Inflation in Times of Overlapping Emergencies: Systemically Significant Prices from an Input-output Perspective

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Abstract

In the overlapping global emergencies of the pandemic, climate change and geopolitical confrontations, supply shocks have become frequent and inflation has returned. This raises the question how sector-specific shocks are related to overall price stability. This paper simulates price shocks in an input-output model to identify sectors which present systemic vulnerabilities for monetary stability in the US. We call these prices systemically significant. We find that in our simulations the pre-pandemic average price volatilities and the price shocks in the COVID-19 and Ukraine war inflation yield an almost identical set of systemically significant prices. The sectors with systemically significant prices fall into three groups: energy, basic production inputs other than energy, basic necessities, and commercial and financial infrastructure. Specifically, they are "Petroleum and coal products", "Oil and gas extraction", "Utilities", "Chemical products", "Farms", "Food and beverage and tobacco products", "Housing", and "Wholesale trade". We argue that in times of overlapping emergencies, economic stabilization needs to go beyond monetary policy and requires institutions and policies that can target these systemically significant sectors.

JEL Codes: C67, E31, E61

Keywords: Inflation; Systematically significant prices; Input-output analysis; Cost-push price formation.

*The authors would like to thank Léonce Ndikumana, Fabricio Pitombo Leite, Robert Pollin, Claudia Sahm, Gregor Semieniuk, and the participants in the Democratic Central Banking workshop at the University of Amsterdam and the economics seminar at American University for their valuable comments on a previous draft, and Evan Wasner for research assistance. We gratefully acknowledge funding by the Groundwork Collaborative and the Political Economy Research Institute.

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Introduction

Global inflation has returned since economies have transitioned out of the COVID-19 shutdowns. The increase in prices has been highly sectoral in the initial phase before emerging throughout the broader economy. The specific price increases can be traced to shocks like supply chain issues and turbulences in global commodity markets that intensified with the war in Ukraine (Bank of International Settlement, 2022). It seems likely that such sectoral shocks will become a more frequent phenomenon in the context of overlapping global emergencies. Geographically-specific changes in temperature and extreme weather events, as well as sanctions – as, for example, in the cases of Russia and China – can have far-ranging implications for the prices of specific goods. This raises the question of how sector-specific shocks are related to overall price stability and whether shocks in some sectors matter more for general price stability than in others. This paper proposes a method to identify industries which present systemic vulnerabilities for monetary stability in the US. We call these prices systemically significant following Hockett and Omarova (2016).[1]

We use simulations of price shocks in an input-output model to pursue an alternative approach to the view that inflation is exclusively macroeconomic in origin. In policy debates, most economists have until recently tended to see inflation as a purely macroeconomic phenomenon: Monetarists as the result of "too much money chasing too few goods" and New Keynesians as a matter of the relation between aggregate demand and capacity utilization. The key variables to control inflation from both perspectives are thus macroeconomic: the quantity of money and government spending. Leontief (1986[1979], p. 422-3) called this an "aggregative approach", "according to which the economy can be controlled effectively through skillful manipulation of a few strategic aggregate variables, such as total government revenue and outlays, the total money supply, and the rate of interest". Today's institutions of economic stabilization are grounded on this aggregative approach. In the current round of inflation, this has implied that central banks, as the institutions responsible for monetary stability, have no adequate tools at hand to counter commodity specific price shocks – as Fed Chair Powell (2022) confirmed during a Congressional Hearing. But the energy crisis, shortages of critical inputs and price rises in response to environmental shocks like the drying up of rivers are difficult to handle in aggregative terms.[2]

By identifying the specific sectors that matter most for general price stability, we contribute to the ongoing expansion of the toolbox of stabilization policies. When faced with large sectoral shocks, it is not sufficient for monetary stabilization to rely on purely macroeconomic means designed to respond to demand-pull inflation. As a result, we have witnessed a return of windfall profit taxes, anti-trust measures, price gouging policies and direct price stabilization as part of the policy toolbox to respond to inflation in Europe and in the US. For the most part, governments pulled together these measures in an ad hoc fashion and were reactive in the sense that they only put them

[1] Note that while wages are certainly systemically significant, this paper focuses on the prices of goods and services.

[2] Leontief observed this in relation to the 1970s: "Questions raised by the energy crisis, potential shortages of some basic raw materials, and the problems of environment cannot be treated ... in aggregative terms." (1986[1979], p. 422-3)

into effect when inflation had already climbed to levels not seen in decades. As shocks are likely to become more systemic in the context of overlapping emergencies, a form of economic disaster preparedness to protect the points of greatest vulnerability becomes relevant for monetary stability even beyond today's inflation. We need to be able to respond to shocks to systemically significant prices before they unleash a broader inflationary dynamic. This paper aims to introduce a method that can help target such micro policies that can complement macroeconomic stabilization.

We use a Leontief price model. This "method of systematically quantifying the mutual interrelationships among the various sectors of a complex economic system" (Leontief, 1985) allows us to study cost-price structures in their interrelationships. The Leontief price model has been employed, for example, to model the impacts of tax changes (Melvin, 1979; Boratyński, 2002) and energy price shocks (Tunali and Aydogus, 2007).[3] We simulate how in an input-output setup a price shock in any specific industry cascades as a cost shock through the whole system, leading to changes in the general price level. This means that we not only take direct effects of a price change on the consumer price index into account, but also the myriad of indirect effects that follow from cost changes in other sectors. Simulating shocks to each of the 71 industries in the input-output table published by the U.S. Bureau of Economic Analysis, we identify the industries that have the greatest total inflation impact and are as such systemically significant for price stability. We use the magnitudes of average price volatilities between 2000 and 2019 as shocks in our simulation to identify latent systemically significant prices in the two decades prior to the present inflation. We compare these latent systemically significant prices with the sectors that acquire systemic significance when we use the price shocks as they occurred in the post-shutdown inflation and in the context of the war in Ukraine.

We find that the sectors that matter most are largely the same when we consider the pre-pandemic average price volatilities and the price shocks in the present inflation. Yet, the average magnitude of the simulated total inflation impact has about tripled in the post-shutdown inflation and in the context of the war in Ukraine compared to the latent inflation impact simulations. Simply put, the latent systemic significance of the pre-pandemic economy has been realized in the post-shutdown and Ukraine war inflation. We can broadly group the sectors with the greatest systemic significance for price stability into three types: energy, basic production inputs other than energy, basic necessities, and commercial and financial infrastructure. Eight out of the top ten latently significant prices have also been identified as the most systemically significant prices in the post-shutdown and the Ukraine war inflation in our simulations. They are "Petroleum and coal products", "Oil and gas extraction", "Farms", "Food and beverage and tobacco products", "Chemical products", "Housing", "Utilities", and "Wholesale trade" – ordered based on their latent systemical significance. The only two exceptions, where latent systemically significant prices were not confirmed as important in the current inflation, are "Federal Reserve banks, credit intermediation, and related activities" – a limited input-output representation of banking services, and "Other retail" – a residual category. This suggests that the points of vulnerability for price stability were already present

[3] For a brief literature review of applications of the Leontief price model, see (Sharify & Sancho, 2011).

before the pandemic.

Our baseline model assumes nominal wages and profits to remain constant after a price shock. But an increase in the CPI that follows from price shocks reduces real wages and can alter profit rates in some sectors. This may trigger conflict inflation (Rowthorn, 1977), where wage and profit earners try to compensate their losses. Conflict inflation can transform a price shock into sustained price rises. We simulate such wage and profit adjustments and find that the same sectors remain systemically significant.

This paper contributes to a long-standing literature that traces a relation between relative prices and the general price level dating back to the pioneering work of Mitchell (1913)[4] and Mills (1927). A number of more recent studies have shown that when the distribution of relative price-changes is right skewed, inflation occurs (Ball & Mankiw, 1995; Debelle & Lamont, 1997). Others have found a positive or a U-shaped relationship between relative price variability and inflation (Choi, 2010; Reis & Watson, 2010). While this literature is concerned with the distribution of changes in relative prices, yet another set of studies has focused on the inflation impact of shocks in one specific commodity, most prominently oil (Blinder, 1983; Hamilton, 1983, 2009). Most recent empirical contributions use a probabilistic method: examining the stochastic relation between certain properties of changes in relative prices and the general price level. This paper pursues an alternative theoretical and empirical approach by considering the mutual relationships of specific prices within a production network. Prices in our framework are linked because any one's price is always someone else's cost and thus influences the latter's price.

From a production network perspective of interrelated prices, actual inflation is both a change in relative prices and in the average price level (Leontief, 1974). This relies on the assumption that some prices going up does not mean that other prices are going down by the same rate. To the contrary, increases in the prices of some sectors push up the costs for other sectors through their input-output relationships. In fact, empirical research shows that cost increases lead to price increases which outpace the price reductions that occur when costs fall (Peltzman, 2000). Idiosyncratic the idea that inflation must involve changes in relative prices may seem, the grandmaster of macroeconomics, Keynes (1963 [1919], p. 80) himself, held the view that: "a change in the value of money, that is to say in the level of prices, is important only insofar as its incidence is unequal." This implies that inflation always involves far-ranging redistribution.

