 2k\underline{q}\left(\gamma+1\right)\right]} > \frac{A}{\gamma F - 2k\underline{q}\left(\gamma+1\right)} > \frac{\gamma F - 2k\underline{q}\left(\gamma+1\right)}{\gamma F - 2k\underline{q}\left(\gamma+1\right)} = 1.$$

Appendix B

Appendix to Chapter 2

B.1 Asian Economy

B.1.1 Proof of Lemma 1′

With the price of silver $P_{s,t}^{ET}$ in Eq. (2.18), the aggregate consumption of basic goods $b_t^{AT*} = \frac{\tau \cdot P_{s,t}^{ET}}{\alpha^A \cdot P_{b,t}^{AT}}$ is

$$b_t^{AT*} = \frac{\tau \cdot P_{b,t}^{ET} \cdot B\left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{\beta-1}}{P_{b,t}^{AT} \cdot \alpha^A \cdot S},$$

which is covered by the local production of basic goods $Y_{b,t}^{AT} = B^A\left(1 - n_{f,t}^{A}\right)^{\beta^A}$ in Eq. (2.27). The market clearing $b_t^{AT*} = Y_{b,t}^{AT}$ yields

$$P_{b,t}^{ET} = \frac{P_{b,t}^{AT} \cdot \alpha^A \cdot S \cdot B^A\left(1 - n_{f,t}^{AT}\right)^{\beta^A}\left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{1-\beta}}{\tau \cdot B}. \tag{B.1}$$

With the silver price $P_{s,t}^{ET}$ in Eq. (2.18) and the income in Asia m_t^{AT} in Eq. (2.32), the aggregate consumption of silver $s_t^{AT*} = \frac{m_t^{AT}}{\tau \cdot P_{s,t}^{ET}} - \frac{2}{\alpha^A}$ is

$$s_t^{AT*} = \frac{P_{b,t}^{AT} \cdot S \cdot B^A \cdot \left(1 - n_{f,t}^{AT}\right)^{\beta^A}\left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{1-\beta}}{\tau \cdot P_{b,t}^{ET} \cdot B\left(1 - n_{f,t}^{AT}\right)} - \frac{2}{\alpha^A},$$

which is covered by the European production of silver $Y_{s,t}^{ET} = S \cdot n_{s,t}^{ET}$ in Eq. (2.13). The market clearing $s_t^{AT*} = \frac{Y_{s,t}^{ET}}{\tau}$ yields

$$P_{b,t}^{ET} = \frac{P_{b,t}^{AT} \cdot \alpha^A \cdot S \cdot B^A \left(1 - n_{f,t}^{AT}\right)^{\beta^A - 1} \left(1 - n_{f,t}^{ET} - n_{s,t}^{ET}\right)^{1-\beta}}{B \left(\alpha^A \cdot S \cdot n_{s,t}^{ET} + 2\tau\right)}. \tag{B.2}$$

Equalizing Eq. (B.1) and Eq. (B.2) results in the equilibrium share of labor in the fancy-good sector of the Asian economy in intercontinental trade:

$$n_{f,t}^{AT*} = \frac{\alpha^A \cdot S \cdot n_{s,t}^{ET} + \tau}{\alpha^A \cdot S \cdot n_{s,t}^{ET} + 2\tau}.$$

B.1.2 Condition for the Interior Solutions in the Asian Trade Equilibrium

The condition for the interior solution is $m_t^{AT} > \frac{2\tau \cdot P_{s,t}^{ET}}{\alpha^A}$. With $P_{b,t}^{ET}$ in Eq. (B.1) and $n_{f,t}^{ET} = 0$, $P_{s,t}^{ET}$ in Eq. (2.18) leads to

$$\frac{2\tau \cdot P_{s,t}^{ET}}{\alpha^A} = 2B^A \cdot P_{b,t}^{AT} \left(\frac{\tau}{\alpha^A \cdot S \cdot n_{s,t}^{ET} + 2\tau}\right)^{\beta^A}.$$

In the trade equilibrium, given $n_{f,t}^{AT*}$ in Eq. (2.33), the income in Asia m_t^{AT} in Eq. (2.32) is

$$\begin{aligned} m_t^{AT} &= \left(2 + \frac{\alpha^A \cdot S \cdot n_{s,t}^{ET*}}{\tau}\right) B^A \cdot P_{b,t}^{AT} \left(\frac{\tau}{\alpha^A \cdot S \cdot n_{s,t}^{ET*} + 2\tau}\right)^{\beta^A} \\ &> 2B^A \cdot P_{b,t}^{AT} \left(\frac{\tau}{\alpha^A \cdot S \cdot n_{s,t}^{ET*} + 2\tau}\right)^{\beta^A} = \frac{2\tau \cdot P_{s,t}^{ET}}{\alpha^A}. \end{aligned}$$

B.1.3 Comparison: Asian Economy in Autarky and Intercontinental Trade

In the trade equilibrium, $n_{s,t}^{ET} > 0$ is exogenous for the Asian economy. In addition, for any $\tau \neq 0$, the trade equilibrium $n_{f,t}^{AT*} = \frac{\alpha^A \cdot S \cdot n_{s,t}^{ET} + \tau}{\alpha^A \cdot S \cdot n_{s,t}^{ET} + 2\tau}$ converges to autarky equilibrium $n_{f,t}^{AA*} = \frac{1}{2}$ with $n_{s,t}^{ET} = 0$.

Consumption. The aggregate consumption of basic goods in the autarky and trade equilibrium is

$$b_t^{AA*} = \frac{m_t^{AA}}{2P_{b,t}^{AA}} = B^A \left(\frac{1}{2}\right)^{\beta^A}; \quad \text{(Autarky)}$$

$$b_t^{AT*} = \frac{\tau \cdot P_{s,t}^{ET}}{\alpha^A \cdot P_{b,t}^{AT}} = B^A \left(\frac{1}{\frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau} + 2}\right)^{\beta^A}. \quad \text{(Trade)}$$

Here, b_t^{AT*} is less than b_t^{AA*} because of $\frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau} > 0$.

The aggregate consumption of fancy goods in the autarky and trade equilibrium is

$$f_t^{AA*} = \frac{m_t^{AA}}{2P_{f,t}^{AA}} = \frac{F^A}{2}; \quad \text{(Autarky)}$$

$$f_t^{AT*} = \frac{\tau P_{s,t}^{ET}}{P_{f,t}^{AT} \alpha^A} = \frac{F^A}{\frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau} + 2}. \quad \text{(Trade)}$$

Thus, the consumption of fancy goods decreases when Asia opens up to trade.

In spite of less consumption of basic and fancy goods in the trade equilibrium, Asian consumers have access to silver which does not exist in a closed economy. The consumption of silver increases linearly with $n_{s,t}^{ET*}$ in the trade equilibrium:

$$s_t^{AA*} = 0; \quad \text{(Autarky)}$$

$$s_t^{AT*} = \frac{S \cdot n_{s,t}^{ET}}{\tau}. \quad \text{(Trade)}$$

Income. With the same normalization $P_{b,t}^{AT} = 1$, the aggregate income in the autarky equilibrium in Eq. (2.10) and the trade equilibrium in Eq. (2.32) is

$$Y_t^{AA} = 2B^A \left(\frac{1}{2}\right)^{\beta^A}; \quad \text{(Autarky)}$$

$$Y_t^{AT} = \left(2 + \frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau}\right) B^A \left(\frac{1}{\frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau} + 2}\right)^{\beta^A}. \quad \text{(Trade)}$$

For any $\tau \neq 0$, there is

$$\frac{\partial Y_t^{AT}}{\partial \left(\frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau}\right)} > 0,$$

meaning that

$$Y_t^{AT} = \left(2 + \frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau}\right) B^A \left(\frac{1}{\frac{\alpha^A \cdot S \cdot n_{s,t}^{ET}}{\tau} + 2}\right)^{\beta^A} > (2+0)\, B^A \left(\frac{1}{0+2}\right)^{\beta^A} = Y_t^{AA}$$

holds because of $n_{s,t}^{ET} > 0$. Therefore, Asia benefits from intercontinental trade in terms of the aggregate income as well.

B.2 European Economy

B.2.1 Proof of Proposition 4

Using $P_{b,t}^{ET}$ in Eq. (B.1), the European local competitive price of fancy goods $P_{f,t}^{ET}$ in Eq. (2.17) is

$$P_{f,t}^{ET} = \frac{P_{b,t}^{AT} \cdot \alpha^A \cdot S \cdot B^A \left(1 - n_{f,t}^{AT}\right)^{\beta^A}}{\tau \cdot F}. \tag{B.3}$$

Using $P_{f,t}^{AT}$ in Eq. (2.31) and the trade cost τ, the price of Asian imports in the European market is

$$\tau \cdot P_{f,t}^{AT} = \frac{\tau \cdot P_{b,t}^{AT} \cdot B^A \left(1 - n_{f,t}^{AT}\right)^{\beta^A - 1}}{F^A}. \tag{B.4}$$

If the price of Asian imports is lower, $\tau \cdot P_{f,t}^{AT} \leq P_{f,t}^{ET}$ will lead to

$$\tau^2 \cdot F \leq \alpha^A \cdot S \cdot F^A \left(1 - n_{f,t}^{AT}\right)$$

based on Eq. (B.3) and Eq. (B.4) derived above. With $n_{f,t}^{AT*}$ in Eq. (2.33), the expression is

$$\tau^2 \cdot F \leq \alpha^A \cdot S \cdot F^A \left(1 - \frac{\alpha^A \cdot S \cdot n_{s,t}^{ET} + \tau}{\alpha^A \cdot S \cdot n_{s,t}^{ET} + 2\tau}\right)$$

which can be rearranged as

$$n_{s,t}^{ET} \leq \frac{F^A}{\tau \cdot F} - \frac{2\tau}{\alpha^A \cdot S}.$$

B.2.2 Individual Optimization Problems in Trade

The interior solutions in the trade model are derived as for the autarky model solved in Appendix A.1, but the price of fancy goods in the trade model is $\tau \cdot P_{f,t}^{AT}$. For low-taste individuals, maximizing the utility function in Eq. (2.21) subject to the budget constraint in Eq. (2.23) leads to the optimal solutions

$$
\begin{aligned}
b_{l,t}^{ET*} &= \frac{m_t^{ET} q_t^{ET} \left(\alpha_t^{ET} - 1\right) + \tau k P_{f,t}^{AT} \left(q_t^{ET} + 1\right)}{P_{b,t}^{ET} q_t^{ET} \left(\gamma + 2\right) \left(\alpha_t^{ET} - 1\right)}; \\
f_{l,t}^{ET*} &= \frac{m_t^{ET} q_t^{ET} \left(\alpha_t^{ET} - 1\right) + \tau k P_{f,t}^{AT} \left(q_t^{ET} + 1\right)}{\tau P_{f,t}^{AT} q_t^{ET} \left(\gamma + 2\right) \left(\alpha_t^{ET} - 1\right)}; \\
e_{l,t}^{ET*} &= \frac{\gamma m_t^{ET} q_t^{ET} \left(\alpha_t^{ET} - 1\right) - 2\tau k P_{f,t}^{AT} \left(q_t^{ET} + 1\right)}{\tau k P_{f,t}^{AT} q_t^{ET} \left(\gamma + 2\right) \left(\alpha_t^{ET} - 1\right)}.
\end{aligned}
$$

For high-taste individuals, maximizing the utility function in Eq. (2.22) subject to the budget constraint in Eq. (2.24) leads to the interior solutions

$$
\begin{aligned}
b_{h,t}^{ET*} &= \frac{m_t^{ET} q_t^{ET} \left(\alpha_t^{ET} - 1\right) + \tau k P_{f,t}^{AT} \left(q_t^{ET} + 1\right)}{P_{b,t}^{ET} q_t^{ET} \left(\alpha_t^{ET} - 1\right) \left(\gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right)}; \\
f_{h,t}^{ET*} &= \frac{\alpha_t^{ET} \left[m_t^{ET} q_t^{ET} \left(\alpha_t^{ET} - 1\right) + \tau k P_{f,t}^{AT} \left(q_t^{ET} + 1\right)\right]}{\tau P_{f,t}^{AT} q_t^{ET} \left(\alpha_t^{ET} - 1\right) \left(\gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right)}; \\
e_{h,t}^{ET*} &= \frac{\gamma m_t^{ET} q_t^{ET} \alpha_t^{ET} \left(\alpha_t^{ET} - 1\right) - \tau k P_{f,t}^{AT} \left(\alpha_t^{ET} + 1\right) \left(q_t^{ET} + 1\right)}{\tau k P_{f,t}^{AT} q_t^{ET} \left(\alpha_t^{ET} - 1\right) \left(\gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right)}.
\end{aligned}
$$

B.2.3 Proof of Proposition 1'

In the following, the trade equilibrium is derived from the global market clearing of fancy goods. The interior solutions to the European consumer problems solved in Appendix B.2.2 express the aggregate consumption of fancy goods in Europe as

$$
\begin{aligned}
D_{f,t}^{ET} &= q_t^{ET} \left(f_{h,t}^{ET*} + k \cdot e_{h,t}^{ET*}\right) + \left(1 - q_t^{ET}\right) \left(f_{l,t}^{ET*} + k \cdot e_{l,t}^{ET*}\right) \\
&= \frac{m_t^{ET} q_t^{ET} (\gamma+1) \left(\alpha_t^{ET} - 1\right) \left[q_t^{ET} \left(\alpha_t^{ET} - 1\right) + \gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right] + \tau k P_{f,t}^{AT} \left(q_t^{ET} + 1\right) \left[q_t^{ET} (\gamma+1) \left(\alpha_t^{ET} - 1\right) - \alpha_t^{ET} (\gamma+1) - 1\right]}{\tau P_{f,t}^{AT} q_t^{ET} (\gamma+2) \left(\gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right) \left(\alpha_t^{ET} - 1\right)}.
\end{aligned}
$$

