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The Effect of Chinese Imports on European Innovation Activities in the Medium-Long Term Period

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Abstract
Studies have been conducted about the role of foreign trade-driven technology transfer in the achievement of the Chinese miracle; however, when focusing on the opposite direction, the literature is not uniform: how are Western businesses affected by trade dealings which China? To what extent does this impact apply to the innovation cycle? In this research we focused on the linear correlation between innovation in European countries (proxied by patent applications) and imports from China, over the 15-year time period following China's accession to the World Trade Organization in 2001. Patent applications are used as a measure of innovation, integrated in an economic model inspired by the "Trapped Factors" model, that makes it possible to account for escape-competition effects. The model analyzes the 2002-2016 period across 22 European countries. Apart from evaluating the impact of Chinese imports on European innovation, our study provides a review of the major contributions that have characterized this research area in the most recent years, trying to categorize and to present them from a proactive and comprehensive point of view.
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1. Introduction

The economic side of the 21st century has so far been characterized by China's rise as a one of the world's most influential players, with its unprecedented growth altering and reshaping many traditional flows of global trade. Part of this dramatic transformation is due to China's accession to the World Trade Organization (WTO) in 2001, which caused import tariffs to be significantly lowered. This fostered a dramatic increase in trade exchanges between other members of the WTO and China, which could eventually take advantage of its huge market and production potential.

The evolving scenario has once again exposed the controversial correlation between trade shocks, welfare, and innovation, encouraging several studies to be carried out in order to explore this relationship under the new light shed by the rise of China. Some of these studies are forming part of the large family of researches that address the impact of lowered trade tariffs between low-wage countries and high-wage countries, especially when China is considered as proper example of low-wage country, among others: Chinese imports into Europe (Bloom, Draca, & Van Reenen, 2011), Chinese imports into United States (Autor, Dorn, & Hanson, 2016), Chinese imports into Canada (Kueng, Li, & Yang, 2016), Chinese imports into South Korea (Ahn, Han, & Huang, 2018), French exports into China (Aghion, Bergeaud, Lequien, & Melitz, 2018). Though reporting contrasting results, mostly due to geographical differences, the leading studies on this subject fundamentally agree about the distribution of affected businesses, as deeper effects are observed in those industries that are more exposed to the increased trade competition. Technological progress and production factor mobility are also playing a role according to certain studies, insofar as "trapped factors" are proved to act as magnifiers of the above-mentioned trade shock effects.

By taking into account the different results of earlier studies, it is still necessary to hold ambivalent opinions about the impact of trade shocks between low-wage countries and high-wage countries, especially when China is involved. Beside the demonstrated benefits, there are also costs that need to be considered, such as distributional costs and adjustment costs. Different situations involve a different understating of trade benefits and costs, and the evaluation of such consequences has lately become a topic of major concern in many economic and business circles.

Innovation is said to be possibly affected by a trade shock, which is a synonym for increased competition in terms of imports or exports. This study focuses primarily on the impact of import volume changes, which effect varies greatly between high-wage countries and low-wage countries, and across countries that feature different mobility levels in terms of production factors. In some cases, import competition is proved to affect innovation negatively, with technological change resulting in less gains for the innovating firm. In the majority of cases, a trade shock of this kind is positively related to innovation activities, especially when the imports originate from a low-wage country. The incoming flow of cheaper goods stimulates firms in high-wage countries to find another way of making profits, and oftentimes this leads to innovation activities. "Escape-competition effect" is a possible way to classify this trend (Aghion et al., 2014).

1.1 The role of China

China's rise is beyond doubt a fundamental feature of the early part of the 21st century, channelled through a process that started much earlier thanks to the economic reforms of Deng Xiaoping and the trade boom ignited by the country's accession to the World Trade Organization in 2001. During the years, China's economic approach gradually abandoned central planning and switched to market orientation, allowing more freedom for private players to operate and stimulating an exponential and unprecedented growth. Deng Xiaoping's idea of Special Economic Zones (SEZ), where foreign direct investment could be attracted proved successful, so much so that the total number of SEZs grew tenfold in only twenty years' time. China's ability of exporting manufacturing escalated quickly, accounting for a fifth of the global share in the mid-2010s and rightfully earning the title of "World's Factory".

China is recently experiencing a slowdown in GDP growth and trade, which is thought to affect negatively the whole global economy, given China's involvement in economic and political contexts all over the world. While China imports a significant amount of manufacturing goods (2 trillion dollars in early 2019), most of it is commodities and components for re-export, and only a fraction of it can be considered as manufactures for domestic use; for this reason, a shock to China's economy has still the potential to be classified as an economic catastrophe in global terms. China is undeniably a giant which slowdown is a major cause of concern for several external players, Europe above all (EU countries combined hold the largest share of exports to China). Not to mention the shock wave generated by changes in the driving force of Chinese economy, namely its export dominance.

China's manufacturing supremacy can be partly explained by its huge supply of labor force, the comparatively high education of average workers, and the unparalleled urbanization process which saw many workers migrating into the industrial ecosystem. Nevertheless, China's emergence as the backbone of global manufacturing cannot be solely explained by the size of its inputs. Most of the foreign direct investment flowing into China is actualized in the form of joint ventures, which are often responsible for a largest induction of technology spillover into domestic firms. Van Reenen and Yueh (2012) found that international joint ventures in China are synonymous with higher productivity, and that this is all the more true when an explicit technology transfer agreement is included in the venture. The government's policy of encouraging the emergence of international joint ventures then somehow facilitated China's pursuit of catching up with developed countries.

The rise of China has transformed the economic scenario, redefining many beliefs and patterns which characterized the previous perception of trade practices. Huge trade shocks, such as that caused by China, are now perceived to imply significant adjustment costs that could conceivably overtake gains from trade. Autor (2016) is also challenging the earlier understanding that, as in the case of United States, consequential benefits are not necessarily featured in the redistributive nature of trade.

1.2 Historical framework of China-Europe commercial relations

When we look at the relationship between China and Europe, we see China is somehow increasingly permeating every aspect of the European economy, through a process that resembles the post-World War II scenario set up by the United States and spread all across its allies. In fact, it can be stated that China is now filling a void left by the United States in the Old Continent: many European countries never really managed to recover from the recession generated by the global financial crisis in 2008, and their compulsive need for foreign investments is now met by the expanding oversea ambitions of fast-growing China. After World War II, the US enacted the Marshall Plan, a set of investments which were intended to help the reconstruction of war-torn Europe and which had the additional effect of fostering international integration between Western European countries. This, of course, contributed to bring Europe under the sphere of influence of the United States. Today, with the American dominance slowly declining and hindered by protectionism, China's foreign investments are percolating throughout Europe, in a trend that started in the last decade and is now burgeoning in the epochal investment project named "Belt and Road Initiative". Chinese FDI is primarily targeting those countries and companies which have been mutilated the most by the 2008 global financial crisis and the economic stagnation that followed. Such investment activities are mostly taking the form of mergers and acquisitions (where economic crisis breeds chronic privatization), and green field investments (mostly in infrastructure), with their magnitude untouched by the global financial crisis (while global FDI dropped 40% on average, Chinese FDI increased sharply during the years 2007 to 2010). Indeed, the sudden wave of investment is a godsend for European business, which, should the opportunity arise, is not in a position to reject any potential aid; besides, it is conceivably positive for Europe when a foreign country invests there and fuels the European job market, instead of when European companies outsource their production abroad, benefitting foreign workers and economies. In contrast with the rapidly deteriorating US-China relationship (most recent issues concerning the legal activity of certain Chinese companies have contributed to the perception of United States as a hostile investing environment), the Europe-China relationship seems to be rather stable at the moment, and foreign investments into European countries have been conducted so far with relative ease.