The rest of this article proceeds as follows: in the next section we develop our concept of systemically significant prices. The third section introduces the Leontief price model. The fourth section presents our analysis of systemically significant prices in the United States. The fifth section examines systemically significant prices in the context of conflict inflation. The final section concludes and discusses the implications of our analysis for stabilization policy and institutional capacity.

[4] O'Sullivan (2022) develops the importance of Mitchell as an alternative to the orthodox business cycle theory of Friedman and Schwartz (1963), emphasizing the central role of relative price changes in Mitchell's work.

Defining systematically significant prices

The bailouts of the "too-big-to-fail" players during the 2008 financial crisis, decisions over which industries can be shut down and which ones need to stay open in the context of the COVID-19 pandemic, and the looming gas shortages in Europe have all shown that policy makers decide ad hoc which economic activities are systemically significant. This raises the question of how systemically significant can be defined. After the financial crisis, the international Financial Stability Board (2011), for example, defined systemically important financial institutions as those "whose distress or disorderly failure, because of their size, complexity and systemic interconnectedness, would cause significant disruption to the wider financial system and economic activity". Taking the lead from this notion of systemic importance in the financial system, Hockett and Omarova (2016) argue that not only financial firms and utilities, but also non-financial prices can acquire systemic significance for financial stability. We build on Hockett and Omarova's argument using a Leontiefian approach to inflation and suggest that systemically significant prices are not only important for financial but also for monetary stability. Using the analytical tools of input-output, we operationalize the notion of systemic significance as a particular point of vulnerability in a measurable form to identify prices that matter most for inflation.

Input-output models have been used to identify strategic vulnerabilities since the Second World War, when Leontief and other economists assisted the American war effort by identifying targets for precision bombing on German industrial facilities (Bollard, 2020, pp. 190-5; Collier and Lakoff, 2021, 39-83; Foley, 1997, p. 119). The assumption was that "it was preferable to cause a high degree of destruction in a few really essential industries than a small degree of destruction in many industries" in order to destroy the enemy's war economy (Webster and Frankland, 1961 as in Parks, 1995, p. 145). In more recent years, Leontief's input-output method has also been used in risk management studies to identify economic units or critical infrastructures which, when hit by a terrorist attack or natural disaster, generate large derivative losses due to cascading effects throughout the system (Haimes & Jiang, 2001; Jiang & Haimes, 2004).

We use this same Leontiefian quantitative, inductive approach (Amsden, 1995; Leontief, 1986, p. 3) to develop an empirical method to identify systemically significant prices, and detect the industries that present the greatest vulnerability for monetary stability. To this end, we simulate price shocks to a single industry in a single period in a Leontief price model. We determine the magnitude of change in a synthetic CPI when the price of any given industry is shocked by a given amount. We call this simulated change in the CPI the inflation impact.[5] In our framework, the most systemically significant prices are those that have the greatest impact on the general price level defined in terms of the CPI. This approach is in parallel with that used in strategic bombing and risk management for critical infrastructure. We identify the most vulnerable points in the price system and argue that they have the potential to acquire systemic significance for overall monetary stability.

[5] Whenever we refer to CPI in the rest of the paper, we refer to a synthetic CPI calculated with the consumption basket of the input-output tables provided by the Bureau of Economic Analysis.

Our input-output approach allows us to refine Hockett and Omarova's (2016 pp. 4-7) definition of systemically significant prices in finance which they derive from designations in the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010. They see three pathways to systemic significance: (1) "Ubiquity of the underlying value as a productive input", (2) "ubiquity of the underlying value as an investment asset", and (3) "Ubiquity of use of the price or index as a benchmark". Our approach comes closest to the first criterion. Ubiquity in production (1) could be understood as referring to what Piero Sraffa defined as basic goods. Sraffa's (1960) "criterion is whether a commodity enters (no matter whether directly or indirectly) into the production of all commodities" (p. 8). The problem with defining systemically significant prices as basic goods in this sense, however, is that, given the low level of granularity of the most recent input-output table for the US (71 industries), all goods and hence all prices would be basic. Even if we had an input-output table with a finer breakdown of industries, it would still be relevant to verify which basic goods were more important in explaining changes in the general price level and should as such be prioritized in stabilization policies.

With our method, we can consider not only for how many industries a good is an input but also the relative importance of an input in relation to all other industries. The most "ubiquitous" industries can then be understood as the ones most central in the production structure captured by an industry's forward linkages.[6] In other words, the most ubiquitous industries in our framework are those whose output is most important for the whole economic system as a direct and indirect input assessed in value terms.

To study the importance of specific industries for overall monetary stability, we are not only interested in the structural importance of an industry as captured by the ubiquity of its products, but also in the degree to which its prices tend to fluctuate, since we know that price volatility varies greatly across different sectors. Mitchell (1913, p. 102) already observed that the prices of raw materials fluctuate more than those of industrial products. Keynes (1938, 1943) and Kaldor (1983, pp. 15-17, 21-24) have also emphasized the heterogeneity in price fluctuations – an observation confirmed in recent empirical work (Bils & Klenow, 2004) – with raw materials showing violent fluctuations compared to other goods.[7] An industry that produces a very ubiquitous input but has very stable prices might thus have less of an impact on overall monetary stability than a less ubiquitous industry with a higher degree of price volatility. For example, "Management of companies

[6] Formally, forward linkages are defined as the row sum of the Leontief inverse matrix $L = (I - A)^{-1}$ of direct and indirect requirements. Forward linkages can be interpreted as the impact on the production of industry i of an increase in the final demand of all sectors by one unit. In other words, it is the amount by which the production of industry i would need to increase in order to allow for a unitary increase in total final demand. The higher the forward linkages of a sector, the more dependent is the productive structure of the whole economy on the good supplied by that sector.

[7] Keynes (1938, p. 450) points out: "the fluctuations in the prices of the principal raw materials which are produced and marketed in conditions of unrestricted competition, are quite staggering. This is the case not only during well-marked trade cycles, but as a result of all sorts of chance causes which lead to fluctuations in immediate demand. The extent of these is apt to be concealed from those who only watch the movements of index numbers and do not study individual commodities; since index numbers, partly by averaging and partly by including many commodities which are not marketed in fully competitive conditions, mask the short-period price fluctuations of the sensitive commodity."

and enterprises" is much more ubiquitous than "Oil and gas extraction". Nonetheless, the impact of the latter on general prices might be larger since its yearly price change has been much higher than that of the earlier sector for the whole period from 2000 to 2021.[8]Thus, instead of separating out goods with high price volatility as not belonging to the core CPI as is commonly done in economic analysis, we consider the systemwide implications of price volatility as transmitted through input-output relations in our simulation-based approach.

Importantly, systemic significance in our framework is not a static concept. The ubiquity of industries varies from economy to economy depending on structural characteristics and industries can acquire systemic significance in relation to monetary stability because of an evolution in production techniques over time or because of changes in price volatility. For example, oil was not as ubiquitous in production as it is today before the invention of the combustion engine and it might become less ubiquitous as a result of efforts to green our economies. Price volatilities in turn can change drastically with changes in the environment via climate change or, for example, as a result of shocks due to war. To take this historical specificity into account, we study the systemic significance of prices in relation to the specific production structure and price shocks of two recent episodes: the inflation of the post-COVID-19 shutdowns and the inflation spike following from the war in Ukraine. We also consider what we call industries' "latent" systemic significance by simulating individual industries' inflation impact using the average price volatility in the two decades before the COVID-19 pandemic (2000-2019).

The Leontief price model

The core premise of the Leontief price model is that the whole of the economy is a vast cross-sectoral network of cost-price linkages. This amounts to an "overall dependence among wage rates, profits earned, and taxes paid per unit of output in each of the many separate industries on the one hand and the prices of all different kinds of goods and services sold by these industries on the other" (Leontief, 1947). The starting point is similar to what Mitchell (1913) called a price system: "The prices ruling at any given time for the infinite variety of commodities, services, and rights which are being bought and sold constitute a system," he argued. "That is, these prices are so related to each other as to make a regular and connected whole."[9] This differs from the standard

[8]Sectoral price volatility for sector x is defined as the standard deviation of sector x's yearly percent price changes between the initial (2000) and final date (2019). Formally,

$$\sigma^x_{t_0,t_1} = \sqrt{\frac{1}{T}\sum_{t=t_0}^{t_1}(\Delta P^x_t - \Delta \bar{P}^x_{t_0,t_1})^2}$$

Where t_0 is the initial date, t_1 the final date, T the number of observations, $\Delta P^x_t = (P_t - P_{t-1})/P_{t-1}$ (percentage yearly price change with yearly data) and $\Delta \bar{P}^x_{t_0,t_1}$ the average yearly percentage price change between t_0 and t_1; the larger the deviations from the mean, the larger the standard deviation and hence the sectoral volatility.