The income m_t^{ET} in Eq. (2.19) is based on $P_{b,t}^{ET}$ in Eq. (B.1) with the condition $n_{f,t}^{ET} = 0$ in the trade equilibrium. Using $P_{f,t}^{AT}$ in Eq. (2.31) and $n_{f,t}^{AT*}$ in Eq. (2.33), the aggregate consumption of fancy goods in Europe is

$$D_{f,t}^{ET} = \frac{\frac{\alpha^A SF^A(\gamma+1)\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]}{\tau\left(\alpha^A Sn_{s,t}^{ET}+2\tau\right)} + \frac{k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]}{q_t^{ET}\left(\alpha_t^{ET}-1\right)}}{(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)}.$$

On the supply side, using $n_{f,t}^{AT*}$ in Eq. (2.33), the amount of fancy goods supplied in the European market is

$$\frac{Y_{f,t}^{AT} - f_t^{AT*}}{\tau} = \frac{F^A n_{f,t}^{AT*} - \frac{\tau P_{s,t}^{ET}}{\alpha^A P_{f,t}^{AT}}}{\tau} = \frac{\alpha^A SF^A n_{s,t}^{ET}}{\tau\left(\alpha^A Sn_{s,t}^{ET}+2\tau\right)}.$$

With the market clearing condition $D_{f,t}^{ET} = \frac{Y_{f,t}^{AT}-f_t^{AT*}}{\tau}$, the equilibrium share of labor in the silver sector is

$$\begin{aligned} n_{s,t}^{ET*} &= \frac{\alpha^A SF^A q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]+2\tau^2 k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]}{\alpha^A S\left\{F^A q_t^{ET}(\gamma+2)\left(\alpha_t^{ET}-1\right)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)-\tau k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]\right\}} \\ &= N_s^{ET}\left(\alpha_t^{ET},\ q_t^{ET}\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right). \end{aligned}$$

To prove $\frac{\partial n_{s,t}^{ET*}}{\partial \alpha_t^{ET}} > 0$.

$$\frac{\partial n_{s,t}^{ET*}}{\partial \alpha_t^{ET}} = \frac{F^A q_T^{ET}\left\{\alpha^A SF^A q_t^{ET2}(\gamma+1)(\gamma+2)^2\left(\alpha_t^{ET}-1\right)^2+\tau k\left(q_t^{ET}+1\right)\left[\alpha^A S(\gamma+1)(A+B)+2\tau(C+D)(\gamma+2)\right]\right\}}{\alpha^A S\left\{F^A q_t^{ET}(\gamma+2)\left(\alpha_t^{ET}-1\right)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)-\tau k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]\right\}^2}$$

with

$$\begin{aligned} A &= \left(1-q_t^{ET2}\right)\left[\alpha_t^{ET2}(\gamma+1)\left(q_t^{ET}+\gamma+1\right)+q_t^{ET}+1\right]; \\ B &= q_t^{ET}\left(\alpha_t^{ET}-1\right)\left[\gamma\left(q_t^{ET}+\gamma+3\right)+4\right]+\alpha_t^{ET}q_t^{ET}\left[q_t^{ET}(\gamma+2)+\gamma^2+\gamma\right]+2\alpha_t^{ET}(\gamma+1); \\ C &= \left(1-q_t^{ET}\right)\left[\alpha_t^{ET2}(\gamma+1)^2+1\right]+\gamma q_t^{ET}(\gamma+2)\left(\alpha_t^{ET}-1\right); \\ D &= \alpha_t^{ET}\left\{q_t^{ET}\left[\gamma(\gamma+2)+2\right]+2(\gamma+1)\right\}. \end{aligned}$$

In this case, $\alpha_t^{ET} > 1$, $0 < q_t^{ET} < 1$, $\tau > 1$, $\gamma > 0$, $\alpha^A > 0$, $k > 0$, $S > 0$, and $F^A > 0$ hold. Thus, $A > 0$, $B > 0$, $C > 0$, and $D > 0$ hold, resulting in $\frac{\partial n_{s,t}^{ET*}}{\partial \alpha_t^{ET}} > 0$.

To prove $\frac{\partial n_{s,t}^{ET*}}{\partial q_t^{ET}} > 0$.

$$\frac{\partial n_{s,t}^{ET*}}{\partial q_t^{ET}} = \frac{F^A\left(\alpha_t^{ET}-1\right)\left\{\alpha^A SF^A q_t^{ET2}(\gamma+1)(\gamma+2)\left(\alpha_t^{ET}-1\right)^2\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)+\tau k\left[\alpha^A SA(\gamma+1)+2\tau B(\gamma+2)\right]\right\}}{\alpha^A S\left\{F^A q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)-\tau k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]\right\}^2}$$

with

$$A = q_t^{ET}\left(\alpha_t^{ET}-1\right)\left\{q_t^{ET}\left[\alpha_t^{ET}(\gamma+1)^2+2\gamma+3\right]+2\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right\};$$
$$B = 2\left(\gamma\alpha_T^{ET}+\alpha_t^{ET}+1\right)^2+q_t^{ET2}(\gamma+1)\left(\alpha_t^{ET}-1\right)\left(\gamma\alpha_T^{ET}+\alpha_t^{ET}+1\right).$$

In this case, $\alpha_t^{ET} > 1$, $0 < q_t^{ET} < 1$, $\tau > 1$, $\gamma > 0$, $\alpha^A > 0$, $k > 0$, $S > 0$, and $F^A > 0$ hold. Thus, $A > 0$ and $B > 0$ hold, resulting in $\frac{\partial n_{s,t}^{ET*}}{\partial q_t^{ET}} > 0$.

B.2.4 Proof of Proposition 2'

The derivation of the taste transmission process in the trade equilibrium is similar to the proof of Proposition 2 in Appendix A.3. The share of high-taste individuals of the generation $t+1$ is

$$\begin{aligned} q_{t+1}^{ET} &= q_t^{ET}\cdot\mathbb{P}_{h,t}^{ET}+\left(1-q_t^{ET}\right)\mathbb{P}_{l,t}^{ET} \\ &= q_t^{ET}\cdot\frac{q_t^{ET}}{q_t^{ET}+1}\cdot e_{h,t}^{ET}+\left(1-q_t^{ET}\right)\frac{q_t^{ET}}{q_t^{ET}+1}\cdot e_{l,t}^{ET}. \end{aligned}$$

The optimal cultivation effort $e_{l,t}^{ET*}$ and $e_{h,t}^{ET*}$ is solved in Appendix B.2.2, leading to

$$q_{t+1}^{ET} = \frac{\gamma m_t^{ET} q_t^{ET}\left(\alpha_t^{ET}-1\right)\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]+\tau kP_{f,t}^{AT}\left(q_t^{ET}+1\right)\left[\gamma q_t^{ET}\left(\alpha_t^{ET}-1\right)-2\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right]}{\tau kP_{f,t}^{ET}(\gamma+2)\left(\alpha_t^{ET}-1\right)\left(q_t^{ET}+1\right)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)}.$$

Moreover, using m_t^{ET}, $P_{f,t}^{AT}$, and $n_{f,t}^{AT*}$ as in Appendix B.2.3, the share of high taste individuals of generation $t+1$ is

$$q_{t+1}^{ET} = \frac{\frac{\gamma\alpha^A SF^A q_t^{ET}\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]}{\tau k\left(q_t^{ET}+1\right)\left(\alpha^A Sn_{s,t}^{ET}+2\tau\right)}+\frac{\gamma q_t^{ET}\left(\alpha_t^{ET}-1\right)-2\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)}{\alpha_t^{ET}-1}}{(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)}.$$

With the trade equilibrium $n_{s,t}^{ET*}$ in Eq. (2.34), q_{t+1}^{ET} only depends on q_t^{ET} and α_t^{ET}:

$$q_{t+1}^{ET} = \frac{\gamma F^A q_t^{ET} X\left(\alpha_t^{ET}-1\right) - \tau k\left(q_t^{ET}+1\right)\left\{X + 2\tau\left[\alpha_t^{ET}\left(2\gamma - \gamma q_t^{ET}+2\right)\right]\right\}}{\tau k\left(\alpha_t^{ET}-1\right)\left(q_t^{ET}+1\right)\left\{X(\gamma+1)+2\tau(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right\}}$$
$$= Q^{ET}\left(\alpha_t^{ET},\ q_t^{ET}\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right)$$

with $X = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]$.

To prove $\frac{\partial q_{t+1}^{ET}}{\partial \alpha_t^{ET}} > 0$.

$$\frac{\partial q_{t+1}^{ET}}{\partial \alpha_t^{ET}} = \frac{2\gamma\alpha^A S F^A q_t^{ET^2}(\gamma+2)^2\left(\alpha_t^{ET}-1\right)^2 + k\left(q_t^{ET}+1\right)\left[X^2(\gamma+1)+2\tau\alpha^A S(A+B+C+D)+4\tau^2 E(\gamma+2)\right]}{k\left(\alpha_t^{ET}-1\right)^2\left(q_t^{ET}+1\right)\left[X(\gamma+1)+2\tau\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right]^2}$$

with $X = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]$ and

$$A = \left(1-q_t^{ET}\right)\left[\gamma\alpha_t^{ET^2}\left(\gamma q_t^{ET}+q_t^{ET}+\gamma^2\right)+3\gamma+4\right];$$
$$B = \gamma q_t^{ET}\left(\alpha_t^{ET}-1\right)\left[\gamma\left(q_t^{ET}+2\right)+3\alpha_t^{ET}+q_t^{ET}+\gamma^2+1\right];$$
$$C = \gamma^2\left(\alpha_t^{ET}-q_t^{ET}\right)+\gamma\alpha_t^{ET}\left[q_t^{ET}\left(\gamma q_t^{ET}+q_t^{ET}+\gamma^2\right)+5\gamma+14\right];$$
$$D = \alpha_t^{ET^2}\left[2q_t^{ET}(\gamma+2)+2\gamma^2(\gamma+5)+11\gamma+4\right]+8\alpha_t^{ET};$$
$$E = (\gamma+1)\left\{\alpha_t^{ET}\left[\alpha_t^{ET}(\gamma+2)+\gamma q_t^{ET}+4\right]+\gamma\alpha_t^{ET^2}\left(1-q_t^{ET}\right)+\gamma q_t^{ET}\left(\alpha_t^{ET}-1\right)\right\}+2.$$

In this case, $\alpha_t^{ET} > 1$, $0 < q_t^{ET} < 1$, $\tau > 1$, $\gamma > 0$, $\alpha^A > 0$, $k > 0$, $S > 0$, and $F^A > 0$ hold. Thus, $A > 0$, $B > 0$, $C > 0$, $D > 0$, and $E > 0$ hold, resulting in $\frac{\partial q_{t+1}^{ET}}{\partial \alpha_t^{ET}} > 0$.

To prove $\frac{\partial q_{t+1}^{ET}}{\partial q_t^{ET}} > 0$.

$$\frac{\partial q_{t+1}^{ET}}{\partial q_t^{ET}} = \frac{2\tau^2\gamma k(\gamma+2)\left(\alpha^A S+2\tau\right)\left(q_t^{ET}+1\right)^2\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)+\gamma\alpha^A S F^A(A+B)}{\tau k\left(q_t^{ET}+1\right)^2\left[X(\gamma+1)+2\tau(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right]^2}$$

with $X = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]$ and

$$A = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]^2;$$
$$B = 2\tau(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)\left(q_t^{ET}+2\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right].$$

In this case, $\alpha_t^{ET} > 1$, $0 < q_t^{ET} < 1$, $\tau > 1$, $\gamma > 0$, $\alpha^A > 0$, $k > 0$, $S > 0$, and $F^A > 0$ hold. Thus, $A > 0$ and $B > 0$ hold, resulting in $\frac{\partial q_{t+1}^{ET}}{\partial q_t^{ET}} > 0$.

To prove $\frac{\partial^2 q_{t+1}^{ET}}{\partial q_t^{ET^2}} < 0$.

$$\frac{\partial^2 q_{t+1}^{ET}}{\partial q_t^{ET^2}} = -\frac{2\gamma\alpha^A S\left\{A+F^A\left[B+2\tau\alpha^A SC(\gamma+1)(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)+4\tau^2(\gamma+2)^2\left(\gamma\alpha_t^{ET}+2\right)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)^2\right]\right\}}{\tau k\left(q_t^{ET}+1\right)^3\left[X(\gamma+1)+2\tau(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right]^3}$$

with $X = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]$ and

$$\begin{aligned}
A &= 2\tau^2 k\left(\gamma+1\right)\left(\gamma+2\right)\left(\alpha^A S+2\tau\right)\left(\alpha_t^{ET}-1\right)\left(q_t^{ET}+1\right)^3\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right);\\
B &= \alpha^{A^2} S^2\left(\gamma+1\right)^2\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]^3;\\
C &= q_t^{ET^2}\left(\alpha_t^{ET}-1\right)\left(q_t^{ET}+3\right)+\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\left[3q_t^{ET}\left(\alpha_t^{ET}-1\right)+2\gamma\alpha_t^{ET}+\alpha_t^{ET}+3\right].
\end{aligned}$$

In this case, $\alpha_t^{ET} > 1$, $0 < q_t^{ET} < 1$, $\tau > 1$, $\gamma > 0$, $\alpha^A > 0$, $k > 0$, $S > 0$, and $F^A > 0$ hold. Thus, $A > 0$, $B > 0$, and $C > 0$ hold, resulting in $\frac{\partial^2 q_{t+1}^{ET}}{\partial q_t^{ET^2}} < 0$.