1.2.1 Shared benefits of commercial relations

A major by-product of this new state of affairs is, indeed, the ever-increasing trade dealings between the two regions. Diplomatic and institutional relationships paved the way for a smoother trade environment where Europe's strong import capacity could finally be used by China to channel its enormous excessive production. Several European countries have also enjoyed their new partnership with China, especially as the burgeoning Chinese middle-class's appetite for high-end products keeps on growing day after day. For instance, the total value of goods traded between China and the European Union was €4 billion in 1978; forty years later, in 2018, that number skyrocketed to €605 billion (Eurostat estimates). Still, it should not be ignored the fact that EU's total exports to China grew much slower compared with EU's total imports from China, meaning that EU's trade deficit with China is constantly rising and could become a factor of major concern.

In general, Europe took advantage of the low labor cost, while China obtained valuable shares of capital and technology spillovers. Chinese investments were also instrumental in sustaining a stagnating economy in many European countries, which in return allowed such countries to engage China on an equal footing concerning commercial and social issues as well. Besides, the relationship is expected to strengthen in the future, given the fact that China is increasingly interested in the service sector and opening up in terms of welcoming foreign businesses in the local market. The Belt and Road Initiative is also contributing in cementing the partnership, as more and more countries accept China's role as a trustworthy partner and commit to the investment plan (Italy was the first member of the Group of Seven advanced economies in the world to formally join the Belt and Road initiative in March 2019). As in the case of United States' Marshall Plan, BRI implies secondary aims for China which digress into the sphere of finance and geopolitics. The Initiative is supported by several large institutions, such as the Asian Infrastructure Investment Bank (AIIB) and several other Chinese investment banks, as well as by many agencies of the Chinese government and other cooperation platforms, such as the Asia Europe Meeting (ASEM), the Association of Southeast Asian Nations (ASEAN), and the Asia Pacific Economic Cooperation (APEC).

1.2.2 Potential points of conflict

While enjoying undeniable benefits from the expanding relationship, it is not all a bed of roses for European countries: the legal certainty and security of investments is not yet proven, and the relative legislation is rather vague and often not implemented (the tracking of investment operations is also troublesome, as much of the Chinese outward investment is "filtered" through Hong Kong and other tax heavens); several antidumping measures have been undertaken in Europe concerning Chinese imports, as well as import tariffs which are deemed necessary to safeguard the local market from an unbearable shock; on the European Union side, it is argued that further integration with China might accelerate the decay process of European identity, with each single country trying to get the best commercial deal with China, at the expense of other member countries (for instance, Italy's 2019 accession to the Belt and Road Initiative was highly criticized by Germany and France, which for their part are already engaging in trade deals with China on a scale that is much larger than that of Italy). Last but not least, an unequivocal opening to China could be perceived by the United States as an act of treason from its oldest ally, at this moment in history when the American global dominance is being seriously challenged and the need for alliance is stronger than ever.

1.3 Significance of the study

When looking at the social and economic dynamics of the last two decades, the significance of this study speaks for itself. It can serve as a practical benchmark for managers and policymakers who deal with China and are concerned by the innovation capacity of the business entity they depend from. Trade with China is an essential feature of business activities for 21st century European business, in a moment in time when their need for a supportive commercial partner has become indispensable; at the same time, Chinese imports into Europe are also responsible for an important resurgence of competition in several stagnant sectors of European economy; the topic of innovation is once again at the very top of the priority list when it comes to European businesses and policymakers, and this study can be valuable in describing the existing relationship between innovation and trade with China and its medium-long period implications.

Although this might look like a serviceable study to private businesses mostly, it is indeed an interesting benchmark for government officials as well: lately the public opinion has been particularly sensible to the topic of counter-liberalization and adoption of trade barriers, thanks mostly to the recent policies of United States and China (a commercial quarrel that has been named "Trade War" for the magnitude of the tariffs imposed), and many entities involved are actually wondering about the real economic effect behind such political moves.

The hope is that this study will join the larger body of knowledge and records that already provide a valuable reference for researchers and analysts concerning the impact of Chinese trade and its consequences on the innovation activities of Western countries. Whether such consequences are positive or negative is currently an issue of major concern.

Compared to other studies on the subject, a major contribution of this work is the broader set of countries, and the longer timeframe. In general, earlier studies tended to focus on a decade-long timeframe encompassing China's accession to the World Trade Organization in 2001; our research, on the other hand, analyzes a 15-year time period subsequent to China's accession, meaning from 2002 to 2016. This temporal location allows us to focus only on the effect of trade relations once they have been already liberated by China's entering of the WTO.

1.4 Purpose of the study

In the context we delineated above, the estimation of Chinese imports affecting innovation activities in Europe shows, theoretically and statistically, that such correlation can actually be positive and of significant magnitude. Specifically, this study aims to: prove how volume changes in imports from China affect innovation processes in Europe, especially concerning the application of new patents; further explore the impact of China's accession to the WTO on global economy in terms that are not strictly related to economic performance or geopolitical assertiveness; add evidence to the existing literature concerning the socioeconomic effects on Western countries stemming from trade liberalization with low-wage countries.

2. Literature review

We are aware of the publication of several studies concerning the role of trade exchanges (mostly imports) on the innovation capability of the recipient country, and we are also aware of the connections between those studies and the theoretical hierarchy existing among them. Although the results presented are sometimes conflicting, we can confidently say that the majority of the literature on the subject finds a positive correlation between trade shocks and innovation activities. When considering imports from a high-wage country into another high-wage country, the outcomes are mixed and it is not easy to define a clear resulting trend.

Our analysis is inspired by the Trapped Factors model of innovation, and it therefore focuses on imports from a low-wage country (China) and their supposedly positive innovation-spurring effect on high-wage countries (European countries), but it sought to go beyond the effects of the trade shock itself, following up into the consequences of a long-term impact.

2.1 Trapped Factors model and trade shocks in high-income countries

Bloom (2011) examined the impact of trade on technical change in high-income countries as a consequence of a trade shock driven by a staggering increase in imports from a low-wage country; specifically, China's accession to the World Trade Organization in 2001 provided a solid case study for addressing this cause-effect correlation. It is found that the technical change observed within firms in 12 European countries is positively related to the increase in Chinese imports in the 1996-2005 period. The analysis was carried out at firm level through a sample of half a million firms. Both within firm margin (technological upgrading) and between firm margin (upgrading through selection) were observed. When looking at patent applications, IT intensity, R&D expenditure, and Total factor productivity as indicators of technology, evidence shows that all of them responded positively to the trade shock; the effect is larger for firms who were more exposed to Chinese import growth. The assessment of between firm impact showed opposite results, with imports from China that were negatively affecting both employment growth and survival; firms with a low patent stock (and therefore more exposed to Chinese imports) had a higher chance of exiting the market rather than high-tech firms. A major underlying principle here is that of 'trapped factors', which implies that workers have some firm-specific human capital and capital has firm-specific adjustment costs.

Bloom, Romer, Terry, & Van Reenen (2010) set up the Trapped Factors model of innovation in order to provide a suitable framework for future observations. In such model, the factors of production are confined to the production of old goods. This is mostly due to sunk investments, and to a process that presupposes workers acquire a particular human capital that is specific to a certain firm only. Because of these assumptions, trade liberalization with low-wage countries results to be beneficial for high-wage countries: in fact, imports from low-wage countries will cause a fall in the profitability of old goods, as well as in the opportunity cost of innovating. Being "trapped", the factor of production will be forced to innovate in order to escape the new competition arising from the low-cost imports. It is important to note that, when the import shock comes from another high-wage country, there is no change in the market price of goods, and therefore no positive relationship with innovation as high-skilled workers will continue to produce the same goods.