[9]Mitchell builds on Veblen (1915), who suggests that "the whole concert of industrial operations is to be taken as a machine process, made up of interlocking detailed processes, rather than as a multiplicity of mechanical appliances

neoclassical perspective, where prices indicate the relative scarcity of factors of production and are linked through consumers' preferences and technical substitutability (Garegnani, 1970; Roncaglia, 2000).[10]

In the model the value of any industry's total output consists of the value of its domestic and imported inputs plus the total value added:

$$\hat{X}P = \hat{X}A'P + V + M \tag{1}$$

Where $\hat{X}$ is the diagonal matrix with the elements of the vector of total output for each sector (X), P is a vector of prices, A is the matrix with domestic direct technical coefficients, V is a vector of value added, and M is a vector of the value of imported inputs.

Dividing the output value by the quantity produced gives us the price per unit of output.

$$P = A'P + v + m \tag{2}$$

The price of an industry then depends on the cost of purchasing inputs from other industries, which is determined by the quantity of inputs required per unit of output (the technical coefficients which are assumed to be fixed) and their prices, and the costs per unit of output of value added (v) and imports (m). The value added can in turn be decomposed into wages (the nominal wage rate w times the number of workers L) and the value of profits (Π).

Assuming that the prices of all domestic sectors take the same functional form, this implies that it is possible to observe the interdependence of all industries in the price formation.[11]

$$P = (I - A')^{-1}(v + m) \tag{3}$$

We can represent the vector of prices of all sectors (P) by the direct and indirect technical coefficients table $(I - A')^{-1}$ of domestically produced inputs, the vector of value added per unit of output (v) and of the value of imports per unit of output (m).[12] The price of any industry is formed by the value added and imports per unit of its output and the value added and imports in all industries

each doing its particular work severally." (p. 7)

[10] As Vining and Elwertowski (1976) observe, "It is very nearly a truism among neoclassical economists that the public is wont to confuse changes in the general price level with relative price changes. Correspondingly, one might speak of the independence between the two as one of the central postulates of the neoclassical tradition" (p. 699). They show that this postulate is key to neoclassical theorizing of inflation from Jevons (1884), to Patinkin (1956), Lucas (1973), Friedman (1974) and Greenspan (1974). This same mindset is for example expressed by Allen Greenspan, the longest serving Fed Chair of recent times: "The relationship between the price of steel, for example, and the price of wheat is a relative concept-that is, it is deter- mined by the relative supplies and demands, and the absolute price level of each is not determined by that relationship, but by the aggregate price level." (as in Vining & Elwertowski, 1976, p. 699)

[11] Simulations in the model are done by altering this assumption and making specific sectors exogenous to the A table. This is presented in equation (4) below.

[12] A' is the transposed input-output direct coefficient table of a standard Leontief quantity model.

that supply inputs directly or indirectly (Bulmer-Thomas, 1982; Valadkhani and Mitchel, 2002; Miller and Blair, 2009). Modeling prices as interconnected in this way allows us to simulate how the increase in any one specific price "is transmitted to the rest of the economy step by step via the chain of transactions that links the whole system together" (Leontief, 1951), leading eventually to an increase in the general price level. In other words, we can simulate cost-push inflation. When the price of any one input increases, there is a direct effect on the price of each industry that uses this input, but there is also an indirect effect through the cost increase of other industries that use the output of the directly affected industries as input. In our model, wages and profits are assumed to be constant in nominal terms. This implies that real wages and the profit share in total output (production) of each sector falls as one price rises unleashing a cost shock. By abstracting from nominal wage and profit adjustments in our baseline model, we aim to isolate the cost-push impact of systemically significant prices from profiteering or wage-price spirals. [13]

The "physical aspects of production" are assumed to be fixed in a price model (Dietzenbacher, 1997, p. 631). Simply put, when costs change, prices change while the quantities produced and the technical coefficients stay constant. As such, the price model is a short run model. In actual input-output tables, we do not have separate data on prices and quantities, we only observe the total values (price times quantity). To separate quantities and prices, we can normalize the system by measuring quantities with Leontief units, meaning that the output of each sector is measured in such a way that all prices for that unit are equal to one.[14] This normalization is the basis of the Leontief price model and allows us to simulate a cost change. As we shock one price, the elements of the price vector become different from one, and we can interpret the final result as a percentage change in each sector's price.

While the Leontief price model assumes that costs determine prices as a general rule, we follow a Kaldorian approach in distinguishing the pricing in commodity markets from those of other goods.[15] We classify sectors according to their pricing regimes, as is common in the literature using input-output models to simulate the impact of subsidy removal (Hughes, 1986; Coady 2006) – a problem analogous to price shocks. Kaldor (1983) argues that – unlike the rest of the economy – commodity markets function more like auction markets. Here prices are determined by supply and demand on the part of traders rather than by the cost accounting of firms. This does not imply an equilibrium – quite to the contrary, fluctuations are wildest in commodity markets – but price movements are somewhat detached from costs. Based on this Kaldorian theory, we set all commodity sectors exogenous, meaning that their prices are not a function of all other prices in the input-output network. We proceed in the same way with rent-extracting activities in the finance, insurance and real estate industries, since these sectors also follow a different pricing logic.[16] Table 2

[13]This means that in the standard Leontief price model, prices are composed simply by adding up costs and the value added. Alternatively, one can think that pricing is a nominal markup over historical costs instead of a real markup over replacement costs. So, when costs go up, the profit share of the production value in each sector will fall.

[14]This same assumption is made in Leontief quantity models. All prices are considered equal to one, so the model can be interpreted in real terms.

[15]In the model this takes the form of altering equation (3).

[16]Figure A4 in the appendix plots the input and output prices by industry for all 71 sectors and presents some

in the appendix lists all 71 sectors in our input-output model. Sectors that have been set exogenous for all simulations are marked with an asterisk.

To apply the price model to empirical data and implement the price shock simulations, we need the following ingredients:

(a) A domestic industry-by-industry direct requirements table (matrix A in equation (1))

(b) Industry-level vectors of value added (or primary costs) and imports of intermediate inputs as shares of gross output (vectors v and m in equations (1) and (2))

(c) An industry-level vector of personal consumption, that is, a vector with the data on how much U.S. households spend on the domestic goods produced by each industry. We use this data to get the shares of personal consumption $c\hat{\imath}$ that are necessary to calculate a synthetic CPI

(d) Price data for the output of each sector, which enters as the price shock ΔP_X in equation (5)

We get (a), (b) and (c) from the Input-Output annual tables at the summary level (after redefinitions) provided by the BEA, which divides the economy into 71 industries. The step-by-step derivation of all these elements is provided in the appendix. For (d), we use the chain-type gross output price indexes by industry, also provided by the BEA. The output price-index for a particular sector is composed of a weighted average of the prices of all commodities produced by the sector. This makes the price data compatible with the input-output tables and vectors described above. We calculate the yearly percent price changes for each industry for selected periods and use these as the price shocks that enter our simulations.

To simulate a price shock, we set the sector in which the shock occurs as exogenous.[17] When one or more sectors are turned exogenous, equation (3) of the Leontief price model becomes:

$$P_E = (I - A'_{EE})^{-1} A'_{XE} P_X + (I - A'_{EE})^{-1}(v_E + m_E) \tag{4}$$

Where P_E and P_X are the vectors of prices of the endogenous and exogenous sectors, respectively.[18] Equation (4) shows that the overall change in the price level will depend on two factors: first, the magnitude of the exogenous price increases ΔP_X and, secondly, the input-output relationships between sectors, as captured by matrices $(I - A'_{EE})^{-1}$ and A'_{XE}. If there is an increase ΔP_X in the

descriptive empirical backing for our modeling choice which is based on economic theory. Note that output prices of commodities might move in parallel with input prices even though they don't follow a cost-plus markup logic because as prices increase, production expands, which brings in producers with higher costs.

[17] It is important to note that the already mentioned commodity sectors and rent-extracting activities in finance,insurance and real estate industries are always considered exogenous, even when they are not the object of the price shock.