B.2.5 Upper Bound $\overline{\alpha^{ET}}$ in Intercontinental Trade

Appendix A.4 derives the upper bound $\overline{\alpha}$ in the autarky equilibrium as the value of α_t that leads to an intersection between the difference equation Eq. (1.12) and the 45° line at (1, 1). The upper bound $\overline{\alpha^{ET}}$ in the trade equilibrium is defined in the same way. According to Appendix B.2.4, the difference equation in Eq. (2.35) is

$$\begin{aligned}
q_{t+1}^{ET} &= \frac{\gamma F^A q_t^{ET} X\left(\alpha_t^{ET}-1\right)-\tau k\left(q_t^{ET}+1\right)\left\{X+2\tau\left[\alpha_t^{ET}\left(2\gamma-\gamma q_t^{ET}+2\right)\right]\right\}}{\tau k\left(q_t^{ET}+1\right)\left(\alpha_t^{ET}-1\right)\left\{X\left(\gamma+1\right)+2\tau\left(\gamma+2\right)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right\}}\\
&= Q^{ET}\left(\alpha_t^{ET},\ q_t^{ET}\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right)
\end{aligned}$$

with $X = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]$. The condition $q_{t+1}^{ET} = q_t^{ET} = 1$ yields the upper bound

$$\overline{\alpha^{ET}} = 1+\frac{2\tau k\left(\alpha^A S+4\tau\right)}{\gamma\alpha^A SF^A-2\tau k\left(\gamma+1\right)\left(\alpha^A S+2\tau\right)}. \tag{B.5}$$

B.3 Comparison: European Economy in Autarky and Intercontinental Trade

B.3.1 Proof of Proposition 5

In the trade equilibrium, $n_{s,t}^{ET*}$ in Eq. (2.34) must meet the condition for trade from Proposition 4:

$$\frac{\alpha^A S F^A q_t(\gamma+1)(\alpha_t-1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_t+1]+2\tau^2 k(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]}{\alpha^A S\{F^A q_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)-\tau k(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]\}} \leq \frac{F^A}{\tau F} - \frac{2\tau}{\alpha^A S},$$

where the variables α_t^{ET} and q_t^{ET} in the trade model are replace with α_t and q_t in the autarky model for the comparison. This condition can be rearranged into

$$F \leq \frac{\alpha^A S\left\{F^A q_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)-\tau k(q_t+1)[q_t(\gamma+1)(\alpha_t+1)-\alpha_t(\gamma+1)-1]\right\}}{\tau q_t(\alpha_t-1)\{\alpha^A S(\gamma+1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_1+1]+2\tau(\gamma+2)(\gamma\alpha_t+\alpha_t+1)\}} .$$

The function F_t^{ET} in Eq. (2.39) is defined as

$$F_t^{ET} = \frac{\alpha^A S\left\{F^A q_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)-\tau k(q_t+1)[q_t(\gamma+1)(\alpha_t+1)-\alpha_t(\gamma+1)-1]\right\}}{\tau q_t(\alpha_t-1)\{\alpha^A S(\gamma+1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_1+1]+2\tau(\gamma+2)(\gamma\alpha_t+\alpha_t+1)\}} .$$

To prove Eq. (2.40): $\boldsymbol{N_s^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) = N_f\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right)}$**.** The autarky equilibrium $n_{f,t}{}^*$ in Eq. (1.11) equals the trade equilibrium $n_{s,t}^{ET*}$ in Eq. (2.34), by replacing the parameter F of $n_{f,t}{}^*$ with F_t^{ET} defined in Eq. (2.39):

$$\begin{aligned}
n_{f,t}{}^* &= N_f\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right)\\
&= \frac{F_t^{ET} q_t(\gamma+1)(\alpha_t-1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_t+1]+k(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]}{F_t^{ET} q_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)}\\
&= \frac{\alpha^A S F^A q_t(\gamma+1)(\alpha_t-1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_t+1]+2\tau^2 k(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]}{\alpha^A S\{F^A q_t(\gamma+2)(\alpha_t-1)(\gamma\alpha_t+\alpha_t+1)-\tau k(q_t+1)[q_t(\gamma+1)(\alpha_t-1)-\alpha_t(\gamma+1)-1]\}}\\
&= N_s^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) = n_{s,t}^{ET*}.
\end{aligned}$$

To prove Eq. (2.41): $\boldsymbol{Q^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) = Q\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right)}$**.** q_{t+1} in Eq. (1.12) in the autarky equilibrium equals q_{t+1}^{ET} in Eq. (2.35) in the trade equilibrium, by replacing the parameter F of q_{t+1} with F_t^{ET} defined in Eq. (2.39):

$$
\begin{aligned}
q_{t+1} &= Q\left(\alpha_t,\ q_t,\ F_t^{ET}\ ;\ \gamma,\ k\right) \\
&= \frac{\gamma F_t^{ET} q_t(\alpha_t-1)[q_t(\alpha_t-1)+\gamma\alpha_t+\alpha_t+1]+k(q_t+1)[\gamma q_t(\alpha_t-1)-2(\gamma\alpha_t+\alpha_t+1)]}{k(\gamma+2)(\alpha_t-1)(q_t+1)(\gamma\alpha_t+\alpha_t+1)} \\
&= \frac{\gamma F^A q_t X(\alpha_t-1)-\tau k(q_t+1)\{X+2\tau[\alpha_t(2\gamma-\gamma q_t+2)]\}}{\tau k(q_t+1)(\alpha_t-1)\{X(\gamma+1)+2\tau(\gamma+2)(\gamma\alpha_t+\alpha_t+1)\}} \\
&= Q^{ET}\left(\alpha_t,\ q_t\ ;\ \tau,\ \gamma,\ \alpha^A,\ k,\ S,\ F^A\right) = q_{t+1}^{ET}
\end{aligned}
$$

with $X = \alpha^A S\left[q_t\left(\alpha_t-1\right)+\gamma\alpha_t+\alpha_t+1\right]$.

To prove $\frac{\partial F_t^{ET}}{\partial \alpha_t} < 0$.

$$
\frac{\partial F_t^{ET}}{\partial \alpha_t^E} = -\frac{\alpha^A S\left\{\alpha^A S F^A {q_t}^2(\gamma+1)(\gamma+2)^2(\alpha_t-1)^2+\tau k(q_t+1)\left[\alpha^A S(\gamma+1)(A+B)+2\tau C(\gamma+2)\right]\right\}}{\tau q_t(\alpha_t-1)^2\{X(\gamma+1)+2\tau(\gamma+2)(\gamma\alpha_t+\alpha_t+1)\}^2}
$$

with $X = \alpha^A S\left[q_t\left(\alpha_t-1\right)+\gamma\alpha_t+\alpha_t+1\right]$ and

$$
\begin{aligned}
A &= (1-q_t)\left[{\alpha_t}^2(\gamma+1)(\gamma+q_t+1)+q_t+1\right]+2\alpha_t(\gamma+1)\,; \\
B &= q_t(\alpha_t-1)\left[\gamma(\gamma+q_t+3)+4\right]+q_t\left[q_t(\gamma+2)+\gamma^2+\gamma\right]; \\
C &= (1-q_t)\left[{\alpha_t}^2(\gamma+1)^2+1\right]+\gamma q_t(\gamma+2)(\alpha_t-1)+\alpha_t\left\{q_t\left[\gamma(\gamma+2)+2\right]+2(\gamma+1)\right\}.
\end{aligned}
$$

In this case, $\alpha_t > 1$, $0 < q_t < 1$, $\tau > 1$, $\gamma > 0$, $\alpha^A > 0$, $k > 0$, $S > 0$, and $F^A > 0$ hold. Thus, $A > 0$, $B > 0$, and $C > 0$ hold, resulting in $\frac{\partial F_t^{ET}}{\partial \alpha_t} < 0$.

To prove $\frac{\partial F_t^{ET}}{\partial q_t} < 0$.

$$
\frac{\partial F_t^{ET}}{\partial q_t} = -\frac{\alpha^A S\left\{\alpha^A S F^A {q_t}^2(\gamma+1)(\gamma+2)(\alpha-1)^2(\gamma\alpha_t+\alpha_t+1)+\tau k\left[\alpha^A S A(\gamma+1)+2\tau B(\gamma+2)\right]\right\}}{\tau {q_t}^2(\alpha_t-1)[X(\gamma+1)+2\tau(\gamma+1)(\gamma+2)(\gamma\alpha_t+\alpha_t+1)]^2}
$$

with $X = \alpha^A S \left[q_t \left(\alpha_t - 1\right) + \gamma\alpha_t + \alpha_t + 1\right]$ and

$$A = 2q_t \left(\alpha_t - 1\right)\left(\gamma\alpha_t + \alpha_t + 1\right) + {q_t}^2 \left(\alpha_t^{ET} - 1\right)\left[\alpha_t \left(\gamma + 1\right)^2 + 2\gamma + 3\right];$$

$$B = \left(\gamma\alpha_t + \alpha_t + 1\right)\left[{q_t}^2 \left(\alpha_t - 1\right)\left(\gamma + 1\right) + \gamma\alpha_t + \alpha_t + 1\right] + \left(\gamma\alpha_t + \alpha_t + 1\right)^2.$$

In this case, $\alpha_t > 1$, $0 < q_t < 1$, $\tau > 1$, $\gamma > 0$, $\alpha^A > 0$, $k > 0$, $S > 0$, and $F^A > 0$ hold. Thus, $A > 0$ and $B > 0$ hold, resulting in $\frac{\partial F_t^{ET}}{\partial q_t} < 0$.

B.3.2 Proof of $\overline{\alpha} = \overline{\alpha^{ET}}$

With the upper bound $\overline{\alpha^{ET}}$ in Eq. (B.5) and $q_t^{ET} = 1$, the upper bound of $n_{s,t}^{ET*}$ is derived as

$$\overline{n_{s,t}^{ET*}} = \frac{\gamma\alpha^A S F^A + 4k\tau^2 \left(\gamma + 1\right)}{2\alpha^A S \left[\gamma F^A - \tau k \left(\gamma + 1\right)\right]}.$$

The condition $\overline{n_s^{ET*}} = \frac{F^A}{\tau F} - \frac{2\tau}{\alpha^A S}$ from Assumption 2 leads to

$$F = \frac{2\alpha^A S \left[\gamma F^A - \tau k \left(\gamma + 1\right)\right]}{\tau\gamma \left(\alpha^A S + 4\tau\right)}.$$

Therefore, $\overline{\alpha}$ in Eq. (A.4) is

$$\begin{aligned}\overline{\alpha} &= 1 + \frac{4k}{\gamma F - 2k \left(\gamma + 1\right)}\\ &= 1 + \frac{2\tau k \left(\alpha^A S + 4\tau\right)}{\gamma\alpha^A S F^A - 2\tau k \left(\gamma + 1\right)\left(\alpha^A S + 2\tau\right)}\\ &= \overline{\alpha^{ET}}.\end{aligned}$$

B.3.3 Comparative Statics $\frac{\partial {n_{f,t}}^*}{\partial F}$ and $\frac{\partial q_{t+1}}{\partial F}$

To prove $\frac{\partial {n_{f,t}}^*}{\partial F} > 0$. Appendix A.2 derives ${n_{f,t}}^*$ in the autarky equilibrium. The first-order derivative of ${n_{f,t}}^*$ with respect to F:

$$\frac{\partial {n_{f,t}}^*}{\partial F} = \frac{k \left(q_t + 1\right)\left[\alpha_t \left(\gamma + 1\right)\left(1 - q_t\right) + q_t \left(\gamma + 1\right) + 1\right]}{F^2 q_t \left(\gamma + 2\right)\left(\alpha_t - 1\right)\left(\gamma\alpha_t + \alpha_t + 1\right)} > 0,$$

holds because of $\alpha_t > 1$, $0 < q_t < 1$, $\gamma > 0$, $k > 0$, and $F > 0$.

To prove $\frac{\partial q_{t+1}}{\partial F} > 0$. Appendix A.3 derives q_{t+1} in the autarky equilibrium. The first-order derivative of q_{t+1} with respect to F:

$$\frac{\partial q_{t+1}}{\partial F} = \frac{\gamma q_t \left[q_t \left(\alpha_t - 1\right) + \gamma \alpha_t + \alpha_t + 1\right]}{k \left(1 - q_t\right) \left(\gamma + 2\right) \left(\alpha_t - 1\right) \left(\gamma \alpha_t + \alpha_t + 1\right)} > 0$$

holds because of $\alpha_t > 1$, $0 < q_t < 1$, $\gamma > 0$, $k > 0$, and $F > 0$.

B.4 Proof of Proposition 6

For generation t, the taste variables q_t^{ET} and α_t^{ET} have already been formed by generation $t-1$. Thus, the aggregate demand should remain the same as in the trade equilibrium.