Bloom (2011) narrows down the focus of the Trapped Factors model to the peculiar case of Europe and China, applying such theory to the decade encompassing China's accession to the WTO and the consequent trade liberalization and import shock. As it is suggested in the model, firms with trapped factors wouldn't innovate unless exposed to a huge trade shock like the rise of China; by all means, the effect of import competition on innovation is greater for firms with a higher past total factor productivity. In its inherent features, China is not quantitatively different from other low wage countries, unless for the size of the trade shock. In terms of magnitude, it is assessed that over the 2000-2007 period Chinese imports accounted for a 14.7% increase in aggregate patenting per worker, a 14.1% increase in IT intensity, and a 11.8% increase in total factor productivity in European manufacturing businesses.

In addition, Bloom et al. (2018) further explored this case study by using the Trapped Factors framework at the micro level within a quantitative equilibrium model of product-cycle trade and growth. In estimating welfare gains from trade, it is accepted that some optimistic results must be necessarily balanced by the increase in inequality caused by trade liberalization. In the two decades bracketing China's accession to the WTO (1994-2014), the surge in Chinese import competition causes the same OECD high-wage firms to experience both a considerable increase in innovation and a significant employment loss at the same time. There is a notable difference with the earlier research by Bloom (2011), where the positive effect was strictly related to high-tech firms, and the negative effect to low-tech firms. Again, the cause-effect correlation is driven by a reduction in the opportunity cost of R&D, which is derived by a fall in the shadow cost of trapped factors.

2.2 Trade-related innovation and technology transfer

This framework belongs to a larger family of earlier studies which tried to rationalize the social and economic consequences that might be associated with international trade. Acharya & Keller (2007) explained total factor productivity differences among countries in terms of domestic technical change and international technology transfer. The main input for technical change was R&D expenditure, which in the thesis was also affected by foreign R&D; international market transactions are proved to be a likely conduit for technology spillover, as it is shown that the majority of technology transfer from the United States and the United Kingdom occurs through imports. The analysis showed that R&D has a significant effect on productivity, and that international technology transfer has even a bigger impact. It was also demonstrated that the global patterns of technology transfer are highly asymmetric, and that some countries benefit more than others because of a different absorptive capacity. The study was instrumental in isolating those high-technology sectors that were the drivers of productivity trends during the late 1980s and 1990s, but it addresses a different kind of innovation benefits, deriving from international transaction with developed countries. Bloom et al. (2018), instead, moved away from this approach and focus on a "necessary" innovation activity due to the increasing import competition from low-wage countries. The opportunity cost of innovation is reduced due to the factors of production being "trapped" in specific firms or industries, a condition which would result in lower returns from such factors as a consequence of their exposure to import competition.

Melitz and Ottaviano (2008) explain the role of the market size effect in the reallocation consequences of trade liberalization, with a bilateral trade shock causing low-productivity firms to exit the market and high-productivity firms to further expand their market share. Market size and trade are directly responsible for a strengthening of competition, which in turn conditions the underlying process of firm selection. A larger market is associated with a stronger competition, which is symptomatic of lower mark-ups – after trade liberalization, the number of firms in each market increases significantly – and higher productivity. Impullitti and Licandro (2010) implement such results by showing how trade-driven competition shocks exert their influence on both firm selection and innovation activities. Firm selection processes allow high-productivity firms to enjoy a larger share resources which can then be channelled into more innovation activities. Because of the enlarged market created by trade liberalization, innovation activities are stimulated for the very reason that innovation itself is cost-reducing. Although significant, this competition-induced effect accounts for a small share of the observed trade-induced growth, the majority of which is ascribed to the process of firm selection.

Coelli, Moxnes, and Ulltveit-Moe (2018) expands the significance of market size by confirming its effect in the domain of innovation. During the period named Great Liberalization (across the 1990s, when import tariffs were reduced from 6 to 3 percent in developed countries, and from 20 to 13 percent in developing countries), a freer market access was significantly positively correlated with innovation. During those years, a 1 percent decrease in weighted average tariffs was associated with a 2 percent increase in innovation (measured in terms of patent applications). In addition, improved market access does not imply a decrease in the quality of innovation: when using patent applications as a proxy for innovation, it can be inferred that a freer market requires a higher degree of intellectual property right protection, which consequently spurs patent applications in the form of mere safe backstops. This is not the case, as the number of average citations is not falling, as well as the economic value of each single patent; hence, the quality of the patents – and therefore of innovation – is unaffected, legitimizing the usage of patents as a proxy for innovation.

Though Bloom et al. (2011) showed mostly positive results related to Chinese-driven trade shocks in Western countries, subsequent studies found different results depending on the time frame or the socio-economic nature of importing countries. The results are evaluated according to several variables such as innovation, productivity, growth, wealth, and others.

Kueng et al. (2017) report conflicting results for Canadian firms exposed to Chinese import competition. Firstly, innovation activities are reduced for manufacturing firms, mostly because of a decline in process innovation rather than in product innovation. In fact, separate sets of surveys from 1999, 2001, 2003, and 2005, show that "firms that initially pursue process innovation strategies exhibit higher profits if they survive, but they are more likely to exit in response to Chinese competition. In contrast, firms that initially pursue product innovation strategies perform better, conditional on survival, with no notable change in exit probability" (Kueng, 2017).

Ahn et al. (2018) provide further support to the "escape-competition effect" by indicating that an increased trade exchange with China in both import and exports stimulated innovation among South Korean manufacturing firms. In the years 1996-2015, the positive correlation is mainly evident for large corporations rather than smaller firms, and only in sectors where there is initial technological supremacy by South Korea with regards to China.

Aghion et al. (2018) address the issue from the opposite direction, investigating the impact on innovation of export shocks. A positive export shock increases market size and therefore provides innovation incentives, especially for high-productivity firms. There is also evidence of an induced competition effect, which affects negatively low-productivity firms in terms of profit and innovation. In spite of the low/high-productivity diversification, this effect is applicable to all domestic firms; the market-size effect, on the other hand, is only relevant for exporting firms, and has it that only firms that have a solid production base combined with a low marginal cost would be able to enjoy the export market upgrading. In conclusion, the impact of an export shock in terms of innovation is magnified positively for high-productivity firms, and negatively for low-productivity firms.

Shu et al. (2018) confirm the hypothesis that the impact of import competition tends to be more positive for firms with a higher initial productivity. The analysis reviews two types of outcome in measuring innovation, in relation to productivity and trade liberalization: direct measures, such as R&D expenditure, patent applications, product mix, and adoption of new technologies; indirect measures, especially labor productivity and residual total factor productivity. The literature supports positive reactions to import competition shocks from the European business world and that of emerging economies, while the response is fairly negative for United States and Canada, where corporate R&D expenditure and process innovations are both reduced. If we abide by the guidelines set out in Bloom (2010), the reasons for this trend could be explained by factors of production being most likely "trapped" at firms in developing countries – and Europe – rather than in North America. Bernard, Jensen, and Schott (2005) emphasized this hypothesis in a non-trapped factor model, in which similar results regarding the United States' exposure to trade shocks are highlighted in the years 1977-97: following the "value share" approach outlined in Bernard et al., 2004), increasing imports from low-wage countries was negatively correlated with firm survival and growth; import shocks had also an impact in terms of reallocation in manufacturing establishments which is consistent with the results obtained by Bloom (2011) concerning Chinese imports into Europe, insofar as the production activity is mostly directed towards high-tech companies. Differently from Europe, firms that are severely affected by low-cost import shocks are quick to change sector in the United States.