[18] See the appendix for a detailed derivation of equation (4).

prices of exogenous sectors, and the quantity of inputs of the endogenous sectors remains constant, then the price increase of the endogenous sectors is given by:

$$\Delta P_E = (I - A'_{EE})^{-1} A'_{XE} \Delta P_X \quad (5)$$

Consider the following illustration: If there are N sectors, and only one sector is assumed to be exogenous – so ΔP_X is a scalar – then ΔP_E is a $(N-1) \times 1$ vector; element i of this vector, ΔP_E^i, is the percent change in the price of sector i caused by ΔP_X. To calculate the overall inflation that follows from the initial price change ΔP_X, we need to "average" ΔP_E and ΔP_X . Following Valadkhani & Mitchell (2002), we use the shares of personal consumption of each sector to produce the synthetic CPI. The total change in the synthetic CPI which results from the simulated price shock ΔP_X is what we refer to as the "inflation impact", and is the key figure which we use to rank systemic significance. It represents the change in the price of the average consumer basket for the U.S. economy that results from a specific price shock.[19] The magnitude of the inflation impact depends on the size of the price shock, the extent to which the shocked industry's output is used as direct and indirect inputs throughout the economy and the weights of the affected industries in consumers' baskets as captured by the synthetic CPI. The larger an industry's total inflation impact, the greater its systemic significance. More formally, we define IP_{tot} as "total inflation impact", which is composed of the "direct inflation impact" (IP_{dir}) and the "indirect inflation impact" (IP_{ind}). Let the share of industry i in personal consumption be c_i. If we assume that industry x is exogenous (so that c_x is sector x's share in personal consumption), we have:

$$IP_{dir} = c_x \Delta P_X \quad (6a)$$

$$IP_{ind} = \sum_{i \neq x} c_i \Delta P_E^i \quad (6b)$$

$$IP_{tot} = \sum_{i \neq x} c_i \Delta P_E^i + c_X \Delta P_X \quad (6c)$$

From these equations, we see that IP_{dir} is the percent change in the CPI directly caused by ΔP_X, IP_{ind} the change in the CPI indirectly caused by ΔP_X (through its effect on the prices of all other sectors), and the sum of the two is the total inflation impact caused by ΔP_X. The simulation results for these three measures are reported in percentage terms in the next section.

The simulated inflation impacts of sector specific shocks do not present a prediction in any strict sense – as Leontief (1986 [1947], p. 62) points out in relation to a similar kind of simulation exercise.

[19] If instead of using the shares of personal consumption, we used the shares of value added to average our vector of prices, we would get a synthetic GDP deflator instead of a synthetic CPI. This synthetic GDP deflator is used in other studies that perform simulations using the price model. Since our focus is on the effect price shocks have on consumers, we do not use this alternative measure of inflation impact.

We are conducting a simulation experiment which gives us what Leontief calls informed guesses "that make efficient use of available information" (ibid.). This kind of experiment can "contribute to (a) realistic understanding of the actual happening and to a reasonable appraisal of various ... alternatives" (ibid.). Importantly, it can allow a comparative assessment of which industries bear the greatest potential to unleash inflationary dynamics and hence present systemic vulnerabilities for monetary stability.

We distinguish between prices that have the potential to acquire systemic significance (latent systemic significance) and those that actually become systemically significant in the context of specific inflationary episodes. It is of important in the context of the current return of inflation to assess whether the prices that turned out to be particularly important drivers of inflation could have been identified before the present crisis. We start by using the magnitudes of average price volatilities in the two decades before the COVID-19 pandemic (2000-2019) as shocks and the economic structure of the US economy as represented in the 71 industries input-output table for 2019. This simulation generates a measure of latent systemic significance before the COVID-19 crisis. To compare this latent systemic significance with the COVID-19 inflation, we simulate the price shocks in the post-shutdown phase using annual price changes in the fourth quarter of 2021, and in the wake of the war in Ukraine using annual price changes in the second quarter of 2022.

Systemically significant prices in the United States, 2000-2022: Results

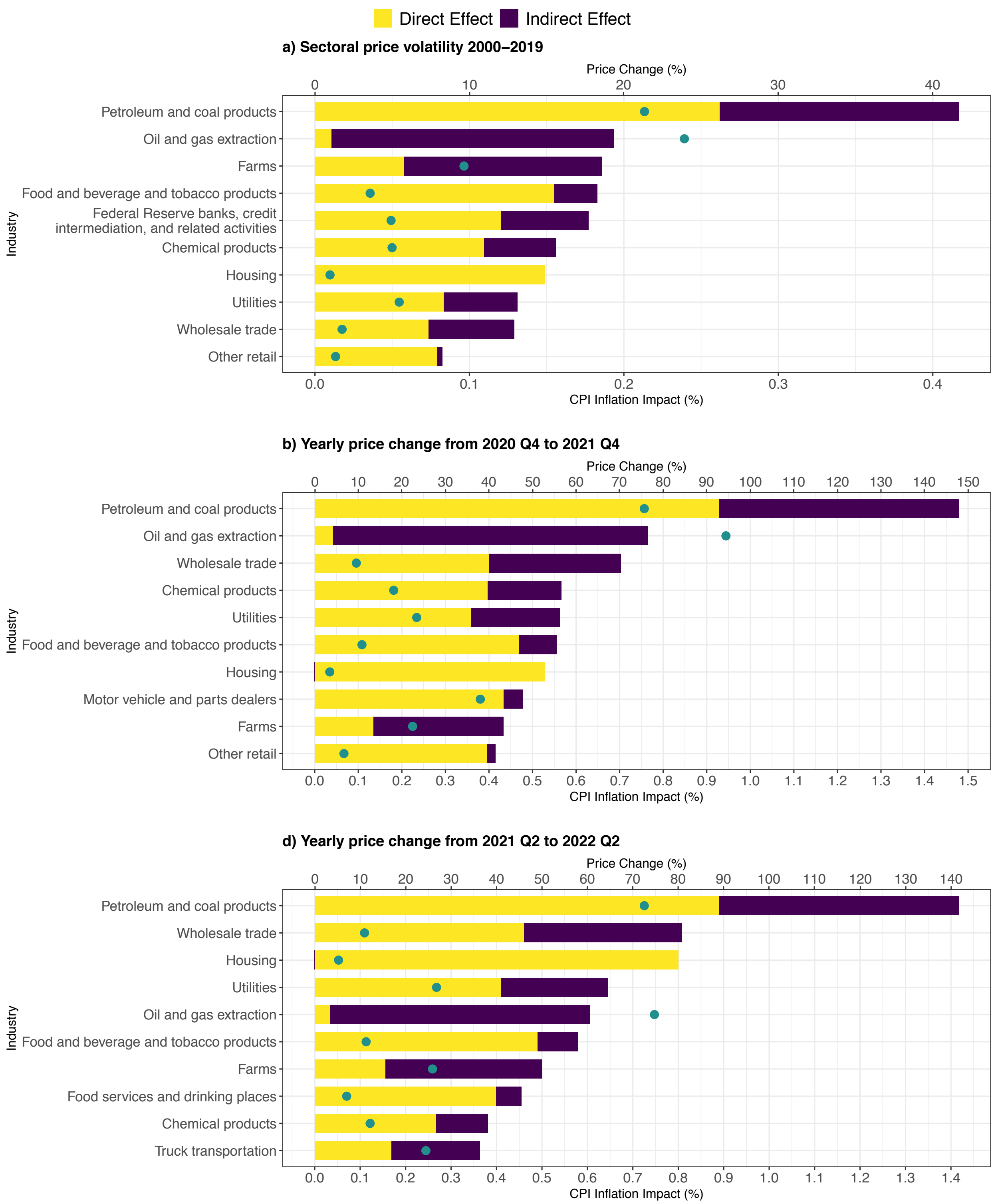
This section presents the results of our simulations of price shocks. Systemic significance is not a binary category but rather an ordinal one, and we present rankings based on our simulated inflation impacts. But we also show that there is a small number of industries which have a much larger inflation impact compared to all others when simulating different forms of price shocks. Almost all sectors that we find to have latent systemically significant prices in our analysis of average price volatility are confirmed as systemically significant in our simulations of COVID-19 inflationary episodes. See Table 1 for a summary of our results for the most systemically significant prices.[20] In other words, with the method we are using, policy makers could have identified systemically significant sectors that present vulnerabilities for overall monetary stability without knowing the actual shocks that later occurred.

Latent systemically significant prices, 2000-2019

The bar graph in Figure 1(a) plots the inflation impact of the top ten industries using the average price volatility in the period 2000-2019 as sectoral price shocks. The green dots represent each industry's average price volatility in terms of the standard deviation of the annual price change.

[20]For a complete report of our inflation impact simulation for all sectors see Table 3 in the appendix.

Figure 1: Inflation impact



Notes: The results of price-shock simulations for the top 10 indflation impact individual industries using the Leontief price model. The combined length of the purple and yellow bars represents the total inflation impact on a synthetic CPI generated by a price shock to each industry. The magnitudes of the price shocks to each industry (indicated by a green dot) are (a) the average annual price change of each industry between 2000-2019, which we call the "sectoral price volatility" of the industry, (b) the annual price change of each industry between 2020-Q4 and 2021-Q4, and (c) the annual price change of each industry between 2021-Q2 and 2022-Q2. The purple bar represents the indirect and the yellow bar the direct inflation impact. Only top-ten industries reported. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

The yellow share shows the direct and the purple the indirect inflation impact. The inflation impact varies widely. The 0.42 percent latent inflation impact of "Petroleum and coal products" is more than twice as large as that of the next most important industry and accounts for almost one quarter of the Fed's target interest rate. The next eight industries in our ranking of inflation impact form another group which has a distinctly greater inflation impact than the industries that follow further down in the ranking (see Figure A1(a) in the appendix). The rest of the ranking is much less segmented by comparison. This suggests that there is a group of industries that have a distinctively high latent systemical significance.