In the basic-good sector, the aggregate demand follows the interior solutions $b_{l,t}^{ET*}$ and $b_{h,t}^{ET*}$ derived in Appendix B.2.2:

$$\begin{aligned} D_{b,t}^{EG} = D_{b,t}^{ET} &= q_t^{ET} b_{h,t}^{ET*} + \left(1 - q_t^{ET}\right) b_{l,t}^{ET*} \\ &= \frac{\left[m_t^{ET} q_t^{ET} \left(\alpha_t^{ET} - 1\right) + \tau k P_{f,t}^{AT} \left(q_t^{ET} + 1\right)\right] \left[\alpha_t^{ET} \left(\gamma + 1\right) - q_t^{ET} \left(\gamma + 1\right) \left(\alpha_t^{ET} - 1\right) + 1\right]}{P_{b,t}^{ET} q_t^{ET} \left(\gamma + 2\right) \left(\alpha_t^{ET} - 1\right) \left(\gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right)}. \end{aligned}$$

Based on the equilibrium $n_{s,t}^{ET*}$ in Eq. (2.34), the aggregate demand for basic goods is

$$D_{b,t}^{EG} = B \left(1 - \frac{X F^A q_t^{ET} (\gamma+1) \left(\alpha_t^{ET} - 1\right) + 2\tau^2 k \left(q_t^{ET} + 1\right) \left[q_t^{ET} (\gamma+1) \left(\alpha_t^{ET} - 1\right) - \alpha_t^{ET} (\gamma+1) - 1\right]}{\alpha^A S \left\{F^A q_t^{ET} (\gamma+2) \left(\alpha_t^{ET} - 1\right) \left(\gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right) - \tau k \left(q_t^{ET} + 1\right) \left[q_t^{ET} (\gamma+1) \left(\alpha_t^{ET} - 1\right) - \alpha_t^{ET} (\gamma+1) - 1\right]\right\}}\right)^{\beta}$$

with $X = \alpha^A S \left[q_t^{ET} \left(\alpha_t^{ET} - 1\right) + \gamma \alpha_t^{ET} + \alpha_t^{ET} + 1\right]$. The aggregate supply $Y_{b,t}^{EG} = B {n_{b,t}^{EG}}^{\beta}$ needs to satisfy the demand $D_{b,t}^{EG}$, so the required share of labor in the basic-good sector is

$$n_{b,t}^{EG*} = 1 - n_{s,t}^{ET*}$$

where $n_{s,t}^{EG*}$ is the equilibrium share of labor in the silver sector in Eq. (2.34). Therefore, the amount of labor needed in the basic-good sector does not change when trade stops.

In the fancy-good sector, the aggregate demand $D_{f,t}^{EG} = D_{f,t}^{ET}$ is already derived in

Appendix B.2.2 as

$$D_{f,t}^{EG} = D_{f,t}^{ET} = q_t^{ET}\left(f_{h,t}^{ET*} + ke_{h,t}^{ET*}\right) + \left(1 - q_t^{ET}\right)\left(f_{l,t}^{ET*} + ke_{l,t}^{ET*}\right)$$
$$= \frac{\frac{\alpha^A S F^A(\gamma+1)\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]}{\tau\left(\alpha^A S n_{s,t}^{ET}+2\tau\right)} + \frac{k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]}{q_t^{ET}\left(\alpha_t^{ET}-1\right)}}{(\gamma+2)\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)}.$$

With $n_{s,t}^{ET*}$ in Eq. (2.34), the aggregate demand for fancy goods is

$$D_{f,t}^{EG} = \frac{XF^A q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)+2\tau^2 k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]}{\tau q_t^{ET}\left(\alpha_t^{ET}-1\right)\left\{X(\gamma+1)+2\tau\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right]\}}$$

with $X = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]$. The European local production of fancy-goods $Y_{f,t}^{EG\text{net}} = Fn_{f,t}^{EG}$ leads to the required share of labor in the fancy-good sector:[1]

$$n_{f,t}^{EG*} = \frac{XF^A q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)+2\tau^2 k\left(q_t^{ET}+1\right)\left[q_t^{ET}(\gamma+1)\left(\alpha_t^{ET}-1\right)-\alpha_t^{ET}(\gamma+1)-1\right]}{\tau F q_t^{ET}\left(\alpha_t^{ET}-1\right)\left\{X(\gamma+1)+2\tau\left(\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right)\right]\}}$$

with $X = \alpha^A S\left[q_t^{ET}\left(\alpha_t^{ET}-1\right)+\gamma\alpha_t^{ET}+\alpha_t^{ET}+1\right]$.

The basic-good sector requires the amount of labor $n_{b,t}^{EG*} = 1 - n_{s,t}^{ET*}$, so $n_{s,t}^{ET*}$ is left to produce fancy goods, which is exactly the labor released from the silver sector when trade stops. Using the condition $F \leq F_t^{ET}$ in Eq. (2.39), it must hold that

$$n_{f,t}^{EG*} \geq n_{s,t}^{ET*}.$$

The case $n_{f,t}^{EG*} = n_{s,t}^{ET*}$ happens at the upper bound $\overline{n_s^{ET*}} = \frac{F^A}{\tau F} - \frac{2\tau}{\alpha^A S}$ based on Assumption 2, but the economy is still far from the upper bound when trade stops. Therefore, the labor released from the silver sector can not produce enough fancy goods when trade stops because of the higher taste resulting from trade. In other words, only when the productivity F increases to F_t^{ET}, Europeans can produce the amount of fancy goods consumed in the trade equilibrium.

[1] At this moment, growth has not started, so the productivity in the fancy-good sector is still F instead of F_t^{EG}.

B.5 Summary Information on the Calibration of Parameters

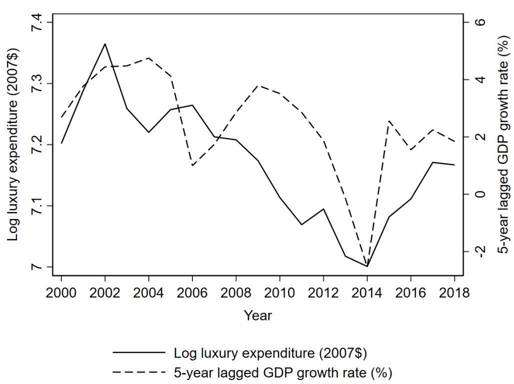
Table B.1: *Summary Information on the Calibration of Parameters*

Parameters set exogeneously	Value	Target
Starting year of trade	1580	History (see Section 2.2 for details)
Starting year of growth	1820	History (see Section 2.2 for details)
Length of one generation	20 years	Cervellati and Sunde (2015)
β	0.6	Normal value for decreasing returns in the production
γ	9	Parameter for altruism from Cervellati and Sunde (2015)
λ	0.95	Transition of taste (consumer revolution) starting from 1600
τ	1.1	Normal value of the iceberg trade cost
B, F, S, B^A	15	Initial TFP from Cervellati and Sunde (2015)
F^A	20	Asian advantage in the fancy-good sector
$\underline{q}$	0.05	Rational value of the lower bound
η	5	Rational value (see text for details)
Parameters solved endogenously	Value	Target
k	6.45	Derived from Eq. (A.3)
$\underline{\alpha}$	1.19	Derived from Eq. (A.4)
$\overline{\alpha}$	5.30	Derived from Eq. (A.2)
$\overline{\alpha^{ET}}$	5.30	$\overline{\alpha^{ET}} = \overline{\alpha}$ based on Eq. (2.42)
$\overline{\alpha^{EG}}$	5.30	$\overline{\alpha^{EG}} = \overline{\alpha}$ based on Assumption 3
α^A	0.63	Derived from Eq. (B.5)
δ	3.41	Real GDP in 1820 (data from the Maddison Project Database 2018)
θ	0.26	Average growth of GDP per capita 1995–2010 (data from the Maddison Project Database 2018)
Initial conditions	Value	Target
q_0	0.1	Larger than the lower bound $\underline{q} = 0.05$
α_0	1.5	The initial equilibrium ${n_{f,0}}^*$ is positive

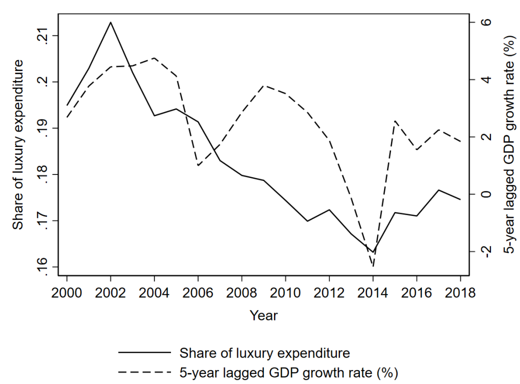
Appendix C

Appendix to Chapter 3

C.1 Additional Figures and Tables



(a) Log Level

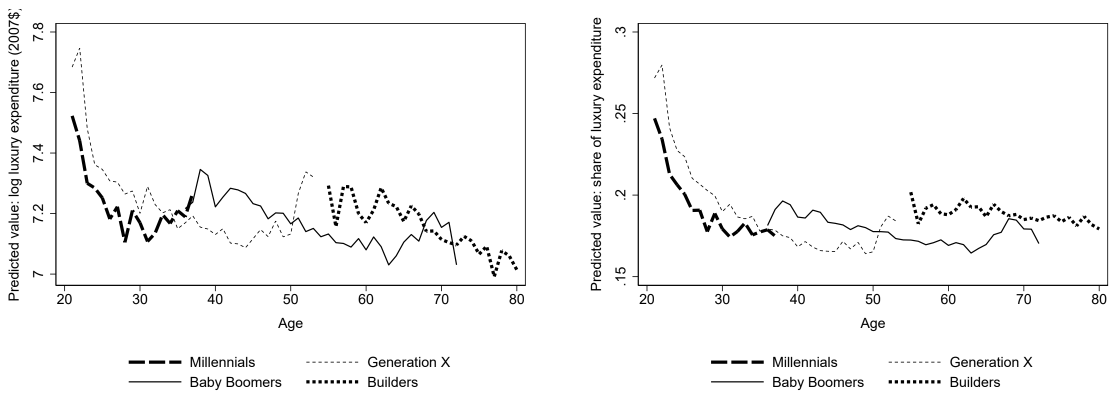


(b) Share

Figure C.1: *Luxury Expenditure and 5-year Lagged GDP Growth Rate*

Notes: Both figures show the 5-year lagged GDP growth rates and average luxury expenditure over the sample period. Figure C.1(a) shows the log level of luxury expenditure level, and Figure C.1(b) shows the share of luxury expenditure.

Sources: Own illustration of data from the World Bank and the Consumer Expenditure Survey (CE) 2000–2018

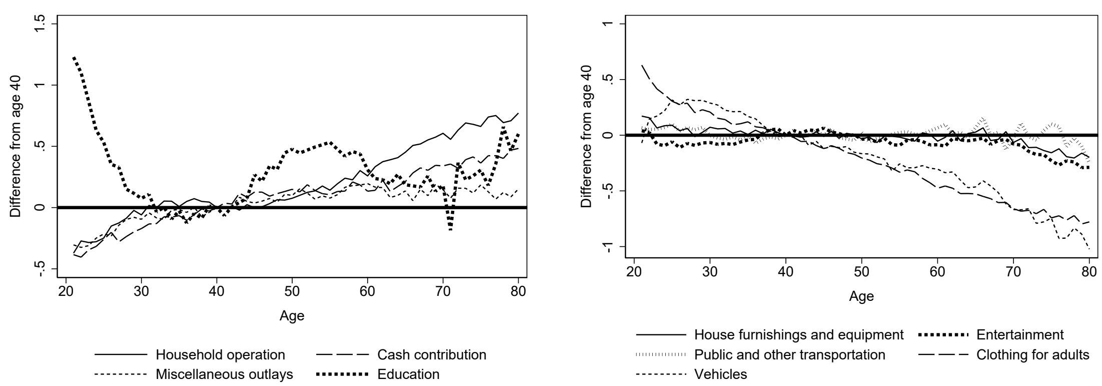


(a) Log Level

(b) Share

Figure C.2: *Heterogeneous Effects: Predicted Generation Specific Luxury Expenditure by Age*

Notes: All values are in US 2007 dollars. Both figures plot predicted means at each age from 21 to 80 for every generation using the estimated coefficients on age dummies in Eq. (3.2). Figure C.2(a) shows the log level of luxury expenditure, and Figure C.2(b) shows the share of luxury expenditure. Predictions are always conducted using the whole data set to pin down pure age and generation effects conditional on all other controls.



(a) Specific Categories I

(b) Specific Categories II

Figure C.3: *Specific Categories: Age Effect on Luxury Expenditure*

Notes: Both figure show the estimated coefficients on age dummies based on the preferred model in Eq. (3.1), with log level of expenditure of different luxury categories being dependent variables. Coefficients are relative to the horizontal zero lines, which correspond to the reference age 40.