Autor et al. (2017) report long-term negative consequences for American firms exposed to Chinese imports. During the years 1975-2013, both output (patenting) and input (R&D expenditure) margins decrease in response to imports. The response is confined to private-sector patenting activity but not to universities or government.

Akcigit, Ates, and Impullitti (2018) explain the contrasting results concerning Europe and North America in the previous literature by staging a model consisting of three highly innovative countries and one lowly innovative country where the removal of import tariffs triggers a rush for innovation. In this scenario, firms that cannot reach the minimum threshold of R&D expenditure required for innovation will be squeezed out of the market, while those firms that are already sufficiently innovative will further increase their innovation capability. As a general rule, the positive or negative effects of an import shock vary significantly from one country to another according to the technological advancement of domestic firms and their distribution across sectors.

(Bombardini et al. (2017) found that a sudden increase in import competition spurred innovation activities in China as well, but mainly for those firms which were already in the high-tech range of the market. In the years 2000-2007, China's accession to the World Trade Organization stimulated an increase in the patenting probability of high-tech firms by 3.6 - 4% for every percentage point drop in import tariffs. Trade liberalization also allowed such firms to enjoy a significant increase in R&D expenditures and in market shares as positive consequences of what can be called "escape-competition effect".

3. Theoretical Framework

3.1. Hypothesis

Within the perspective of trade liberalization, a trade shock consisting of changing import volumes from China to Europe will be positively correlated with an increase in the innovation capacity of European countries. The theoretical basis for this hypothesis lies in the framework set out by Bloom et al. (2010) in the Trapped Factors model: in a situation whereby workers in a high-wage country have some firm-specific human capital and capital has firm-specific adjustment costs, the factors of production cannot easily move across sectors, and are therefore restricted to the production of non-innovative goods; an import shock from a low wage country will generate a new and stronger competition for this kind of "old" products, which existing firms won't be able to fight on an equal footing; this is the case with Chinese imports, which are posing serious challenges to several European industries thanks to their lower price. Because of their inability to migrate to other sectors, the factor of productions in Europe are left with only one choice to counter this threat to their very survival: existing firms will be somehow compelled to innovate and upgrade their products in order to escape the asymmetrical competition arising from the consequences of trade liberalization.

In this analysis we go beyond the effects of the trade shock itself, focusing instead on the consequences of Chinese imports' long-term impact on the innovation activities in Europe. We refer to a broad concept of international trade policy, focusing primarily on the country-level analysis of trade volume changes, and enabling a heterogeneity across countries which allows for a more even capture of the resulting effect.

Earlier literature has it that trade liberalization's repercussions on welfare are ambivalent, especially in static terms, where a positive outcome is by definition balanced by an increase in inequality. On the other hand, dynamic effects give a more optimistic outlook, with trade liberalization encouraging innovation through technology spillovers and escape-competition effects (Akcigit et al., 2018).

3.2. Methodology

3.2.1 Model Specification

This analysis draws inspiration from the Trapped Factors model of innovation, where the positive correlation between a trade shock caused by imports from a low-wage country and innovation activities in high-wage countries is explained by the compelled innovative impetus as a way to escape the surging competition.

The panel data regression analysis is instrumental in estimating the relationship that exists between patent applications (our proxy variable for innovation) and the explanatory variables of trade-related innovation in Europe. Our main explanatory variable is imports from China, the major player behind the escape-competition innovation effect as theorized by Bloom et al. (2011). We run a regression analysis in order to estimate the correlation between different pairs of quantitative variables, and we seek to analyze and describe the results obtained from such test as a conclusion to our study. The pattern in the data is represented by the following equation:

$$\ln Patent = \beta 0 + \beta 1 \ln Imports + \beta 2 \ln Labor + \beta 3\ R\&D + \beta 1 \ln FDI + \beta 1 \ln FDI\_sq + \mu \quad (1)$$

Beside imports from China, other independent variables that we incorporate in our model and that can interact with patent applications include: Labor, FDI inflow, and the ratio of R&D expenditure over GDP. It is important to contextualize the effect of R&D expenditure as a comparison with that of imports from China, being both related to innovation activities. With regard to FDI inflow, we also add its squared term in order to account for the curve it produces. After obtaining a first estimate of the general picture, we divide our dataset into three different sections, in order to observe the specific behavior of variables in each single period. Every section encompasses five years, the first one running from 2002 to 2006, the second one from 2007 to 2011, and the third one from 2012 to 2016.

3.2.2 Data

While earlier studies focus primarily on short period of time bracketing China's accession to the World Trade Organization, our analysis starts off directly from China's accession and goes as far as encompassing a 15-year time period, from 2002 to 2016. In our framework, we don't look at European Union member countries but, instead, at European countries in broader geographical terms: we deem this framework to be more suitable as we look at trade with China, considering the most recent developments in the sphere of investments and trade agreements concluded under the auspices of the Belt and Road Initiative.

The sample of 22 European countries has been collected according to each country's volume of Chinese imports, since this work is following the "trapped factors" model set up by Bloom et al. (2011) which regards Chinese imports as the primary source of competition-driven innovation activities. European countries with the largest Chinese import volumes across the years 2002-2016 have been selected for this analysis, the largest being Germany and the smaller being Belarus. Russia has been excluded for its geographical uniqueness and for the nature of its trade with China, which – differently from most of European countries – is dominated by the exchange of natural resources conducted between the Chinese-Russian border in eastern Asia. Although being extraordinarily amalgamated into the Russian sphere of influence, Belarus has been included in the analysis given its geographical position and its exponentially growing involvement in terms of investment and commerce with China in recent years.

Both primary and secondary sources are used in order to collect, access, and evaluate information. Theoretical information is mainly found in academic papers from the National Bureau of Economic Research (NBER), Stanford University, Massachusetts Institute of Technology (MIT), Centre for Economic Performance, Princeton University, University of Bologna, Collège de France, Journal of Economic Literature; statistical data is extracted from organization databases, such as OECD Structural Analysis Database, the World Bank, the European Statistical Office (Eurostat), UNESCO, and the World Intellectual Property Organization, which provide reliable and diverse historical data for GDP, trade flows, employment, and patent applications (direct and PCT national phase entries).

The GDP data in constant 2010 US dollars is collected from the World Bank for all countries except for Denmark and Romania, whose data is incomplete in such database; the GDP data for Denmark and Romania has been incorporated from the OECD Structural Analysis Database. The employment data for Belarus was collected from the National Statistical Committee of the Republic of Belarus.

Patent applications are used here as a proxy for innovation. Patent data is collected at application filing date instead of publication date, as conventional in the innovation literature, since it is temporally closer to the actual implementation of the innovation activity. Coelli et al. (2018) demonstrate that there is a strong link between patent application and R&D expenditure, or between patent application and other innovation measures. Furthermore, patent data can serve as a reliable proxy for innovation given its resistance to trade shocks in terms of quality. Because of the liberalization, a higher number of patent applications might as well have emerged as a response to the need for a tougher protection system; Coelli (2018) proved this hypothesis wrong by controlling the number of citations in each single patent and their economic value. Since both variables are not negatively affected by the market shock – and therefore patent quality does not decline – there is sound proof that "patent applications" is actually a reliable proxy for measuring innovation.

In collecting the data for patent application, we decided to focus only on those applications filed by actual residents of each country. In fact, as in the graphs shown in Figure 5 and Figure 6 for the two sample years 2006 and 2015, the share of patent applications filed by non-residents varies greatly over time, especially in certain countries such as Ireland, Czech Republic, Norway, Poland, and others, thus biasing the validity of our dependent variable. From a theoretical standpoint, it is safe to assume that the trade-driven innovation capacity of a country must be primarily significant for those citizens which are actually residents of that country, and therefore more exposed to the consequences of increasing import volumes.