The number of forward linkages, the weight of an industry in the CPI as well as the average price volatility drive our results and provide insights into the pathways to systemic significance. All three measures are reported in Table 1 for the top 8 most systemically significant sectors across the different price shocks. Forward linkages and price volatility are also plotted in Figure 2. The direct inflation impact only depends on the weight in the CPI and the magnitude of the price shock. The indirect inflation impact is what captures the position of an industry in the input-output network as measured by the number of forward linkages. The large indirect effects for some of the sectors, which render them in the top ten (e.g. "Farms"), illustrate that the ranking in terms of total inflation impact differs from one that would only rely on the direct effects obtained without input-output analysis.

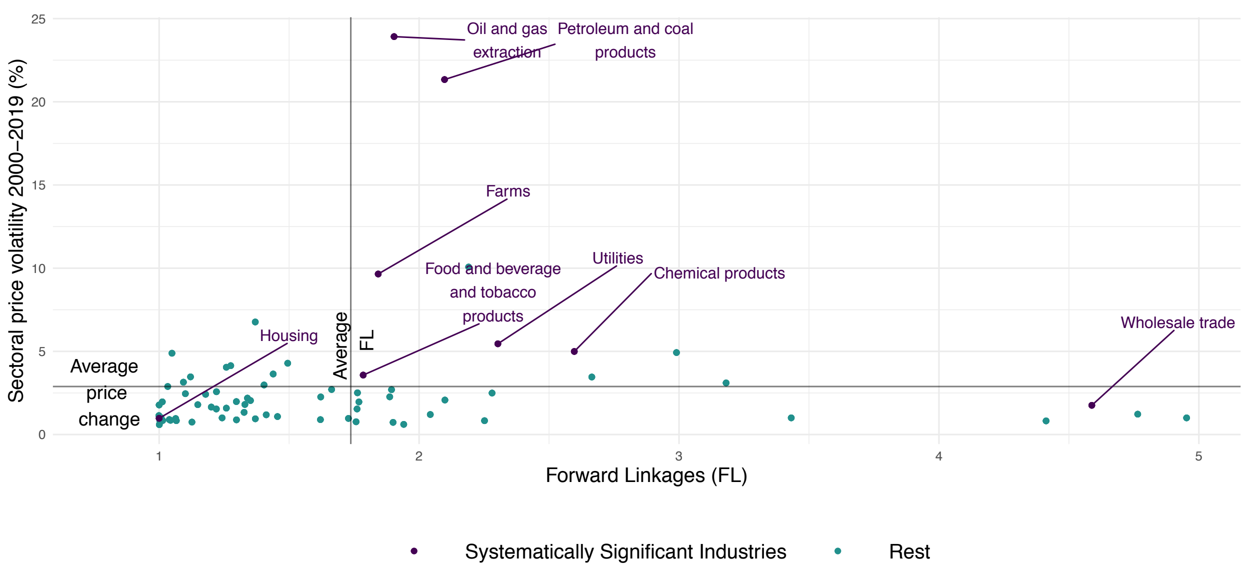
The contrast between "Oil and gas extraction" and "Housing" shows the difference between the direct and indirect inflation impact. Housing is at the bottom of the ranking in terms of forward linkages and has a purely direct effect which is large enough to land this sector on rank seven in terms of its total inflation impact. The average price volatility of housing is low compared with other top ranked industries. The high rank reflects the great importance of the basic need of shelter in consumer baskets (15.3% share in CPI). By contrast, the price volatility of "Oil and gas extraction" is highest among all industries and it has an above average upstreamness. Consumers are not directly serviced by this industry,[21] thus the entire inflation impact operates through the price swings driving up input costs for other sectors. But even with below average price volatility, a sector can attain systemic significance, if it is very upstream, as in the case of "Wholesale trade" (see Figure 2).

This has important political economy implications. While housing has long been a sector for which pricing decisions are discussed in public and often a target of community organizing, price increases in upstream sectors such as "Oil and gas extraction" and "Wholesale trade" have received far less attention from consumer protection activism. Their effects are mediated through intermediary industries, but our simulation suggests that this upstream sector might be of even greater importance for people's purchasing power than housing.

We can broadly group the nine industries with the greatest latent systemic significance for price

[21] To be clear, although households hardly directly consume the main output of the "oil and gas extraction" industry, they consume secondary commodities produced by this industry, such as "petroleum and coal products", "chemical products", and others.

Figure 2: Sectoral price volatility vs forward linkages



Notes: The measure of forward linkages of each industry is equal to the sum of the rows of the total domestic requirements matrix, and is given by the x-axis. The average annual price change of each industry between 2000-2019, which we call the "sectoral price volatility" of the industry,is displayed on the y-axes. The position of the horizontal and vertical axes indicate the average sectoral volatility of all industries and the average measure of forward linkages of all industries, respectively. Industries identified as systematically significant are colored purple and displayed with their description. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

stability into three groups: *energy, basic necessities, basic production inputs other than energy and commercial and financial infrastructure.*

In the energy category, the most important industry – "Petroleum and coal products" – is also the most important for overall price stability given the present production structure. This industry includes petroleum refining and is a ubiquitous input (rank 15 in terms of forward linkages) in a wide range of production activities (indirect CPI impact of 0.15%), but is also serving consumers (direct CPI impact of 0.26%), for example by provisioning for heating or at the gas pump. This sector has a high average price volatility of more than 20%. "Utilities" include electric power, natural gas, steam supply, water supply, and sewage treatment and disposal and mainly cater directly to consumers, yet also play an important role for producers (0.08% direct effect compared to 0.05% indirect effect). This sector has an above average price volatility of 5.46%. Finally, the industry with the highest average price volatility (23%) is "Oil and gas extraction" in which subsectors operate and/or develop oil and gas field properties is mainly catering to producers (0.01% direct and 0.18% indirect effect).

Table 1: Inflation impact simulation results for systemically significant prices

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
324	Petroleum and coal products	Sectoral price volatility 2000-2019	15	21.34	1.23	0.42	0.26	0.15	1
		Yearly price change from 2020 Q4 to 2021 Q4	15	75.66	1.23	1.48	0.93	0.55	1
		Yearly price change from 2021 Q2 to 2022 Q2	15	72.52	1.23	1.42	0.89	0.53	1
211	Oil and gas extraction	Sectoral price volatility 2000-2019	18	23.92	0.04	0.19	0.01	0.18	2
		Yearly price change from 2020 Q4 to 2021 Q4	18	94.41	0.04	0.77	0.04	0.72	2
		Yearly price change from 2021 Q2 to 2022 Q2	18	74.75	0.04	0.61	0.03	0.57	5
111CA	Farms	Sectoral price volatility 2000-2019	22	9.65	0.60	0.19	0.06	0.13	3
		Yearly price change from 2020 Q4 to 2021 Q4	22	22.48	0.60	0.43	0.13	0.30	9
		Yearly price change from 2021 Q2 to 2022 Q2	22	25.92	0.60	0.50	0.16	0.34	7
311FT	Food and beverage and tobacco products	Sectoral price volatility 2000-2019	23	3.57	4.33	0.18	0.15	0.03	4
		Yearly price change from 2020 Q4 to 2021 Q4	23	10.84	4.33	0.56	0.47	0.09	6
		Yearly price change from 2021 Q2 to 2022 Q2	23	11.32	4.33	0.58	0.49	0.09	6
325	Chemical products	Sectoral price volatility 2000-2019	9	4.99	2.19	0.16	0.11	0.05	6
		Yearly price change from 2020 Q4 to 2021 Q4	9	18.13	2.19	0.57	0.40	0.17	4
		Yearly price change from 2021 Q2 to 2022 Q2	9	12.20	2.19	0.38	0.27	0.11	9

Table 1: Inflation impact simulation results for systemically significant prices *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
HS	Housing	Sectoral price volatility 2000-2019	70	0.98	15.26	0.15	0.15	0.00	7
		Yearly price change from 2020 Q4 to 2021 Q4	70	3.46	15.26	0.53	0.53	0.00	7
		Yearly price change from 2021 Q2 to 2022 Q2	70	5.24	15.26	0.80	0.80	0.00	3
22	Utilities	Sectoral price volatility 2000-2019	10	5.45	1.53	0.13	0.08	0.05	8
		Yearly price change from 2020 Q4 to 2021 Q4	10	23.42	1.53	0.56	0.36	0.21	5
		Yearly price change from 2021 Q2 to 2022 Q2	10	26.81	1.53	0.64	0.41	0.23	4
42	Wholesale trade	Sectoral price volatility 2000-2019	3	1.76	4.20	0.13	0.07	0.06	9
		Yearly price change from 2020 Q4 to 2021 Q4	3	9.56	4.20	0.70	0.40	0.30	3
		Yearly price change from 2021 Q2 to 2022 Q2	3	10.97	4.20	0.81	0.46	0.35	2

Note:
This table summarizes the main results of simulated price shocks using the Leontief price model sectors that have been identified as systemically significant. Each row provides the overall inflation impact (total, direct, and indirect) resulting from a simulated price shock to an individual industry. For each industry, three different magnitudes of price shocks are used: (1) the average sectoral price volatility of the industry over the period 2000-2019, (2) the annual price change of the industry from 2020-Q4 to 2021-Q4 (the post-shudown period), and (3) the annual price change of the industry from 2021-Q2 to 2022-Q2 (the period which includes the 2022-Q2 price shock resulting from the beginning of the war in Ukraine). The magnitude of the price shocks for each of the three scenarios is given. In addition, each industry's ranking among the 71 industries in terms of forward linkages is provided, as is the industry's ranking in terms of the overall inflation impact for each of the three price shocks. The industries are arranged in descending order according to their inflation impact when we simulate the sectoral price volatility as a shock to the industry.