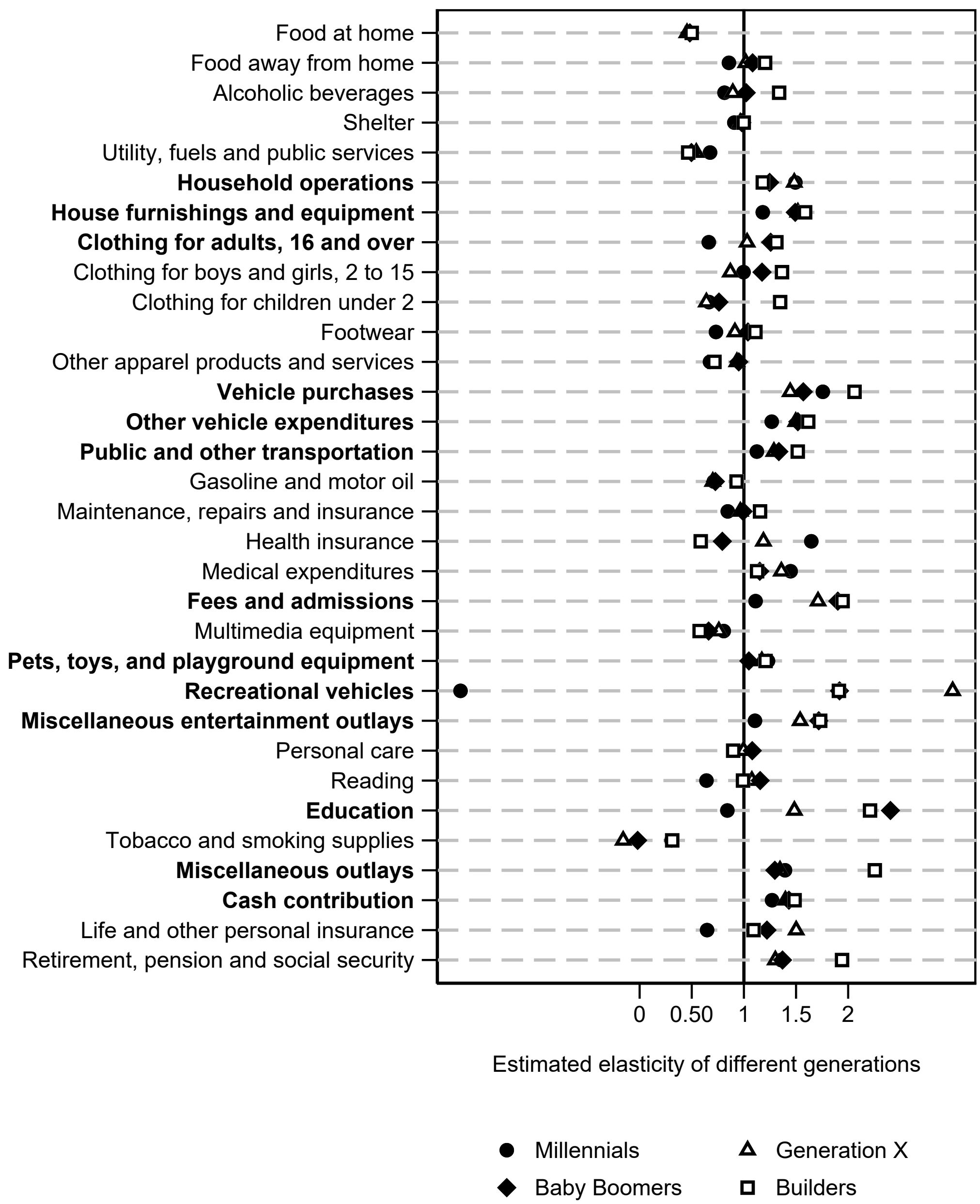
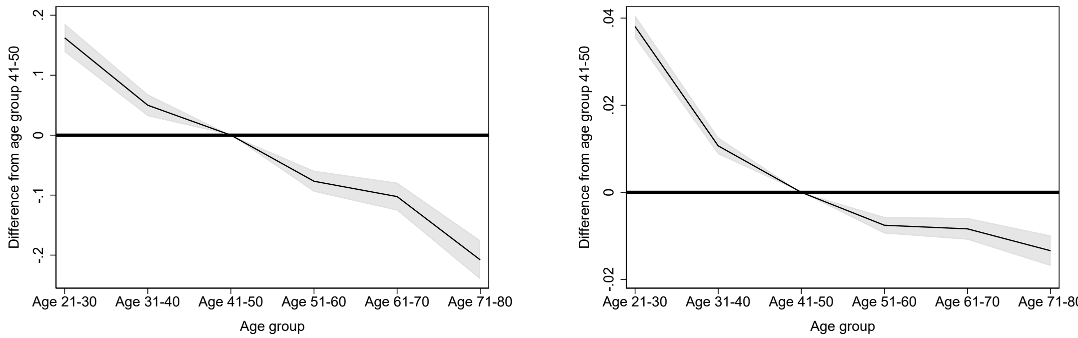


Figure C.4: *Generation Specific Total Expenditure Elasticity*

Notes: This figure reports how different generations classify the 32 expenditure categories into luxury and necessity, and the 13 categories that are classified as luxury by the overall sample households in the main specification are boldfaced. Estimations are only conduct for the whole sample period 2000–2018 using the sample of each generation. *Health insurance*, *life and other personal insurance*, and *retirement, pensions, social security* are dropped from the luxury categories here as they belong to the consumption transferred into the future, as described in Section 3.3.

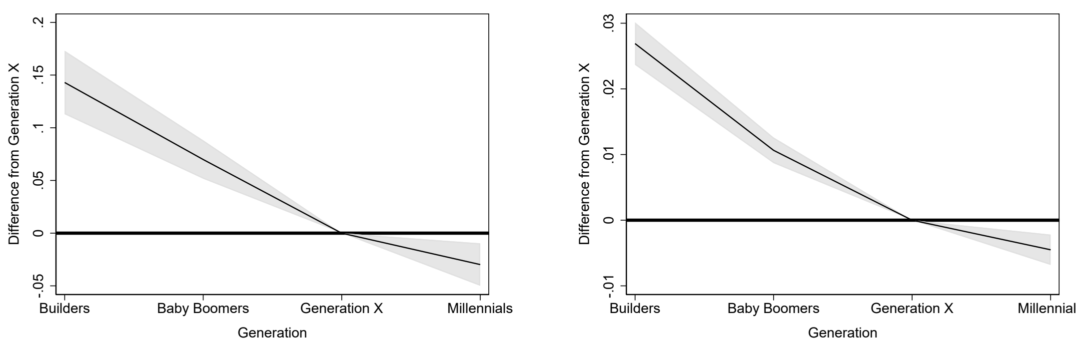


(a) Log Level

(b) Share

Figure C.5: *Controlling for Age Group: Age Effect on Luxury Expenditure*

Notes: Both figures show the estimated coefficients on age group dummies, including 95% confidence intervals. Figure C.5(a) shows the effect on log level of luxury expenditure, and Figure C.5(b) shows the effect on share of luxury expenditure. Coefficients are relative to the horizontal zero lines, which correspond to the reference age group 41–50.



(a) Log Level

(b) Share

Figure C.6: *Controlling for Age Group: Generation Effect on Luxury Expenditure*

Notes: Both figures show the estimated coefficients on generation dummies, including 95% confidence intervals. Figure C.6(a) shows the effect on the log level of luxury expenditure, and Figure C.6(b) shows the effect on the share of luxury expenditure. Coefficients are relative to the horizontal zero lines, which correspond to the reference Generation X.

Table C.1: *Historic Events by Generation*

Millennials	Ranking	Frequency
Sept. 11	1	86%
Obama election	2	47%
Iraq/Afghanistan wars	3	24%
Gay marriage	4	19%
The tech revolution	5	18%
Orlando shooting	6	17%
Hurricane Katrina	7	11%
Columbine shooting	8	10%
Bin Laden	9	10%
Sandy Hook	10	7%
Generation X	Ranking	Frequency
Sept. 11	1	79%
Obama election	2	40%
Fall of Berlin Wall/End of Cold War	3	21%
The tech revolution	4	20%
Iraq/Afghanistan wars	5	18%
Gulf War	6	15%
Challenger disaster	7	14%
Gay marriage	8	10%
Hurricane Katrina	9	10%
Columbine shooting	10	9%
Baby Boomers	Ranking	Frequency
Sept. 11	1	70%
JFK assassination	2	45%
Vietnam War	3	41%
Obama election	4	38%
Moon landing	5	35%
The tech revolution	6	26%
Civil rights movement	7	18%
Fall of Berlin Wall/End of Cold War	8	16%
MLK assassination	9	15%
Iraq/Afghanistan wars	10	11%
The Silent Generation	Ranking	Frequency
Sept. 11	1	59%
WWII	2	44%
JFK assassination	3	41%
Vietnam War	4	37%
Moon landing	5	29%
Obama election	6	28%
The tech revolution	7	27%
Civil rights movement	8	18%
Korean War	9	18%
Iraq/Afghanistan wars	10	14%

Notes: This table features results from the survey *"Americans Name the 10 Most Significant Historic Events of Their Lifetimes"*, conducted in 2016 by the Pew Research Center (Deane *et al.*, 2016). Shown are answers to a survey question called *"Please name the 10 historic events that occurred in your lifetime that you think have had the greatest impact on the country. This could be one specific event, a series of related events or any other historic development or change that had an important on the nation."*. This information is available at *https://www.pewresearch.org/politics/2016/12/15/americans-name-the-10-most-significant-historic-events-of-their-lifetimes/* (accessed 9 September 2021).

Table C.2: *Categorization of the FMLI Files*

My expenditure categories	*Corresponding FMLI expenditure categories*
Food at home	*Food at home*
Food away from home	*Food excluding meals as pay; meals as pay*
Alcoholic beverages	*Alcoholic beverages*
Shelter	*Owned home outlays including mortgage principal and interest, property taxes, maintenance, insurance, and other expenses; rented dwelling; outlays for other lodging such as owned vacation home including mortgage principal and interest, property taxes, maintenance, insurance, and other expenses*
Utilities, fuels and public services	*Natural gas, electricity, fuel oil and other fuels; telephone services; water and other public services*
Household operations	*Domestic services; other household expenses*
House furnishings and equipment	*Household textiles; furniture; floor coverings; major appliances; small appliances, miscellaneous housewares; miscellaneous household equipment*
Clothing for adults, 16 and over	*Clothing for men, 16 and over; clothing for women, 16 and over*
Clothing for children, 2 to 15	*Clothing for boys, 2 to 15; clothing for girls, 2 to 15*
Clothing for children under 2	*Clothing for children under 2*
Footwear	*Footwear*
Other apparel products and services	*Other apparel products and services*
Vehicle purchases	*New vehicle purchases including down payment, principal and interest paid on loans, or if not financed, purchase amount; used vehicles purchases including down payment, principal and interest paid on loans, or if not financed, purchase amount; other vehicle purchases including down payment, principal and interest paid on loans, or if not financed, purchase amount*
Other vehicle expenditures	*Vehicle rental, leases, licenses, and other charges*
Public and other transportation	*Public and other transportation on trips; Public and other transportation, excluding trips*
Gasoline and motor oil	*Gasoline and motor oil*
Maintenance, repairs and insurance	*Maintenance, repairs and insurance on transportation*
Health insurance	*Health insurance*
Medical expenditures	*Medical services, prescription drugs and medical supplies*
Fees and admissions	*Fees and admissions for entertainment events*
Multimedia equipment	*Televisions, radios, and sound equipment*
Pets, toys, and playground equipment	*Pets, toys, and playground equipment*
Recreational vehicles	*Motored and non-motored recreational vehicles*
Miscellaneous entertainment outlays	*Photographic and sports equipment and boat and RV rentals*
Personal care	*Personal care products and services*
Reading	*Reading*
Education	*Education*
Tobacco and smoking supplies	*Tobacco and smoking supplies*
Miscellaneous outlays	*Safety deposit box rental, checking account fees and other bank service charges, credit card memberships, legal fees, accounting fees, funerals, cemetery lots, union dues, occupational expenses, expenses for other properties, and finance charges other than those for mortgages and vehicles*
Cash contribution	*Cash contribution*
Life and other personal insurance	*Life and other personal insurance*
Retirement, pensions society security	*Retirement, pensions society security*

Notes: The right column lists the original specific expenditure categories in the FMLI files, and I aggregate them into 32 categories shown in the left column. The FMLI files also report aggregated expenditure categories, but they are too broadly defined and the heterogeneity among individual categories might already average out. For example, *shelter*, *utilities, fuels and public services*, *household operations*, and *house furnishings and equipment* are all included in a single category called *total housing outlays*.

Table C.3: *Correlation between Luxury Expenditure and GDP Growth Rates*

	Log luxury expenditure		Share of luxury expenditure		
	Correlation coefficient	P-value	Correlation coefficient	P-value	N
Current-year GDP growth rate	0.0227	0.9266	0.1598	0.5134	19
1-year lagged GDP growth rate	0.2195	0.3665	0.2785	0.2482	19
2-year lagged GDP growth rate	0.5463	0.0155	0.5132	0.0246	19
3-year lagged GDP growth rate	0.5821	0.0089	0.5794	0.0093	19
4-year lagged GDP growth rate	0.6198	0.0047	0.6055	0.0060	19
5-year lagged GDP growth rate	0.6750	0.0015	0.6649	0.0019	19
6-year lagged GDP growth rate	0.5215	0.0220	0.5612	0.0124	19

Notes: This table reports the correlations between luxury expenditure and the GDP growth rates of each year from 2000 to 2018. Shown are correlations and corresponding P-values with respect to the log level and share of luxury expenditure.)