Labor in this study is defined as the total number of employed persons (the total number of persons working in the various industries), aged 15 to 64; it is extracted from the Eurostat database for the years 2002 to 2016, except for Belarus, as mentioned above. FDI inflows represents the total value of inbound Foreign Direct Investments for each country, recorded annually by the World Bank and the International Monetary Fund; we include the squared term of this variable in order to control for the curve pattern produced in the FDI inflows interval.

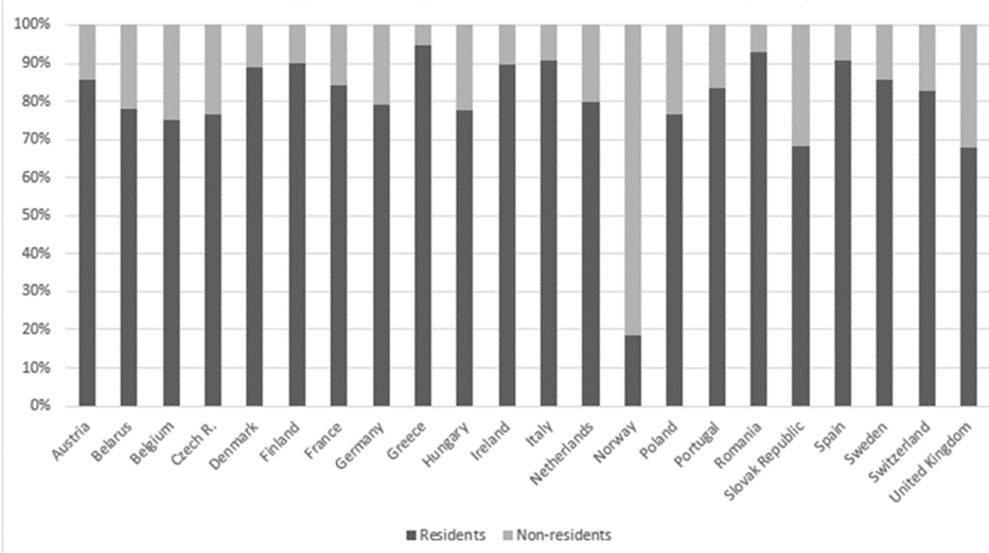

Figure 1. Patent applications by Residents and Non-residents (2006). Source: WIPO

In addition, we faced a choice concerning the very nature of the "imports from China" dataset used for this analysis: whereas the total value of Chinese imports is considered a straightforward measure, we found ourselves contemplating the usage of a potential substitute, namely the ratio of imports over the total trade with China (imports from China plus export to China). The latter measurement embraces the observation of two different variables instead of only one (imports and exports instead of imports only), and the significance of its values is therefore connected with the fluctuation of both variables: a decrease in the percentage share of imports over total trade could be symptomatic of a decrease of the import value itself, but also of an increase in the total value of exports included in the denominator. Hence, we came to the conclusion that the total value of imports would be more suitable to our model, as a "purer" representation of the changes in import volumes.

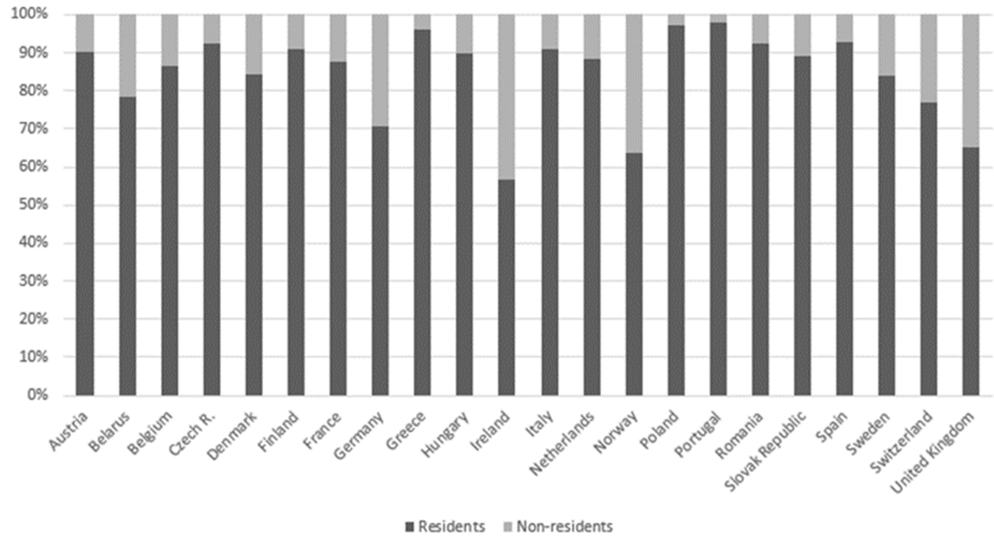

Figure 2. Patent applications by Residents and Non-residents (2015). Source: WIPO

4. Analysis of Results

Although our analysis is primarily aimed at estimating the role of Chinese imports in the scope of European innovation, there are several conclusions for us to infer. To begin with, we cannot only evaluate the mere effect of Chinese imports, but we also have to assess its uniformity across time periods of different lengths, as well as compare its impact with that of other innovation-related variables, such as the ratio of R&D expenditure to total GDP. The correlation with FDI inflow is also an interesting feature to observe, given its stability in our model paired up with a peculiar non-linearity. In the following sections we will analyze these effects separately, specifying the nature and magnitude of their impact. For each variable it has been employed the logged value, except for R&D expenditure to total GDP, which is in the form of ratio. The main results are presented in Column (1) of Table 1.

4.1 General results

Across the fifteen years of our sample, the impact from each one of our different variables changes in time according to its own specific features. Overall, it is recorded that imports from China have a positive correlation with patent application (in detail, a 10-percentage point increase in imports from China accounts for an average increase in innovation of 2.7% throughout the years 2002 to 2016). By looking at the p-value of Imports in Column (1) of Table 1, one could argue that the final results concerning our main variable are actually not significant. We can find a reasonable explanation for this by observing the single results obtained by the three different time periods in next section: in the regression analysis, the p-value of Imports changes dramatically at the moment we input the variable R&D expenditure, which is clearly the cause for this dysfunction (a comparison between statistical results before and after inputting R&D expenditure is shown in Appendix C); arguably, the ratio of R&D expenditure to total GDP displays a very positive correlation with patent applications, as already pointed out by Coelli (2018), and it is safe to assume that its cumbersome presence is somehow hindering the significance of our main variable (imports), whose underlying effect is, in any case, positively assessed.

Table 1. The Impact of Chinese Imports on Patent Applications in European Countries
Dependent variable is change in ln_Patents

	Panel Data Analysis of Random Effects			
	(1)	(2)	(3)	(4)
Variables	**2002-2016**	**2002-2006**	**2007-2011**	**2012-2016**
ln_Imports	.27278	-.11686***	.14419*	.26592**
	(.02986)	(.03197)	(.07402)	(.10554)
ln_Labor	.81426***	1.19425***	.91287***	1.01625***
	(.15287)	(.18946)	(.17320)	(.16721)
R&DtoGDP	19.01934***	.62167	17.90862**	23.21985***
	(5.81889)	(4.21997)	(8.19237)	(7.18196)
ln_FDI	.06999***	.09771	-.02113	.07268**
	(.02593)	(.11027)	(.04464)	(.02925)
ln_FDI_sq	-.00340***	-.00219	.00101	-.00457***
	(.00119)	(.00361)	(.00179)	(.00154)
_cons	-.43589	-3.01233	-1.89960	-4.40104
P> chi2	0.00000	0.00000	0.00000	0.00000
Wald chi2	65.26	45.09	57.20	113.61
Number of observations	324	103	109	109
Number of groups	22	22	22	22

Note: standard error in parentheses. *** p > 0.01; ** p > 0.05; * p > 0.1

The positive correlation between patent applications and imports is shown in the two graphs in Figure 3, the first image being a scatter plot generated by the two logged variables interacting with each other, and the second one showing the same results in the form of a linear prediction plot, featuring a darker coloration for the 95% confidence intervals. The same methodology is used to portray another important relationship, the one between patent applications and FDI inflows into each single country. The scatter plot graph and the linear prediction plot graph are reported in Figure 4.