The group of basic necessities is one where demand management is likely to fail to bring down prices substantially, since demand elasticities are relatively low. In this group we have both industries that primarily serve consumers directly such as "Housing" and "Food and beverage and tobacco products" (high weight in CPI of 15.26% and 4.33%, respectively), and "Farms" (low weight in CPI of 0.6%) as producers of both inputs for other industries and of consumer goods. Accordingly, food has a relatively high direct (0.15%) and a relatively low indirect inflation impact (0.03%) compared to farms (direct impact on CPI 0.06%, indirect 0.13%). The output of farms includes the whole spectrum of agricultural products such as grains, fruit and vegetables, cattle and dairy products. As such, the sector's output is relatively ubiquitous (rank 22). Farms are subject to above-average price volatility of 9.65%. "Housing" and "Food and beverage and tobacco products" in contrast show a low latent volatility with a respective 0.98% and 0.77% annual average price change. The three sectors have similar total inflation impacts but attain systemic significance through different channels. For housing the most important factor is the large weight in consumer expenditure. For farms the most important channel is the high price volatility. For food there is no clear dominant channel.

"Chemical products" is divided into consumer goods, including necessities such as toiletry and soap, and basic production goods, including basic chemicals and intermediate products. As such, the chemical sector has both a considerable direct (0.11%) and an indirect (0.05%) impact on the CPI. Although one might think of chemicals primarily as production inputs – reflected in the high ubiquity rank (9) of this industry – chemicals also have a sizeable weight in personal consumption (2.19%). Finally, "Wholesale trade" –providing the basic infrastructure for commerce – is systemically significant due to both its ubiquity in production (rank 3) and consumption (4.2%), despite its low price volatility (1.76%). To use Mitchell's (1913, p. 23) words, there is a "peculiar degree of dependence" between "the whole mass of industries on the one hand" and activities like transportation and wholesale trade on the other.

A possible criticism of our approach could be that our results are driven by the heavy weight of food and energy in the CPI, which is the reason why economists commonly separate core inflation from the volatile prices of food and energy. However, as Figure A2 in the appendix shows, with the exception of "Food and beverage and tobacco products" for which the systemic significance depends largely on its sizeable direct impact on the CPI, all other sectors we have identified as significant based on their total inflation impact are also in the top ranks of systemic significance when simulating the impact of sectoral price shocks on the core CPI.

Systemically significant prices in the post-shutdown and the Ukraine war inflation

Figure 1(b) shows our simulation results for the post-shutdown price shocks using the 2019 input-output table and annual price changes in the fourth quarter of 2021.[22] This is the inflationary

[22] Our reason for using the 2019 input-output table for calculations of price shocks in 2021 is that the input-output table for 2021 has not been published yet, and the input-output table for 2020 is affected by the wide-ranging shutdowns in ways that makes it a problematic approximation for 2021.

episode that occurred in the context of the transition to reopening the economy while the COVID-19 pandemic still prevailed.

We find that the average magnitude of the total inflation impact has about tripled in the post-shutdown inflation compared to the latent inflation impact calculation, which used average price volatilities between 2000-2019 simulated in the previous section. Yet, the sectors that matter most are largely the same. With the exception of the "Motor vehicle and part dealers" industry, which experienced a pandemic-specific increase in prices of nearly 40%, all other eight industries in the top nine most significant prices have also been identified by our analysis of latent systemic significance. "Petroleum and coal products" is again by far the most potent industry for price stability. Its inflation impact of 1.48%, which results from the large price increase of 75.66%, is about twice as large as that of the next most important industry. Just as in the case of average price volatilities, there is a clear hierarchy of importance, although the relative importance of each has somewhat changed. Most notably, "Wholesale trade" has shot up to the rank of third most important industry for total inflation. The pandemic-induced supply chain issues presented unusual opportunities for wholesale traders to increase their prices. The sector's annual price increase was 9.56%, more than fivefold larger than the average price volatility of the last two decades. "Chemical products" rose to rank 4 in terms of the total inflation impact, as prices increased by a staggering 18.13% – almost four times the average volatility.

The results of inflation impact in the wake of the war in Ukraine largely resemble those for the post-shutdown phase. Figure 1(c) shows our simulation results using the annual price shocks in the second quarter of 2022, after the outbreak of the war on February 24. "Petroleum and coal products" continue to be the most important sector by far. It is no surprise that this sectors latent importance for inflation was materialized in the global energy crisis. Reflecting the high cost of energy, the price increase of "Utilities" also climbed up even further to 26.81%, landing this sector on rank four in terms of total inflation impact. "Wholesale trade" climbed to second rank as a result of a large annual price increase of 10.97%. "Housing" has become even more important (rank three in terms of inflation impact), reflecting that prices continued to rise on a heated housing market reaching an annual increase of 5.24%. The annual price increase of "Farms" reached 25.92% as the war in Ukraine shook global food markets, landing the sector on rank seven in terms of inflation impact. The prices of "Chemical products" eased somewhat and this sector fell to rank nine. Two new sectors joined the top ten ranks, "Food services and drinking places" (rank eight) reflecting high food prices and the return of eating out after the COVID-19 shutdowns, and "Truck transportation" (rank ten), likely as a result of high fuel prices.

Conflict inflation in response to price shocks in systemically significant sectors

Our analysis so far assumed that nominal wages and profits would remain constant through price adjustments in response to an increase in input costs due to a sector-specific price shock. It is, however, at least as plausible to assume that firms would try to keep their profit shares constant, which, in the case of a price increase, implies a nominal increase in profits that in turn would set off another round of price increases that cascade through the whole system. Similarly, it is equally reasonable to assume that wage earners would fight for nominal wage increases in ways that make up for the inflation-induced loss in real wages. This is the conflict inflation scenario modeled by Rowthorn (1977) in his classic paper. Inflation can accelerate as wage and profit earners try to compensate for or benefit from price shocks. If conflict inflation follows from price shocks, price shocks can spark a more sustained form of inflation through second round effects. In this section we simulate price increases that follow from wage and profit adjustments and show that the prices we identify as systemically significant prices preserve their importance when considering the same sector-specific price shocks for all industries in the conflict inflation scenario.

We use three different models to consider wage and profit adjustments following sector-specific price shocks:

(i) No profit or wage adjustment (this is the model used in the preceding sections)

(ii) Industries adjust their prices to keep the profit share of the value of their output constant[23]

(iii) Wages adjust to keep real wages constant [24]

Each of these models has different distributional implications and reflects the fact that the "price system plays ... the role of a silent but powerful redistributing agency" (Leontief, 1986 [1947], p. 63). In the first case (model i), real wages fall as a result of the increase in the CPI that follows from a price shock. The wage share in GDP falls accordingly and the profit share rises. But there is also a redistribution of profit between industries: assuming that the initial price shock happens

[23]To implement the assumption that firms in each industry manage to keep their profit share constant, we build a diagonal matrix (A_π) whose elements are the ratio of profits to the value of output. We also adapt the domestic primary costs vector (v^*) excluding profits (Bulmer-Thomas, 1982). Our new model thus becomes:

$$P = (I - A - A_\pi)(v^* + m)$$

[24]The way to endogenize wages is by introducing a new sector to the economy representing labor. We assume that workers adjust their price (wages) whenever the cost of their inputs (consumption goods) increases, in the same fashion as other sectors adjust their prices in response to cost increases. The direct requirement matrix (A') now has an extra row and column representing the labor sector. The domestic primary costs vector (v^{**}) is also adapted to exclude wages (Bulmer-Thomas, 1982).

$$P = (I - A)(v^{**} + m)$$

Figure 3: Conflict inflation impact. Sectoral price volatility 2000-2019

Notes: Each point represents the total inflation impact on a synthetic CPI generated by the sectoral price volatility of each industry across three specifications of the price model: i) Wages and other income factors fixed: ii) Profits adjusting to increase profit shares back to initial level: iii) Wages adjusting to compensate for real wage loss, other income factors fixed. Sources: BEA chain-type price indexes for gross output by industry, and BEA Input-Output accounts, after redifinitions 2019 tables.