Sources: Own illustration of data from the World Bank and the Consumer Expenditure Survey (CE) 2000–2018

Table C.4: *Summary Statistics of Expenditure on Specific Categories*

	N	Mean	SD	Min	Max
Household operations	443497	232.73	579.21	0	39293.45
Millennials	51797	243.29	567.15	0	10180.17
Generation X	132364	305.48	712.84	0	39293.45
Baby Boomers	174083	201.32	469.27	0	20442.57
Builders	85253	177.51	545.76	0	37978.33
House furnishings and equipment	443497	310.80	851.51	0	29116.52
Millennials	51797	261.33	692.49	0	18711.30
Generation X	132364	328.24	883.15	0	29116.52
Baby Boomers	174083	335.15	901.93	0	26335.61
Builders	85253	264.05	776.63	0	25726.84
Clothing for adults	443497	136.00	281.98	0	18798.15
Millennials	51797	103.30	222.01	0	6597.87
Generation X	132364	137,28	282.55	0	18798.15
Baby Boomers	174083	153,30	304.77	0	9576.67
Builders	85253	118.54	261.72	0	7847.08
Vehicles	443497	801.39	2012.88	0	40613.03
Millennials	51797	683.25	1646.73	0	33299.80
Generation X	132364	883.10	1819.60	0	39352.65
Baby Boomers	174083	858.48	2086.31	0	39000.00
Builders	85253	629.70	2312.23	0	40613.03
Public and other transportation	443497	124.32	496.07	0	29514.80
Millennials	51797	105.70	361.05	0	13787.20
Generation X	132364	122.50	453.96	0	13628.00
Baby Boomers	174083	133.02	516.78	0	29514.80
Builders	85253	120.67	579.07	0	21970.34
Entertainment	443497	319.14	771.35	0	34256.47
Millennials	51797	239.29	573.52	0	24470.13
Generation X	132364	355.46	769.07	0	27068.18
Baby Boomers	174083	349.01	808.57	0	34256.47
Builders	85253	250.27	793.43	0	31798.92
Education	443497	190.24	1068.50	0	41309.55
Millennials	51797	255.90	1378.33	0	39508.71
Generation X	132364	185.99	973.31	0	37156.30
Baby Boomers	174083	242.39	1206.45	0	38054.10
Builders	85253	50.46	560.63	0	41309.55
Cash contribution	443497	342.59	997.87	0	38335.28
Millennials	51797	172.10	621.42	0	30064.79
Generation X	132364	292.54	824.10	0	36304.79
Baby Boomers	174083	395.48	1063.70	0	37000.00
Builders	85253	415.87	1244.18	0	38335.28
Miscellaneous outlays	443497	134.37	669.22	0	38520.80
Millennials	51797	62.26	379.72	0	27092.93
Generation X	132364	116.95	579.66	0	34992.56
Baby Boomers	174083	157.08	728.84	0	38520.80
Builders	85253	158.85	794.05	0	28930.38

Notes: This table reports summary statistics of the expenditure on the 9 individual luxury categories. See Section 3.5.5 for detailed information on the 13 original luxury categories. All expenditure data are quarterly-based.

Table C.5: *Main Results: Frequency Weights and State Fixed Effect*

	Log luxury expenditure		Share of luxury expenditure	
	Frequency weights	State fixed effect	Frequency weights	State fixed effect
	(1)	(2)	(3)	(4)
Millennials	-0.0796***	-0.0823***	-0.0143***	-0.0148***
	(0.0110)	(0.0114)	(0.0012)	(0.0013)
Baby Boomers	0.0895***	0.0955***	0.0142***	0.0150***
	(0.0100)	(0.0102)	(0.0011)	(0.0011)
Builders	0.1926***	0.2044***	0.0327***	0.0353***
	(0.0167)	(0.0173)	(0.0018)	(0.0019)
ln(Income)	0.6108***	0.6453***	0.0245***	0.0280***
	(0.0046)	(0.0045)	(0.0005)	(0.0004)
Household scale (equivalence)	0.0544***	0.0513***	-0.0023***	-0.0038***
	(0.0064)	(0.0062)	(0.0007)	(0.0006)
Number of adults	-0.0236***	-0.0098*	-0.0050***	-0.0015**
	(0.0061)	(0.0058)	(0.0006)	(0.0006)
Male	-0.0133**	-0.0262***	-0.0015**	-0.0025***
	(0.0058)	(0.0057)	(0.0007)	(0.0006)
Married	0.2707***	0.2488***	0.0173***	0.0134***
	(0.0072)	(0.0071)	(0.0008)	(0.0007)
Below 9th grade	-0.5010***	-0.4914***	-0.0343***	-0.0316***
	(0.0159)	(0.0162)	(0.0015)	(0.0015)
High school, diploma	-0.3945***	-0.3738***	-0.0308***	-0.0274***
	(0.0122)	(0.0122)	(0.0011)	(0.0011)
College graduate	0.2470***	0.2363***	0.0170***	0.0157***
	(0.0068)	(0.0065)	(0.0008)	(0.0007)
Masters degree and above	0.4018***	0.3948***	0.0291***	0.0283***
	(0.0092)	(0.0089)	(0.0011)	(0.0010)
Black	-0.1571***	-0.1418***	-0.0124***	-0.0088***
	(0.0097)	(0.0094)	(0.0010)	(0.0009)
Native American	-0.0897**	-0.1250***	0.0009	-0.0053
	(0.0385)	(0.0395)	(0.0043)	(0.0039)
Asian or Pacific Islander	-0.1896***	-0.1683***	-0.0113***	-0.0086***
	(0.0141)	(0.0134)	(0.0016)	(0.0015)
Other races	0.0367	0.0386	0.0041	0.0060**
	(0.0263)	(0.0243)	(0.0030)	(0.0027)
Urban	-0.0115	0.0400	-0.0009	-0.0005
	(0.0156)	(0.0443)	(0.0018)	(0.0048)
Metropolitan statistical area	0.0410***	0.0233	-0.0122***	-0.0099***
	(0.0123)	(0.0353)	(0.0014)	(0.0038)
Period	✓	✓	✓	✓
Age	✓	✓	✓	✓
Region	✓	✓	✓	✓
Quarter	✓	✓	✓	✓
State		✓		✓
Observations	1376799	373198	1432292	387495
R^2	0.2692	0.2926	0.0653	0.0832

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. The frequency weight of each generation is calculated based on the size of each generation in the sample, which is shown in Figure 3.2: Millennials (51797), Generation X (132364), Baby Boomers (174083), and Builders (85253). So the frequency weights are: Millennials (7), Generation X (3), Baby Boomers (2), and Builders (4). Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. High school graduate is the base group of education, and White is the base group of race.

Table C.6: *Results from Specific Categories (Full Table: Part 1)*

	Log luxury expenditure				
	Household operations	House furnishings and equipment	Clothing for adults	Vehicles	Public and other transportation
	(1)	(2)	(3)	(4)	(5)
Millennials	0.1959***	-0.0319**	-0.2867***	-0.1900***	-0.1384***
	(0.0142)	(0.0147)	(0.0114)	(0.0193)	(0.0217)
Baby Boomers	-0.2051***	0.0600***	0.2742***	0.0994***	0.0105
	(0.0111)	(0.0131)	(0.0104)	(0.0179)	(0.0197)
Builders	-0.4324***	0.1370***	0.6169***	0.1603***	0.0799**
	(0.0172)	(0.0212)	(0.0170)	(0.0300)	(0.0326)
ln(Income)	0.3593***	0.3984***	0.3583***	0.4225***	0.3810***
	(0.0043)	(0.0053)	(0.0043)	(0.0072)	(0.0073)
Household scale (equivalence)	0.3790***	0.0274***	-0.1928***	0.0342***	-0.0504***
	(0.0072)	(0.0076)	(0.0064)	(0.0105)	(0.0118)
Number of adults	-0.3300***	-0.0067	0.2334***	0.1197***	0.0356***
	(0.0063)	(0.0071)	(0.0059)	(0.0097)	(0.0108)
Male	-0.0861***	0.0321***	-0.0655***	0.0150	-0.0180*
	(0.0059)	(0.0068)	(0.0055)	(0.0096)	(0.0105)
Below 9th grade	-0.3155***	-0.1689***	-0.0963***	-0.1125***	-0.1513***
	(0.0180)	(0.0186)	(0.0149)	(0.0289)	(0.0257)
High school, no diploma	-0.1862***	-0.0981***	-0.1035***	-0.0324	-0.1946***
	(0.0129)	(0.0146)	(0.0116)	(0.0201)	(0.0228)
College graduate	0.1377***	0.1091***	0.1340***	-0.1378***	0.1338***
	(0.0067)	(0.0079)	(0.0064)	(0.0110)	(0.0128)
Masters degree and above	0.3040***	0.1540***	0.2368***	-0.3056***	0.2295***
	(0.0097)	(0.0111)	(0.0090)	(0.0160)	(0.0161)
Urban	0.0078	-0.0335*	0.1377***	-0.1579***	-0.1492***
	(0.0153)	(0.0182)	(0.0150)	(0.0251)	(0.0388)
Married	0.0935***	0.1739***	0.0507***	0.1656***	0.2796***
	(0.0069)	(0.0085)	(0.0069)	(0.0116)	(0.0131)
Metropolitan statistical area	0.1318***	0.0882***	0.0703***	-0.0358*	0.0237
	(0.0120)	(0.0141)	(0.0114)	(0.0198)	(0.0291)
Black	-0.0227**	-0.0381***	0.1007***	0.1593***	-0.0527***
	(0.0098)	(0.0121)	(0.0095)	(0.0160)	(0.0154)
Native American	-0.0870**	0.0216	-0.0283	0.1049*	-0.1676***
	(0.0381)	(0.0437)	(0.0334)	(0.0605)	(0.0625)
Asian or Pacific Islander	-0.1455***	-0.1366***	-0.0559***	-0.2373***	0.2045***
	(0.0136)	(0.0163)	(0.0126)	(0.0229)	(0.0201)
Other races	-0.0210	0.0014	-0.0588**	-0.0142	-0.1373***
	(0.0260)	(0.0310)	(0.0263)	(0.0438)	(0.0447)
Period	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓
Region	✓	✓	✓	✓	✓
Quarter	✓	✓	✓	✓	✓
Observations	302213	249698	249599	273465	93028
R^2	0.1438	0.0748	0.1428	0.0868	0.1197

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. High school graduate is the base group of education, and White is the base group of race.

Table C.7: *Results from Specific Categories (Full Table: Part 2)*

	Log luxury expenditure			
	Entertainment	Education	Cash contribution	Miscellaneous outlays
	(6)	(7)	(8)	(9)
Millennials	-0.0389***	0.1190***	-0.0190	-0.0529***
	(0.0122)	(0.0325)	(0.0241)	(0.0190)
Baby Boomers	0.0248**	-0.0331	0.0195	0.0027
	(0.0114)	(0.0269)	(0.0185)	(0.0169)
Builders	0.0689***	-0.2285***	0.0435	0.0491*
	(0.0196)	(0.0591)	(0.0274)	(0.0275)
ln(Income)	0.4745***	0.3603***	0.4286***	0.2930***
	(0.0049)	(0.0119)	(0.0069)	(0.0070)
Household scale (equivalence)	0.1697***	-0.4981***	-0.0016	0.0215**
	(0.0067)	(0.0162)	(0.0114)	(0.0103)
Number of adults	-0.1708***	0.4187***	-0.0500***	-0.0113
	(0.0062)	(0.0141)	(0.0102)	(0.0094)
Male	0.0046	0.1309***	0.1649***	0.0311***
	(0.0062)	(0.0162)	(0.0094)	(0.0091)
Below 9th grade	-0.4309***	-0.2168***	-0.2415***	-0.1104***
	(0.0183)	(0.0493)	(0.0253)	(0.0275)
High school, no diploma	-0.2649***	-0.4593***	-0.1364***	-0.0595***
	(0.0131)	(0.0346)	(0.0199)	(0.0191)
College graduate	0.2125***	0.3288***	0.1207***	-0.0127
	(0.0072)	(0.0184)	(0.0108)	(0.0104)
Masters degree and above	0.3410***	0.4646***	0.2861***	0.1004***
	(0.0101)	(0.0256)	(0.0145)	(0.0151)
Urban	-0.0358**	0.2631***	-0.0405*	0.0075
	(0.0170)	(0.0441)	(0.0240)	(0.0246)
Married	0.1858***	0.0719***	0.1801***	0.0100
	(0.0076)	(0.0201)	(0.0117)	(0.0113)
Metropolitan statistical area	0.1000***	-0.0340	-0.0176	0.0683***
	(0.0130)	(0.0322)	(0.0187)	(0.0189)
Black	-0.4887***	-0.0543**	0.2500***	-0.0152
	(0.0106)	(0.0260)	(0.0143)	(0.0150)
Native American	-0.1579***	-0.0116	-0.0848	-0.0230
	(0.0391)	(0.0970)	(0.0675)	(0.0584)
Asian or Pacific Islander	-0.3278***	0.2826***	-0.1781***	-0.0625***
	(0.0147)	(0.0331)	(0.0223)	(0.0215)
Other races	-0.0474*	-0.0859	-0.0832*	0.0651*
	(0.0282)	(0.0654)	(0.0425)	(0.0388)
Period	✓	✓	✓	✓
Age	✓	✓	✓	✓
Region	✓	✓	✓	✓
Quarter	✓	✓	✓	✓
Observations	298734	67974	214811	183118
R^2	0.1729	0.1563	0.1028	0.0460

*Notes:** $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. High school graduate is the base group of education, and White is the base group of race.