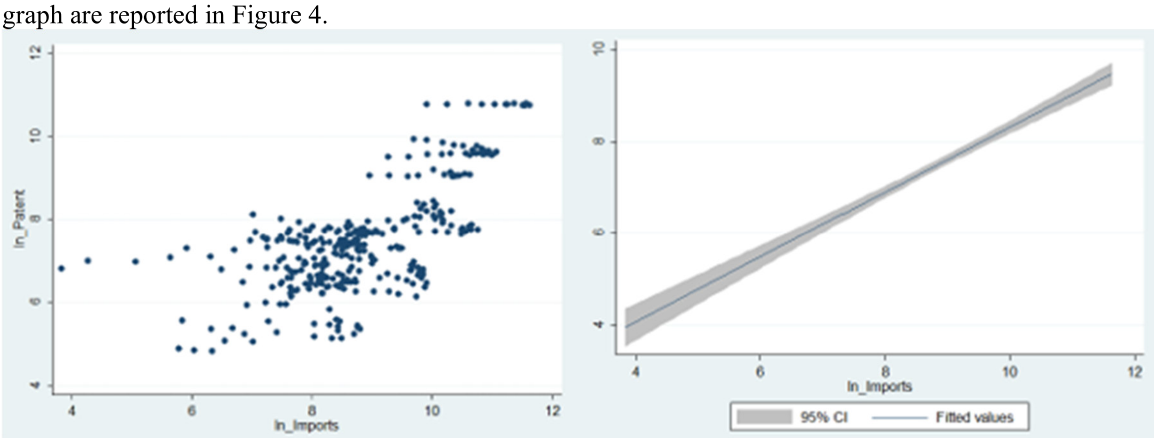

Figure 3. Patent applications and import correlation (scatter and linear).

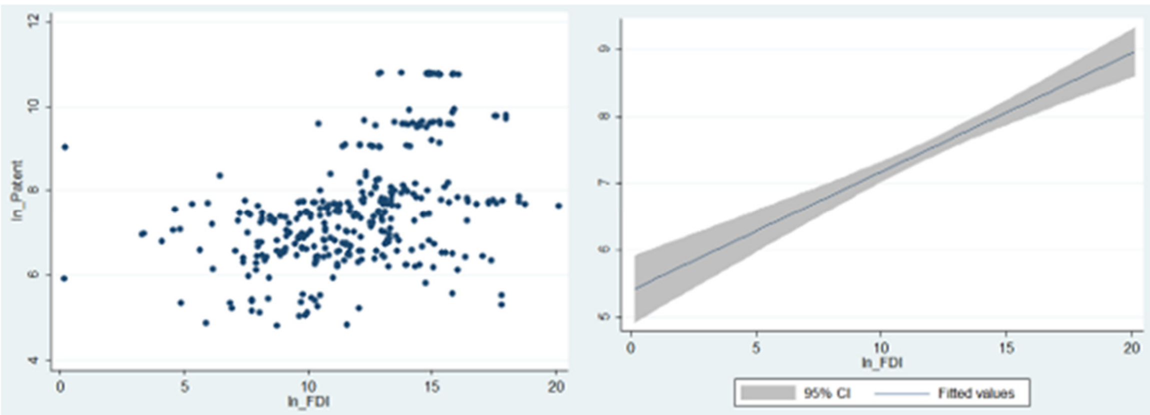

Figure 4. Patent applications and import correlation (scatter and linear).

As expounded in the next paragraph, the overall result for the impact of Chinese imports is somehow little, especially when compared with that displayed by the analysis of the single time periods 2007-2011 and 2012-2016.

Given the negative outcome emerging from the first section (years 2002 to 2006), this result is somehow understandable, as it balances the different magnitudes corresponding to each different growing stage. The positive correlation between imports and patent applications is easier to understand by looking at its evolution across the years.

4.2 Results by time period

In order to better observe and account for the swinging trend of our main variable, we divide our dataset into three separate sections, each of them encompassing five years. After that, we run the model again for each single time frame; the results are presented in Table 1, respectively: in Column (2) for the years 2002 to 2006; in Column (3) for the years 2007 to 2011; and in Column (4) for 2012 to 2016.

With respect to the years 2002 to 2006, we observe a negative correlation between patent applications and imports from China. During these first five years after China's accession to the WTO, arguably, it had not passed enough time yet for import volume variations to manifest their effect on innovation activities. This first section is the most problematic, as even the effect of other variables – such as FDI inflows and the ratio of R&D expenditure to total GDP – is not clear.

In the second time section (Column (3)), the results associated with our expectations start to take shape: in the years 2007 to 2011, a 10 percentage point increase in imports from China corresponds to a 1.4% increase in patent applications, and starts to assume a positive position along the lines of the general results for the whole 15-year period. Likewise, R&D expenditure is also entering its later stage, with its positive impact on innovation far exceeding the one generated by imports. The convoluted p-value displayed by FDI inflows is again obfuscating the actual role this variable has in our model.

The final time period is the most eloquent expression of this whole experiment: during the years 2012 to 2016, the coefficient of Chinese imports keeps on growing, almost getting to the point of the one accounting for the whole 15-year period. The ratio of R&D expenditure to total GDP displays a linear growth as well, and the weight of its effect is visibly the largest on the table; in fact, its cumbersome presence is somehow hindering the significance of our main variable (imports), whose underlying effect is, in any case, positively assessed.

4.3 FDI inflows

It is interesting to look at the role of FDI inflow, and at the way it is correlated with patent applications. Whereas the general outlook seems positive, when we analyze each single 5-year time frame, we observe that the behavior of FDI inflow is not linear. In the years 2002 to 2006 the coefficient is positive, while it is negative in the years 2007 to 2011, but in both cases the effect is not clear; in the last period, from 2012 to 2016, FDI inflow has a clear and positive effect. We include the squared term in the panel data regression in order to detect the pattern in the scope of the FDI inflows interval. By using a simple equation, we estimate the behavior of FDI inflows and identify the turning point at which its effect on patent applications ceases to be positive and enters a regressive tendency. We identify this turning point in our data sample at ln_FDIinflow = 10.2625 approximately, which in real terms is translated in 5.352 billion US dollars in inward Foreign Direct Investment. Therefore, the correlation between FDI inflows and patent applications for the European countries in our sample across the years 2002 to 2016 takes the form of an "inverted-U curve", with the value of 5.352 billion US dollars considered as a turning point at which FDI inflows stops increasing linearly with patent applications and enters into a negative correlation trend.

4.4 Extensions – Exports to China

It could be argued that, as well as imports from China, exports from China into European countries might also affect innovation, especially through the market size effect, as shown by Aghion (2018) in relation to France. We construct a model that's similar to our main experiment, by substituting imports with an "Exports to China" variable compiled with data from OECD. The overall results show a positive correlation, with values that are somehow comparable to those found in our main import-driven model. The time period subdivisions in Table 2 allow us to more accurately assess the behavior of exports as a stimulator of innovation activities.