without an increase in costs, the profit share of that sector in GPD increases while it falls for all other sectors. In the second model (ii) prices are adjusted to keep the ratio between profits and the value of output constant (both aggregate and industry-level). This results in an increase in the profit share in the value added (GDP) and a decrease in the wage share. The inflation conflict is settled in favor of profit earners. In the third model (iii) the increase in nominal wages is equal to the increase in the synthetic CPI that resulted from the price shock under consideration. Here, the wage share in the value added (GDP) increases and that of profits falls. The inflation conflict is settled in favor of labor.[25]

[25] The wage share in GDP can change even though real wages stay constant. Nominal wages are adjusted based on the synthetic CPI, while GDP changes based on the GDP deflator. If the two measures of inflation fall apart, the wage share in GDP changes. Formally, let w be the nominal wage, L the number of workers, W the total wages (wL), Y real GDP, and p the price level. The wage share is defined as:

$$\omega = \frac{W}{pY} = \frac{wL}{pY}$$

The wage share after the adjustment in model (iv) is then:

$$\frac{w(1 + CPI)L}{p(1 + GDPdeflator)Y}$$

Figure 3 plots our simulated total inflation impact for these three models using the average price volatility in 2000-2019. We can see that for all three periods for which we simulate sectoral price shocks with the three models, t The eight industries we identified as systemi- cally significant stay on top of the hierarchy of inflation impact when we take profit adjustments (model ii) and wage adjustments (model i) into account, even though the magnitude of the total inflation impact increases considerably in some cases (e.g. "Petroleum and coal products"). This also holds when we consider conflict inflation in the post-shutdown price shocks and the initial Ukraine war price shocks (see Figure A3 in the appendix). In a few cases, there is a change in ranking across the systemically significant industries between the different models (consider for example the position of "Oil and gas extraction" in 2020-2021), but taken as a group their importance is confirmed by this analysis.

Compensating wage adjustments are more consequential in terms of the total second round inflation impact than profit adjustments for all sectoral price shocks. Put differently, increases in nominal wages aiming to keep real wages constant in response to a shock to a systemically significant price create a greater increase in inflation in our simulation than adjustments in prices that keep the profit share constant. However, it does not follow from this simulation result that wages have been more important for the present inflation than profits. In the context of the post-shutdown and Ukraine war inflation, profits have exploded, reaching levels not seen since the post-World War II inflation and climbing to unprecedented levels for certain sectors, while wages have not caught up with price increases (Konczal & Lusiani, 2022). Here we have limited our analysis to assuming that wage or profit earners return to their initial distributional positions, making no statement on the ability of labor or businesses to adhere to such outcomes.

What does follow implicitly from our analysis is that, generally speaking, if both wages and profits do not compensate for the increase in the CPI resulting from a shock on a systemically significant price, wage earners tend to lose more than beneficiaries of profits. When experiencing a price shock, some sectors show particularly large inflation impacts via rising prices to compensate for real wage losses (model iii) compared to the profit channel (model ii). Shocks in "Housing", "Food and beverage and tobacco products" and "Other retail" using price changes for all three periods (a-c) and the pandemic-specific price shock in "Motor vehicle and part dealers" all lead to considerable inflation impacts following from wage adjustments (model iii), while the inflation impact as a result of profit adjustments is negligible (model ii). Conversely, when left uncompensated, price shocks in these sectors almost exclusively hit wage earners. By contrast, the burden of price shocks in "Oil and gas extraction" is shared about equally between wage and profit earners. For all other sectors, wage earners carry a heavier burden when price shocks go uncompensated.

Conclusion and outlook

This paper has introduced a new method to identify systemically significant prices for price stability. These sectors are "Petroleum and coal products", "Oil and gas extraction", "Farms", "Food and beverage and tobacco products", "Chemical products", "Housing", "Utilities", and "Wholesale trade". We have shown that the sectors which acquired systemic significance in the post-shutdown period and in the wake of the Ukraine war are the same sectors that our simulations indicated as systemically significant when using average price volatilities between 2000-2019. This suggests that, had institutions and policies been in place to stabilize these systemically significant prices, the current inflation crisis could have been managed in a more preemptive fashion.

Policy makers are increasingly reverting to ad hoc price stabilization efforts for key commodities like oil and gas as inflation endures at high levels in the context of the war in Ukraine. Such targeted measures can be an important emergency policy. To preserve monetary stability, they should, however, be swiftly implemented before a price shock can cascade through the system and driving up inflation. This requires monitoring capacity on the part of the state for systemically significant prices. If emergency contingency plans for price stabilization and greater oversight and regulation in systemically significant sectors were in place, firms might not have drastically raised prices in the first place. Price stabilization policies can thereby take different forms ranging from strict price gouging legislation, automatic taxes on windfall profits for systemically significant prices that become effective in emergency situations, to strategic price caps. Strict regulation on financial speculation in systemically significant sectors and anti-trust legislation could also play an important role.

As the most important American analyst of price controls in the 20th century, John Kenneth Galbraith (1943, 258), observed, price stabilization policies can always only gain time for measures that resolve the drivers of a price explosion. To prevent prices from shooting up in the first place, it is important to have mechanisms that stabilize supply. These mechanisms, like the precise form that price stabilization measures should take, need to be tailored to the physical, institutional and social realities of each sector. For important commodities, (international) buffer stocks have long been suggested by Keynes, Kaldor and others (Ussher, 2016), and have been used in a limited way in the US in the form of the strategic reserves for oil. Hockett and Omarova (2016) put forward the idea of central bank-style open market operations for systemically significant prices. Where underinvestment is an issue, programs that encourage investment are needed. For supply chains, measures which increase resilience, such as minimum inventory requirements for systemically important goods, could attenuate supply shocks. These are just examples. Further research is needed to develop a full policy design.

In this paper we have focused on systemic significance in relation to inflation. In principle, the approach we have developed can be adapted to reveal systemic significance in other dimensions, such as employment or output. Our analysis also has implications for price stability in a green transition can inform future research. Our finding that “Coal and petroleum products” is by far the most important sector for inflation underscores the challenges involved in maintaining price stability while transitioning to non-fossil fuel energy sources.

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Appendix

Mathematical derivations

In this appendix we explain our derivation of all the elements of the Leontief price model. The main component of the model is the domestic industry-by-industry direct requirements matrix, which describes the relationship between all industries in terms of domestic inputs used and outputs produced.

The domestic industry-by-industry direct requirements matrix is built from the use, make and import matrices from the BEA's input-output accounts, each of which relates commodity inputs and outputs with industries. Use tables express the interconnection of all economic productive industries by describing the commodities that are used as inputs in the production of all industries' final output, while the make tables describe all the commodities that are produced by each industry. Finally, the import matrix reveals the imported commodities used as inputs for each industry, which can be subtracted from the total use table to derive the domestic use table. This allows to separately analyze domestic and imported inputs.

For the yearly input-output tables, the BEA divides the US economy into classifications of 71 different industries and 73 commodities. Of these, 71 of the classifications of commodities and industries are identical; the remaining two additional commodities are scrap and secondhand goods, and non-comparable imports.

We follow the step-by-step method proposed by the BEA to derive the domestic industry-by-industry domestic requirements matrix A^d (Medeiros & Howells III, 2017). This matrix is defined as:

$$A^d = DB^d \tag{i}$$

Where D is the Market-share matrix – which reveals the fraction of each commodity's total output produced by each industry – and B^d is the domestic use table, showing the use of domestically produced commodities as inputs by the different industries. Pre-multiplying B^d by the market share matrix D redistributes commodities to the industries that produce them. For instance, if industry a only uses commodity b as an input, and, in particular, if it needs 0.80 of (domestically produced) commodity b to produce one dollar of output, and commodity b by industries b and c, 50% each, the 0.80 are redistributed in the following way, $0.80 \times 0.50 = 0.40$ from industry b and another $0.80 \times 0.50 = 0.40$ from industry c. So that, instead of showing that industry a needs 0.80 of commodity b, the new matrix will show that it needs 0.40 of industry b and 0.40 of industry c. Repeating this for all commodities (which is what the pre-multiplication by D achieves) gives the domestic direct requirements of inputs at the industry level, so that element ij of matrix A^d represents how much domestically produced output of industry i industry j needs to produce a dollar of output. In all what follows and in the main text, we refer to matrix A^d as A, for simplicity.

The next step is the derivation of the consumption shares of each industry which enter as weights in the derivation of the synthetic CPI. The information on personal consumption expenditures comes from the Use table, so it is at the commodity level. In order to transform this information to the industry level, we follow the same procedure as before: if h is the personal consumption vector, representing how much U.S. households spend on each commodity for their final consumption, then the vector:

$$H = Dh \tag{ii}$$

represents how much U.S. households spend on the output produced by each industry. As before, pre-multiplying by the market share matrix D implies a redistribution of commodities. For instance, if households spend 100$ on commodity x, and commodity x is produced by industries x and y with shares 90% and 10%, respectively, then the 100$ spent on x are redistributed in the following way: 90$ for industry x and 10$ for industry y. Repeating this for all commodities returns personal consumption spent on the output of each industry. We apply exactly the same procedure to to get the domestic personal consumption vector by industry:

$$H^d = Dh^d \tag{iii}$$

For the derivation of the consumption shares, we simply divide each element of H and H^d by total and total domestic personal consumption, respectively, by doing that we get vectors c and c^d, representing the total and domestic industry shares of personal consumption, respectively.