Table C.8: *Robustness: IV Estimation*

	Log luxury expenditure			Share of luxury expenditure		
	OLS	IV 1st stage	IV 2nd stage	OLS	IV 1st stage	IV 2nd stage
	(1)	(2)	(3)	(4)	(5)	(6)
Millennials	-0.0691***	-0.0083**	-0.0741***	-0.0137***	-0.0087**	-0.0150***
	(0.0082)	(0.0037)	(0.0083)	(0.0011)	(0.0037)	(0.0012)
Baby Boomers	0.0791***	0.0073**	0.0825***	0.0131***	0.0077**	0.0140***
	(0.0073)	(0.0035)	(0.0074)	(0.0010)	(0.0036)	(0.0010)
Builders	0.1787***	0.0038	0.1828***	0.0306***	0.0051	0.0319***
	(0.0121)	(0.0061)	(0.0122)	(0.0016)	(0.0061)	(0.0016)
ln(Total expenditure)	1.7814***		1.5673***	0.1218***		0.0657***
	(0.0039)		(0.0070)	(0.0006)		(0.0009)
ln(Income)		0.4090***			0.4153***	
		(0.0018)			(0.0018)	
Period	✓	✓	✓	✓	✓	✓
Age	✓	✓	✓	✓	✓	✓
Household characteristics	✓	✓	✓	✓	✓	✓
Observations	422382	422145	422145	438897	438658	438658
R^2	0.5904	0.5809	0.5846	0.2471	0.5903	0.2062
F		2764.19			2992.13	

*Notes:** $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Expenditure data are quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. High school graduate is the base group of education, and White is the base group of race. In the first stages, the dependent variable is ln(total expenditure).

Table C.9: *Robustness: Different Household Scales*

	Log luxury expenditure		Share of luxury expenditure	
	Modified	Square root	Modified	Square root
	(1)	(2)	(3)	(4)
Millennials	-0.0872***	-0.0866***	-0.0156***	-0.0156***
	(0.0109)	(0.0108)	(0.0012)	(0.0012)
Baby Boomers	0.0939***	0.0944***	0.0145***	0.0145***
	(0.0098)	(0.0098)	(0.0011)	(0.0011)
Builders	0.1887***	0.1894***	0.0322***	0.0322***
	(0.0164)	(0.0164)	(0.0018)	(0.0018)
ln(Income)	0.6409***	0.6395***	0.0273***	0.0274***
	(0.0042)	(0.0042)	(0.0004)	(0.0004)
Household scale (modified)	0.0947***		-0.0052***	
	(0.0097)		(0.0010)	
Household scale (square root)		0.1354***		-0.0060***
		(0.0105)		(0.0011)
Period	✓	✓	✓	✓
Age	✓	✓	✓	✓
Household characteristics	✓	✓	✓	✓
Observations	422145	422145	438658	438658
R^2	0.2854	0.2856	0.0721	0.0721

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. The household scale (modified) represents the "OECD-modified scale". The household scale (square root) represents the "Square root scale". See Section 3.4.1 and Footnote 22 for details.

Table C.10: *Robustness: More Disaggregated Generational Segments and the Orthogonal Period Effect*

	Log luxury expenditure		Share of luxury expenditure	
	Different generational segments	Orthogonal period effect	Different generational segments	Orthogonal period effect
	(1)	(2)	(3)	(4)
Millennials I	-0.0821***		-0.0205***	
	(0.0209)		(0.0026)	
Millennials II	-0.0878***		-0.0152***	
	(0.0110)		(0.0013)	
Baby Boomers	0.0939***		0.0147***	
	(0.0098)		(0.0011)	
The Silent Generation	0.1887***		0.0326***	
	(0.0164)		(0.0018)	
The Greatest Generation	0.1926***		0.0409***	
	(0.0313)		(0.0033)	
Millennials		-0.0254**		-0.0029**
		(0.0122)		(0.0014)
Baby Boomers		0.0266**		0.0013
		(0.0112)		(0.0012)
Builders		0.0621***		0.0065***
		(0.0197)		(0.0021)
ln(Income)	0.6409***	0.6426***	0.0273***	0.0274***
	(0.0042)	(0.0042)	(0.0004)	(0.0004)
Period	✓		✓	
Year		✓		✓
Age	✓	✓	✓	✓
Household characteristics	✓	✓	✓	✓
Observations	422145	422145	438658	438658
R^2	0.2854	0.2874	0.0722	0.0758

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is always taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months. High school graduate is the base group of education, and the White is the base group of race.

C.2 Heterogeneous Effects Details

I develop the following two more general models including interaction terms:

Model 1

$$L_{i,t} = \alpha_0 + \boldsymbol{\beta_a D^a_{i,t}} + \boldsymbol{\beta_g D^g_i} + \boldsymbol{\beta_{g,p} D^g_i} \cdot \text{Period}_t + \alpha_1 \text{Period}_t + \alpha_2 \ln\left(\text{Income}\right)_{i,t} + \boldsymbol{\beta_h X_{i,t}} + \varepsilon_{i,t}$$

follows the main specification except for vector $\boldsymbol{\beta_{g,p}}$. It denotes the coefficients on the interaction terms between generation dummies and the 5-year lagged GDP growth rate which is a proxy for the period effect.

Model 2

$$L_{i,t} = \alpha_0 + \boldsymbol{\beta_a D^a_{i,t}} + \boldsymbol{\beta_g D^g_i} + \boldsymbol{\beta_{g,a} D^g_i} \cdot \boldsymbol{D^a_{i,t}} + \alpha_1 \text{Period}_t + \alpha_2 \ln\left(\text{Income}\right)_{i,t} + \boldsymbol{\beta_h X_{i,t}} + \varepsilon_{i,t}$$

includes the interaction terms between generation and age dummies $\boldsymbol{\beta_{g,a} D^g_i} \cdot \boldsymbol{D^a_{i,t}}$. The results of the two models are shown in Table C.11.

Columns (1) and (2) are based on Model 1. The pure generation effect remains almost unchanged, but the estimated coefficients on all interaction terms between generation dummies and the period effect are insignificant. Columns (3) and (4) are based on Model 2. When interactions between age and generation effects are included, the estimated coefficients on pure generation dummies are substantially disrupted.

To further validate the results, I conduct two hypothesis tests of the separability assumption to determine the most suitable model. Specifically, I use F-tests to check whether the coefficients on interaction terms are jointly zero:

Test 1 *Null:* $\boldsymbol{\beta_{g,p}} = \boldsymbol{0}$;

Test 2 *Null:* $\boldsymbol{\beta_{g,a}} = \boldsymbol{0}$.

The first test is based on Model 1. If this condition holds, the time control (5-year lagged GDP growth rate) is separable from generation dummies, implying that Model 1 converges

Table C.11: *Heterogeneous Effects: Including Interaction Terms*

	Model 1		Model 2	
	Log luxury expenditure	Share of luxury expenditure	Log luxury expenditure	Share of luxury expenditure
	(1)	(2)	(3)	(4)
Millennials	-0.0834***	-0.0150***	-0.1612**	-0.0247**
	(0.0155)	(0.0017)	(0.0756)	(0.0102)
Baby Boomers	0.0863***	0.0137***	-0.1697**	-0.0108
	(0.0136)	(0.0014)	(0.0731)	(0.0080)
Builders	0.1990***	0.0306***	-0.1041	0.0032
	(0.0217)	(0.0023)	(0.1129)	(0.0119)
ln(Income)	0.6409***	0.0273***	0.6413***	0.0273***
	(0.0042)	(0.0004)	(0.0042)	(0.0004)
Period×Millennials	-0.0020	-0.0005		
	(0.0049)	(0.0006)		
Period×Baby Boomers	0.0021	0.0003		
	(0.0037)	(0.0004)		
Period×Builders	-0.0045	0.0005		
	(0.0049)	(0.0005)		
Period	✓	✓	✓	✓
Age	✓	✓	✓	✓
Age×Generation			✓	✓
Household characteristics	✓	✓	✓	✓
Observations	422145	438658	422145	438658
R^2	0.2854	0.0721	0.2860	0.0727

Notes: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors (in parentheses) are clustered at household level. Generation X is taken as the base group among generation dummies. Period stands for the 5-year lagged GDP growth rate as the proxy for the period effect. Luxury expenditure is quarterly-based, while ln(Income) is the log of total amount of household income after taxes in the last 12 months.

to the main specification. The second test is based on Model 2. It tests if the interaction terms $\boldsymbol{\beta_{g,a} D_i^g \cdot D_{i,t}^a}$ should be included such that the age effect varies across generations. Table C.12 shows the results of the hypothesis tests. There are no discrepancies in the results when using either the level or the share of luxury expenditure as the dependent variable. For Model 1, the null hypothesis that the coefficients $\boldsymbol{\beta_{g,p}}$ are jointly zero can not be rejected at conventional significance levels. This means, the separability assumption holds for the generation effect and the period effect. As for Model 2, the results of Test 2 confirm the existence of an heterogeneous age effect across generations.

Table C.12: *Sensitivity Tests (P-values)*

			Log luxury expenditure	Share of luxury expenditure
Model 1	**Test 1**	*Null:* $\boldsymbol{\beta_{gp} = 0}$	0.5419	0.3892
Model 2	**Test 2**	*Null:* $\boldsymbol{\beta_{ga} = 0}$	< 0.0001	< 0.0001

C.3 Neural Network Details

As one of the currently most popular machine learning methods, neural networks are employed in this chapter to study information patters in the data. They are approximate mathematical models of biological processes in the brain and date back to the 1940s. Until recently, neural networks only had low impact because of limited computing power, lacking scalable optimization techniques, and small, unstructured data sets. Benefiting from theoretical and empirical breakthroughs in these areas in the 2000s and the 2010s, neural network are now the state-of-the-art technique in the machine learning community (Zhang *et al.*, 2018; Farrell *et al.*, 2021).

C.3.1 Fully Connected Neural Network

Figure C.7 below shows an example of a *fully connected neural network*. It starts with an input layer, that contains independent variables $\boldsymbol{X}$, and ends up with an output, the dependent variable Y. Input and output layers are connected through hidden layers, each of which consists of several hidden nodes or unobserved variables $\boldsymbol{Z}$. In a *fully connected neural network*, all nodes in one layer are connected to the nodes in the next layer. Node k of the first hidden layer, $Z_k^{(1)}$ is a linear combination of all inputs X_i as

$$Z_k^{(1)} = \sum_i w_i X_i + b_i,$$

where w_i and b_i are called weight and bias respectively. Then, $Z_k^{(1)}$ experiences a transformation through a non-linear activation function $f(\cdot)$. With only a single hidden layer, the predicted output is

$$\hat{Y} = \sum_k w_k f(Z_k^{(1)}) + b_k.$$

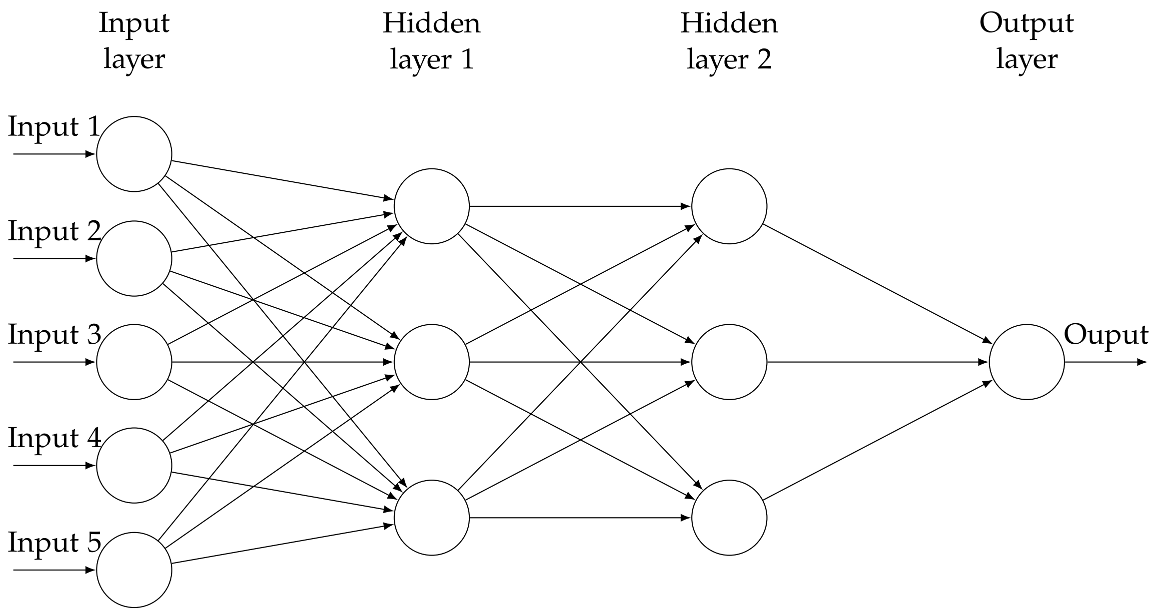


Figure C.7: *Illustration of a Fully Connected Neural Network*

If there are multiple hidden layers, the non-linearly transformed $f(Z_k^{(1)})$ acts as an input to the following layer, and this is iteratively repeated until the last layer of the network.