The 2002-2006 section in Column (2) is negative and not significant, consistent with the findings of Bloom (2011) who did not extend the study further than 2005. In the second and third section, however, we witness a positive correlation that grows exponentially along the same lines of what we have seen in the case of imports. On a side note, when compared to the effect of imports from China on patent applications, the impact of exports is still weaker and it is slightly less significant.

We then go as far as saying that exports to China were initially unlikely to significantly spur innovation, consistently with Bloom (2011), but that their role has changed in most recent years: with China's technological capacity growing steadily and outmatching that of several European countries, as well as wealthier Chinese middle class booming in urbanized areas, the export-related innovation effects take on a new significance for European businesses; as positive as it may get, the impact of exports is still not as weighty as that of other variables we observed, such as imports from China and R&D expenditure.

Table 2. The Impact of Exports to China on Patent Applications in European Countries
Dependent variable: ln_Patents

	Panel Data Analysis of Random Effects			
	(1)	(2)	(3)	(4)
Variables	**2002-2016**	**2002-2006**	**2007-2011**	**2012-2016**
ln_Exports	.03519	-.00459	.19055***	.12907*
	(.02493)	(.03894)	(.04340)	(.07417)
ln_Labor	.98221***	1.07158***	.98523***	1.16989***
	(.11516)	(.16305)	(.12217)	(.13638)
R&DtoGDP	18.97034***	-1.82861	13.89028*	27.63150***
	(5.92649)	(4.86950)	(8.09939)	(7.41218)
ln_FDI	.07194***	.02458	-.00620	.07070**
	(.02680)	(.02191)	(.04455)	(.03061)
ln_FDI_sq	-.00342***	-.00111	.00064	-.00454***
	(.00123)	(.00106)	(.00178)	(.00160)
_cons	-1.95162	-3.01233	-2.77556	-4.38684
P> chi2	0.00000	0.00000	0.00000	0.00000
Wald chi2	116.33	48.68	117.34	131.63
Number of observations	324	106	109	109
Number of groups	22	22	22	22

Note: standard error in parentheses. *** p > 0.01; ** p > 0.05; * p > 0.1

5. Conclusions

We sought to observe the extent to which volume changes in imports from China affect innovation activities in Europe, which are delineated here as total applications of new patents by the residents of each single country. The effect is positive but weaker than the one recorded by Bloom (2011). First of all, Bloom (2011) focuses on the ten years embracing China's accession to the WTO, and by including a time period prior to such accession, it accounts for the sharp break between the two time periods. Our study does not include this earlier period, and therefore the import volume variations are less dramatic and follow a more regular pattern. In any case, we account for a positive correlation between patent applications and imports from China which exponentially grows in time; the low coefficient representing the whole 15-year period is due to the act of balancing the fluctuating behavior of such relationship: the first section of our sample (2002-2006) displays a slightly negative correlation, since the time passed since China's accession to the WTO was not yet enough for import volume variations to exert their effect on innovation activities; in the following years, the relationship between the two variables grew strongly on the positive side. Also, the magnitude of the said correlation might be weakened by the fact that China's economic rise goes hand in hand with a staggering increase in average wage, which is now overcoming that of several European countries; given the fact that China cannot be considered a low wage country anymore, the innovation-spurring effect of its exports is no longer covered by the theoretical assumptions of the trapped factors model, where increasing import volumes from a low-wage countries are stimulating innovation through an escape-competition effect. Same goes for certain European countries that, after entering a downward spiral several years ago, never really recovered and are now suffering both socially and economically.

One more contribution to the larger body of knowledge is related to the role of FDI inflows in relation to patent applications: according to our results, FDI inflows in European countries across the years 2002 to 2016 have a positive correlation with patenting, but only up a certain point; in fact, when FDI inflows exceed a certain turning point (identified in our sample with the value of 5.352 billion US dollars), their effect on patent applications stops being positive and enters a negative tendency, in a pattern that can be visualized as an "inverted-U curve".

R&D expenditure over total GDP is the single most influential variable in this study, with its positive effect on patenting outshining that of every other variable; its bulky presence is shown to be somehow hampering the significance of our main value of interest, namely imports from China. We also observe the weight of European exports to China, and report that their impact on patent applications in European countries is also positive, but not as strong and significant as other variables that we evaluated, such as imports from China and, in particular, R&D expenditure.

5.1 Policy implications

In light of what has been said in the previous paragraph, it is reasonable for business entities and policymakers to understand and quantify the actual impact of trading with China. Imports from China and innovation activities in Europe are correlated; in this moment in time when China's rise on the world stage has reached unprecedented levels, it becomes fundamental for all parties involved to be able to recognize the ramifications of such extraordinary event.

Empirical evidence, consistent with previous studies on the subject, suggests that there is a positive correlation between imports from China and the total number of patent applications in European countries. The recorded growth is expected to be exponential, as our commercial world is witnessing the occurrence of a peculiar state of affairs: China is set to abandon the status of low-wage country, while several European countries are entering a downward economic trend; at the same time, China couples this technology improvements with an undiminished export capacity, which is still huge and able to provide Europe with a massive quantity of products at a relatively competitive price. In strictly economic terms, trade with China is at the present a unique chance of growth and internationalization, although still hampered by political frictions ad non-matching standards. Finding a good compromise in this constantly evolving scenario could be instrumental in securing a priority position in the globalized trade network that is being created through heavy investment projects and market expansion.

5.2 Prospects for future research

The results we presented can shed new light on the correlation between commercial ties with low-wage countries and innovation activities in high-wage countries, in particular with regard to certain trade liberalization issues that have recently become a primary concern for public and private entities alike.

As we look at the theoretical and empirical results, we must keep in mind that a research in this field by its own nature imposes certain limitations on the study and analysis. For instance, innovation is by definition not clearly defined, and therefore difficult to quantify and describe. Moreover, given the speed rate at which China and other developing countries are growing, it is difficult to frame their long-term trade-related impact in one model only, as their internal market is changing yearly. Whereas China can be considered a low-wage country in the 2000s, this definition cannot properly suit the country’s economic situation in 2015.

Along these lines, there are indeed several unresolved issues which can be taken into consideration for future research, in order to extend the body of knowledge and lay out a more comprehensive framework concerning this interesting and very pressing contemporary topic.

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Appendix A

Patent applications breakdown for the year 2009*

Year	Residents	Non-residents	Total
Austria	2263	292	2555
Belarus	1753	173	1926
Belgium	669	148	817
Czech R.	789	92	881
Denmark	1518	131	1649
Finland	1806	127	1933
France	14100	1593	15693
Germany	47859	11724	59583
Greece	698	22	720
Hungary	757	30	787
Ireland	908	53	961
Italy	8814	903	9717
Netherlands	2575	279	2854
Norway	1246	2358	3604
Poland	2899	241	3140
Portugal	571	46	617
Romania	1054	37	1091
Slovak R.	176	63	239
Spain	3596	207	3803
Sweden	2186	463	2649
Switzerland	1684	394	2078
UK	15985	6480	22465

Source: compiled by Author with information from OECD

*We picked the year 2009 as an example for this display as it is the median year in our 15-year sample.