C.3.2 Optimization

For a given neural network, the parameters consisting of weights $\boldsymbol{w}$ and biases $\boldsymbol{b}$ are gradually updated during the training. These parameter updates are achieved by minimizing a loss function on the network output (often a mean squared error) using stochastic gradient descent, as introduced by Robbins and Monro (1951) and Kiefer and Wolfowitz (1952). Different from classic gradient descent which calculates the actual gradient from the whole sample, stochastic gradient descent only uses a randomly drawn data subset (also called batch) each time. This means each individual step is noisy, but after multiple iterations the result still converges with an increased computation speed, especially when the data set is large. The most common algorithm to determine the parameter updates is *backpropagation* (Rumelhart *et al.*, 1986) which computes gradients of the loss function with respect to parameters. This is performed for each network operation individually, backwards from the last layer using the chain rule. Due to their approximative powers on non-linear functions, it can happen that the network actually loses generality during training, which is called overfitting. Intuitively, this happens when a network starts fitting the training data too closely. Thus, penalty or regularization terms that explicitly penalize too complex models are usually added to the loss function. Furthermore, the approximation power is also affected by the activation function and hyperparameters, e.g., the learning rate, the number of hidden layers, and the number of nodes per hidden layer.

C.3.3 Model Selection

Here, the non-linear transformation $f(.)$ after each hidden layer is performed with the rectified linear unit (ReLU),

$$f(x) = \begin{cases} x, & \text{if } x \geq 0; \\ 0, & \text{otherwise} \end{cases}$$

that was introduced by Nair and Hinton (2010). ReLU exhibits a more stable convergence performance than the traditional hyperbolic tangent or logistic functions (Farrell *et al.*, 2021). Concerning regularization for overfitting, I use an L^2 weight decay penalty that is added to the loss function with a weighting factor of 0.0001. The number of randomly draw observations for stochastic gradient descent step (batch size) is set to 200. Given that there are around 400000 observations in the full sample, 2000 iterations are required for an epoch, i.e., one pass over the whole data set. The maximum number of training iterations is set to 50000, meaning at most 25 training epochs. I choose the commonly used adaptive moment estimation (Adam) as the optimization method (Kingma and Ba, 2014). Compared to basic stochastic gradient descent, Adam typically is a more efficient optimization algorithm, due to its adaptive learning rate, especially for large data sets.

Appendix D

Appendix to Chapter 4

Additional Figures and Tables

(a) Age Group Effect

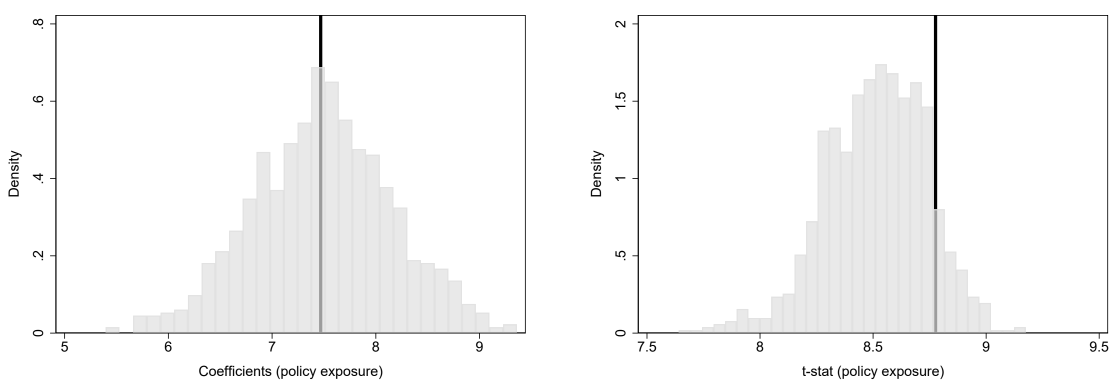
(b) Cohort Effect

Figure D.1: *Elderly Suicide Rates: Age and Cohort Patterns*

Notes: Figure D.1(a) shows coefficient estimates for age group dummies as in specification of Column (4) of Table 4.1, where coefficients are relative to reference group aged 70–74. Figure D.1(b) shows coefficient estimates for birth cohort dummies as in specification of Column (4) of Table 4.1, where coefficients are relative to reference group born in 1950.

Figure D.2: *Heterogeneous Effects Across Cohorts*

Notes: This figure shows the coefficients on the interaction terms between cohort dummies and policy exposure relative to the main effect (for the cohort born in 1950). Other controls are as in the specification of Column (4) of Table 4.1.

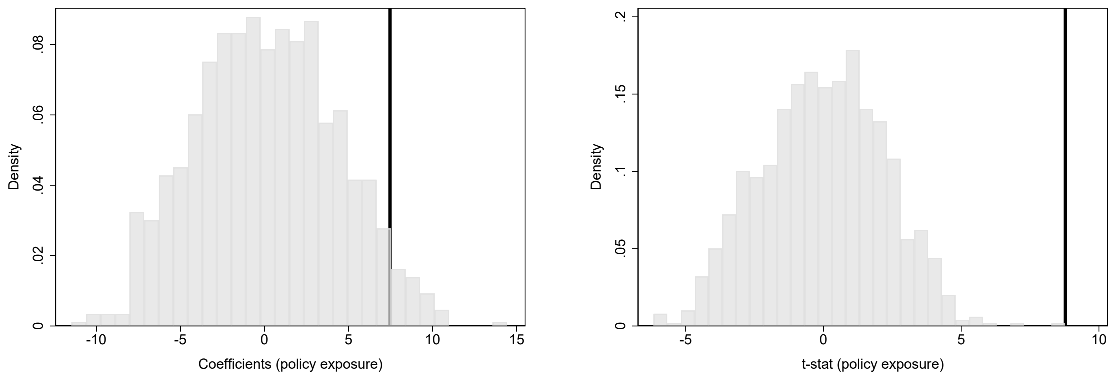


(a) Coefficient Estimates

(b) Inference (t-statistics)

Figure D.3: *Placebo: Random Implementation of Policy (Time) (Alternative Specification)*

Notes: Figure D.3(a) shows coefficient estimates for β as in specification of Column (4) of Table 4.1. Figure D.3(b) shows t-values for estimates of β in Figure D.3(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments over time. See text for details.

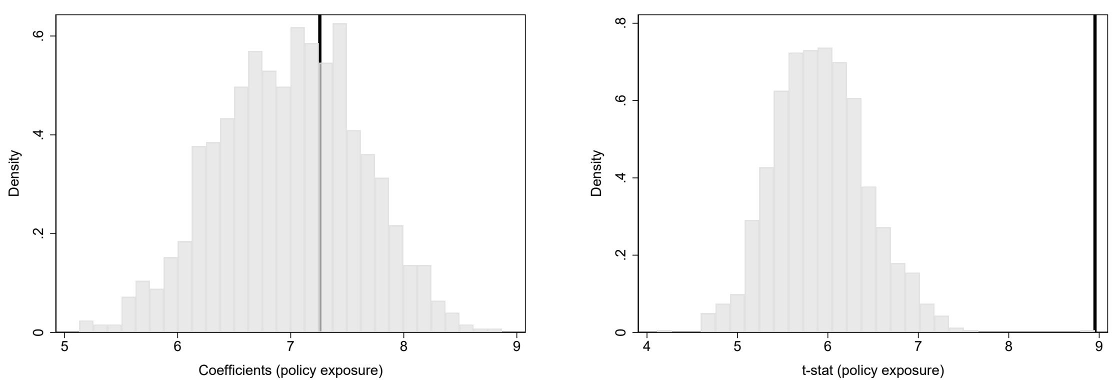


(a) Coefficient Estimates

(b) Inference (t-statistics)

Figure D.4: *Placebo: Random Implementation of Policy (Space and Cohorts) (Alternative Specification)*

Notes: Figure D.4(a) shows coefficient estimates for β as in specification of Column (4) of Table 4.1. Figure D.4(b) shows t-values for estimates of β in Figure D.4(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments across both space and cohorts. See text for details.

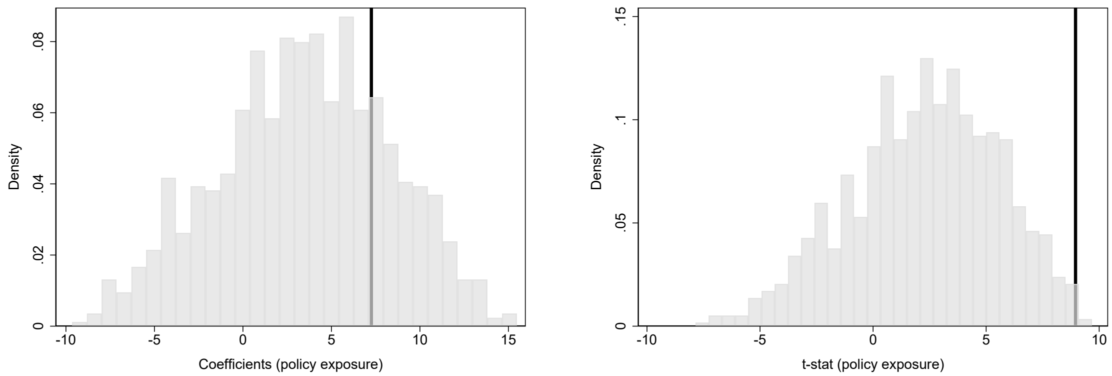


(a) Coefficient Estimates

(b) Inference (t-statistics)

Figure D.5: *Placebo: Random Implementation of Policy (Cohorts) (Baseline Specification)*

Notes: Figure D.5(a) shows coefficient estimates for β as in specification of Column (1) of Table 4.1. Figure D.5(b) shows t-values for estimates of β in Figure D.5(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments across cohorts. See text for details.

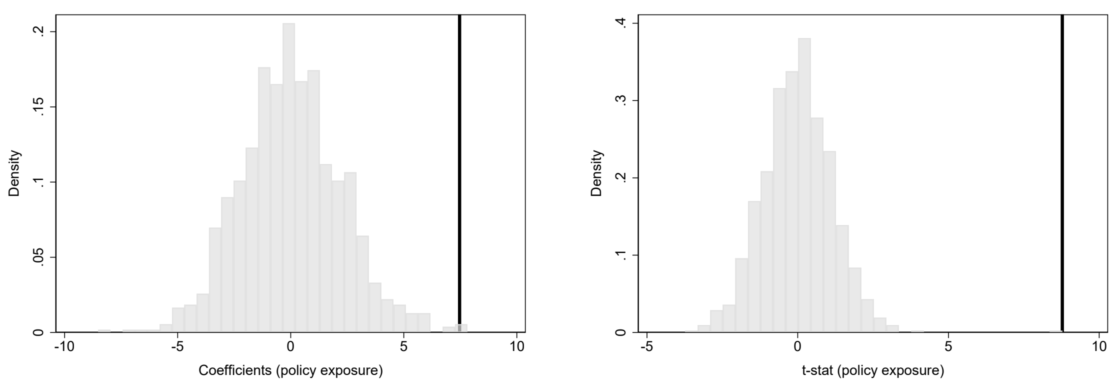


(a) Coefficient Estimates

(b) Inference (t-statistics)

Figure D.6: *Placebo: Random Implementation of Policy (Space) (Baseline Specification)*

Notes: Figure D.6(a) shows coefficient estimates for β as in specification of Column (1) of Table 4.1. Figure D.6(b) shows t-values for estimates of β in Figure D.6(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments across space. See text for details.



(a) Coefficient Estimates

(b) Inference (t-statistics)

Figure D.7: *Placebo: Random Implementation of Policy (Space, Cohorts, and Time) (Alternative Specification)*

Notes: Figure D.7(a) shows coefficient estimates for β as in specification of Column (4) of Table 4.1. Figure D.7(b) shows t-values for estimates of β in Figure D.7(a). Estimates are based on a placebo data set of 1000 iterations of randomized policy assignments across space, cohorts, and time. See text for details.

Table D.1: *Robustness: Policy Exposure and Elderly Suicides*

	Suicide Rate			
	(1)	(2)	(3)	(4)
Policy exposure	6.5803***	6.6128***	7.1607***	6.6933***
	(0.7150)	(0.7153)	(0.7801)	(0.7392)
Male	10.0919***	10.0919***	10.0919***	10.0919***
	(0.7297)	(0.7309)	(0.7310)	(0.7337)
Time trend	-3.0826***			
	(0.2596)			
Cohort trend			-1.0560***	
			(0.1813)	
Age group	✓	✓	✓	✓
Year		✓	✓	✓
Cohort				✓
Region	✓	✓	✓	✓
Observations	3612	3612	3612	3612
R^2	0.5370	0.5414	0.5453	0.5588

Notes:: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. This table shows OLS estimates. Standard errors (in parentheses) are clustered at region×cohort level. Policy Exposure refers to exposure to LLF policy, see texts for details. Age group: full set of dummies for quinquennial age groups (reference group: 70–74); Year: full set of year dummies (reference year: 2004); Cohort: full set of cohort dummies (reference cohort: 1950).

Eidesstattliche Versicherung

Ich versichere hiermit eidesstattlich, dass ich die vorliegende Arbeit selbständig und ohne fremde Hilfe verfasst habe. Die aus fremden Quellen direkt oder indirekt übernommenen Gedanken sowie mir gegebene Anregungen sind als solche kenntlich gemacht. Die Arbeit wurde bisher keiner anderen Prüfungsbehörde vorgelegt und auch noch nicht veröffentlicht. Sofern ein Teil der Arbeit aus bereits veröffentlichten Papers besteht, habe ich dies ausdrücklich angegeben.

München, 09. März 2022

Manfei Li