Appendix B1

Statistical Bulletin of Imports from China, Total Trade in Goods (US Dollars, Thousands) 2002-06

Country	2002	2003	2004	2005	2006
Austria	1317085,69	1994972,00	2710712,14	3663346,36	4666446,31
Belarus	46473,00	71775,00	158016,00	284103,00	548615,00
Belgium	4483285,00	6209906,00	8310300,00	10811542,00	12644910,00
Czech R.	2151254,00	2681355,00	3511680,00	3924158,00	5711365,00
Denmark	1401269,00	2068991,00	2681942,00	3609716,00	4451729,00
Finland	1165464,00	1774841,00	2445418,00	3491941,00	5146041,00
France	10693297,00	15035689,00	20520022,00	25957090,00	30100036,00
Germany	20003681,00	28197341,00	40198888,00	50308894,00	62805681,00
Greece	1006466,00	1383112,00	1764602,00	2121195,00	2283667,00
Hungary	2084878,00	3298099,00	2874298,00	3587953,00	3858845,00
Ireland	1408080,00	2509257,00	3532718,00	4618218,00	5581796,00
Italy	7832903,00	10787436,00	14699244,00	17574868,00	22465431,00
Netherlands	8075798,00	11769061,00	17827987,00	23315724,00	28713521,00
Norway	1852017,00	1744103,00	2406521,00	3112307,00	3662628,00
Poland	2050109,00	2861560,00	4064568,00	5496607,00	7711682,00
Portugal	324891,00	419777,00	569987,00	703301,00	966149,00
Romania	372502,00	662065,00	1063524,00	1633013,00	2186618,00
Slovak Republic	346529,00	558786,00	797079,00	1114141,00	1670198,00
Spain	5463059,00	7623031,00	10613252,00	14557161,00	18050438,00
Sweden	1125900,00	1796437,00	2396615,00	3012099,00	3938725,00
Switzerland	1423756,00	1801300,00	2287952,00	2714221,00	3138035,00
UK	16212725,00	20189144,00	26342081,00	31785924,00	36976088,00

Source: compiled by Author with information from OECD.

Appendix B2

Statistical Bulletin of Imports from China, Total Trade in Goods (US Dollars, Thousands) 2007-11

Country	2007	2008	2009	2010	2011
Austria	5423080,39	7185964,77	6184085,97	7101380,75	8899480,09
Belarus	815791,00	1414812,00	1080126,00	1684084,00	2166471,00
Belgium	17011503,00	19481063,00	14477661,00	16085272,00	20151706,00
Czech R.	9193963,00	12386268,00	10470914,00	15332151,00	18905321,00
Denmark	5493660,00	6485964,00	5369014,00	6367614,00	6705671,00
Finland	6080915,00	6412777,00	4820847,00	5014485,00	3035973,00
France	38714224,00	45493989,00	41252583,00	48872681,00	56189433,00
Germany	74787152,00	86360220,00	77242640,00	101377133,00	112184062,00
Greece	3830294,00	4865081,00	4242968,00	3797415,00	3467939,00
Hungary	5128121,00	6129649,00	4949087,00	6173898,00	6076206,00
Ireland	6556427,00	5756412,00	3591183,00	3344747,00	3574478,00
Italy	29715296,00	34789589,00	26912057,00	38134114,00	41131342,00
Netherlands	35978534,00	36641208,00	30412100,00	40899877,00	42497105,00
Norway	4850662,00	5762374,00	5349101,00	6555804,00	8245490,00
Poland	11753417,00	16797908,00	13780180,00	16514374,00	18116250,00
Portugal	1437468,00	1956519,00	1543800,00	2079759,00	2077753,00
Romania	2284511,00	3505096,00	2646080,00	3381517,00	3524775,00
Slovak Republic	3091981,00	4173214,00	3122115,00	4003766,00	4643541,00
Spain	25382674,00	30279433,00	20166444,00	25071366,00	25932836,00
Sweden	5296175,00	5685492,00	4568077,00	7407657,00	6845033,00
Switzerland	3986579,00	4641568,00	4714293,00	5848179,00	7119261,00
UK	46624661,00	50330871,00	43434342,00	52398421,00	56807417,00

Source: compiled by Author with information from OECD.

Appendix B3

Statistical Bulletin of Imports from China, Total Trade in Goods (US Dollars, Thousands) 2012-16

Country	2012	2013	2014	2015	2016
Austria	8577141,56	8927902,40	9625626,15	8756280,01	5813408,18
Belarus	2345021,00	2827152,00	947958,00	2321406,00	2117296,00
Belgium	17348824,00	18514317,00	18108907,00	16212822,00	16173278,00
Czech R.	15672786,00	15486206,00	17426277,00	18998267,00	17770970,00
Denmark	6405170,00	6573975,00	7113521,00	6375316,00	6441266,00
Finland	5882450,00	4857719,00	4950628,00	4368658,00	4456431,00
France	53458273,00	54221963,00	56416480,00	51871364,00	51032598,00
Germany	102389745,00	100313473,00	107593170,00	103348242,00	105289753,00
Greece	2944647,00	2914167,00	3313758,00	2831346,00	3194687,00
Hungary	5408549,00	5312914,00	5103185,00	4776877,00	4868856,00
Ireland	3547683,00	3998043,00	4500699,00	4766005,00	4579105,00
Italy	32162562,00	30634044,00	33305149,00	31315511,00	30194171,00
Netherlands	41012544,00	42060625,00	47026706,00	38433062,00	35846316,00
Norway	8077563,00	8260525,00	8484222,00	8126388,00	8011716,00
Poland	17258096,00	19300516,00	22992572,00	22380369,00	23447667,00
Portugal	1789521,00	1819906,00	2123608,00	1970979,00	2012714,00
Romania	2687505,00	2620886,00	3149705,00	3205017,00	3818301,00
Slovak Republic	4855332,00	6072253,00	6676017,00	6432928,00	6348683,00
Spain	22671308,00	23059557,00	26227845,00	26474440,00	26404752,00
Sweden	6621088,00	6720462,00	7292223,00	6986536,00	6511679,00
Switzerland	11072618,00	12334782,00	13284726,00	12957716,00	12576584,00
United Kingdom	56267400,00	57587865,00	64147254,00	62979614,00	59575883,00

Source: compiled by Author with information from OECD.

Appendix C

Comparison between panel data regression analysis with and without R&D expenditure over GDP

Dependent variable is change in ln_Patents

	Panel Data Analysis of Random Effects			
Variables	**2002-2016**	**2002-2006**	**2007-2011**	**2012-2016**
ln_Imports	.27278	-.11686***	.14419*	.26592**
	(.02986)	(.03197)	(.07402)	(.10554)
ln_Labor	.81426***	1.19425***	.91287***	1.01625***
	(.15287)	(.18946)	(.17320)	(.16721)
R&DtoGDP	**19.01934*****	**.62167**	**17.90862****	**23.21985*****
	(5.81889)	(4.21997)	(8.19237)	(7.18196)
ln_FDI	.06999***	.09771	-.02113	.07268**
	(.02593)	(.11027)	(.04464)	(.02925)
ln_FDI_sq	-.00340***	-.00219	.00101	-.00457***
	(.00119)	(.00361)	(.00179)	(.00154)
_cons	-.43589	-3.01233	-1.89960	-4.40104

Note: standard error in parentheses. *** p > 0.01; ** p > 0.05; * p > 0.1

Dependent variable is change in ln_Patents

	Panel Data Analysis of Random Effects			
Variables	**2002-2016**	**2002-2006**	**2007-2011**	**2012-2016**
ln_Imports	.07208***	-.11729***	.15607**	.29936***
	(.02672)	(.02996)	(.07437)	(.10981)
ln_Labor	.73732***	1.18009***	.87142***	.97821***
	(.16159)	(.20121)	(.18675)	(.17708)
ln_FDI	.07425***	.10149	-.02672	.06427**
	(.02605)	(.10430)	(.04457)	(.02973)
ln_FDI_sq	-.00376***	-.00232	.00101	-.00393**
	(.00118)	(.00341)	(.00179)	(.00154)
_cons	.0998388	-2.90473	-1.33206	-4.02549

Note: standard error in parentheses. *** p > 0.01; ** p > 0.05; * p > 0.1