The price model with exogenous industries

For this section we rely on the method and notation of Valadkhani & Mitchell (2002).

In order to simulate the price shock, we must assume some industries are exogenous, which means that their prices will not be impacted by any changes in the prices of their inputs. Let X denote the set of exogenous industries and E the set of endogenous industries, and let x be the number of exogenous industries and e the number of endogenous industries (so $x + e = n$, the total number of industries)

Starting from equation (2) in the main paper, $P = A'P + v + m$, we separate P, A, v, and m into their endogenous and exogenous components. Equation (2) can then be expressed in the following way:

$$\begin{bmatrix} P_X \\ P_E \end{bmatrix} = \begin{bmatrix} A'_{XX} & A'_{EX} \\ A'_{XE} & A'_{EE} \end{bmatrix} \begin{bmatrix} P_X \\ P_E \end{bmatrix} + \begin{bmatrix} v_X \\ v_E \end{bmatrix} + \begin{bmatrix} m_X \\ m_E \end{bmatrix} \tag{iv}$$

For P, v and m, subindex E means the corresponding price indices, value-added and imports of intermediate goods as shares of the value of output for the endogenous industries, and X for the exogenous industries.

The four elements on the first matrix on the right-hand side are partitions of matrix A:

- A'_{XX} is an $x \times x$ matrix, containing the direct input requirements of exogenous industries from exogenous industries.
- A'_{EX} is an $x \times e$ matrix, containing the direct input requirements of the exogenous industries (rows) from the endogenous industries (columns).
- A'_{XE} is an $e \times x$ matrix, containing the direct input requirements of the endogenous industries (rows) from the exogenous industries (columns).
- Finally, A'_{EE} is an $e \times e$ matrix containing the direct input requirements of endogenous industries (rows) from endogenous industries (rows).

Therefore, for the determination of the prices of the endogenous sectors, only the last two partitions of matrix A (A'_{XE} and A'_{EE}) are relevant, since P_E is not affected by the input requirements of exogenous industries, captured by matrices A'_{XX} and A'_{EX}. Thus, solving the multiplication in the equation above, the price vector of the endogenous industries is:

$$P_E = A'_{XE}P_X + A'_{EE}P_E + v_E + m_E \tag{v}$$

The term $A'_{XE}P_X$ captures how prices of the endogenous industries are affected by the prices of exogenous industries, and $A'_{EE}P_E$ captures how they are affected by the prices of all the other endogenous industries. Solving for P_E in equation (v) retrieves equation (4) in the main text, which is the basic equation for the price model when there are exogenous industries.

In the case of the conflict inflation models, the procedure is the same; the only difference is that the domestic direct requirements matrix A (before the partitions) and the vector of value-added as a share of the value of output v will be modified in the following ways:

- For model (ii) (industries adjust their prices to keep the profit share of the value of their output constant): subtract matrix A_π, whose main diagonal elements are the ratio of profits to the value of output, from matrix A. Exclude profits from v.

- For model (iii) (wages adjust to keep real wages constant): add the vector of domestic consumption shares, c^d, as a row, and the ratio of wages to personal consumption as a column to matrix A. Exclude wages from v.

Supplementary tables and figures

Table 2: Bureau of Economic Analysis Input-Output Industries

Code	Description	Code	Description
111CA	Farms	486	Pipeline transportation
113FF	Forestry, fishing, and related activities	487OS	Other transportation and support activities
211*	Oil and gas extraction	493	Warehousing and storage
212*	Mining, except oil and gas	511	Publishing industries, except internet (includes software)
213	Support activities for mining	512	Motion picture and sound recording industries
22	Utilities	513	Broadcasting and telecommunications
23	Construction	514	Data processing, internet publishing, and other information services
321	Wood products	521CI*	Federal Reserve banks, credit intermediation, and related activities
327	Nonmetallic mineral products	523*	Securities, commodity contracts, and investments
331	Primary metals	524*	Insurance carriers and related activities
332	Fabricated metal products	525*	Funds, trusts, and other financial vehicles
333	Machinery	HS*	Housing
334	Computer and electronic products	ORE*	Other real estate
335	Electrical equipment, appliances, and components	532RL	Rental and leasing services and lessors of intangible assets
3361MV	Motor vehicles, bodies and trailers, and parts	5411	Legal services
3364OT	Other transportation equipment	5415	Computer systems design and related services
337	Furniture and related products	5412OP	Miscellaneous professional, scientific, and technical services
339	Miscellaneous manufacturing	55*	Management of companies and enterprises
311FT	Food and beverage and tobacco products	561	Administrative and support services
313TT	Textile mills and textile product mills	562	Waste management and remediation services
315AL	Apparel and leather and allied products	61	Educational services
322	Paper products	621*	Ambulatory health care services
323	Printing and related support activities	622*	Hospitals
324	Petroleum and coal products	623*	Nursing and residential care facilities
325	Chemical products	624	Social assistance
326	Plastics and rubber products	711AS	Performing arts, spectator sports, museums, and related activities
42	Wholesale trade	713*	Amusements, gambling, and recreation industries
441	Motor vehicle and parts dealers	721	Accommodation

Table 2: Bureau of Economic Analysis Input-Output Industries *(continued)*

Code	Description	Code	Description
445	Food and beverage stores	722*	Food services and drinking places
452	General merchandise stores	81	Other services, except government
4A0	Other retail	GFGD	Federal general government (defense)
481	Air transportation	GFGN	Federal general government (nondefense)
482	Rail transportation	GFE	Federal government enterprises
483	Water transportation	GSLG	State and local general government
484	Truck transportation	GSLE	State and local government enterprises
485	Transit and ground passenger transportation		

Note:
Industry codes and descriptions as defined by the Bureau of Economic Analysis. Industry codes with an asterisk are assumed exogenous in all our simulations. When an industry is exogenous in the model, its price is assumed to be fixed and thus unaffected by the output prices of other industries.

Table 3: Inflation impact simulation results for all industries

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
324	Petroleum and coal products	Sectoral price volatility 2000-2019	15	21.34	1.23	0.42	0.26	0.15	1
		Yearly price change from 2020 Q4 to 2021 Q4	15	75.66	1.23	1.48	0.93	0.55	1
		Yearly price change from 2021 Q2 to 2022 Q2	15	72.52	1.23	1.42	0.89	0.53	1
211	Oil and gas extraction	Sectoral price volatility 2000-2019	18	23.92	0.04	0.19	0.01	0.18	2
		Yearly price change from 2020 Q4 to 2021 Q4	18	94.41	0.04	0.77	0.04	0.72	2
		Yearly price change from 2021 Q2 to 2022 Q2	18	74.75	0.04	0.61	0.03	0.57	5
111CA	Farms	Sectoral price volatility 2000-2019	22	9.65	0.60	0.19	0.06	0.13	3
		Yearly price change from 2020 Q4 to 2021 Q4	22	22.48	0.60	0.43	0.13	0.30	9
		Yearly price change from 2021 Q2 to 2022 Q2	22	25.92	0.60	0.50	0.16	0.34	7
311FT	Food and beverage and tobacco products	Sectoral price volatility 2000-2019	23	3.57	4.33	0.18	0.15	0.03	4
		Yearly price change from 2020 Q4 to 2021 Q4	23	10.84	4.33	0.56	0.47	0.09	6
		Yearly price change from 2021 Q2 to 2022 Q2	23	11.32	4.33	0.58	0.49	0.09	6
521CI	Federal Reserve banks, credit intermediation, and related activities	Sectoral price volatility 2000-2019	7	4.93	2.45	0.18	0.12	0.06	5
		Yearly price change from 2020 Q4 to 2021 Q4	7	4.68	2.45	0.17	0.11	0.05	24
		Yearly price change from 2021 Q2 to 2022 Q2	7	3.46	2.45	0.12	0.08	0.04	28

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
325	Chemical products	Sectoral price volatility 2000-2019	9	4.99	2.19	0.16	0.11	0.05	6
		Yearly price change from 2020 Q4 to 2021 Q4	9	18.13	2.19	0.57	0.40	0.17	4
		Yearly price change from 2021 Q2 to 2022 Q2	9	12.20	2.19	0.38	0.27	0.11	9
HS	Housing	Sectoral price volatility 2000-2019	70	0.98	15.26	0.15	0.15	0.00	7
		Yearly price change from 2020 Q4 to 2021 Q4	70	3.46	15.26	0.53	0.53	0.00	7
		Yearly price change from 2021 Q2 to 2022 Q2	70	5.24	15.26	0.80	0.80	0.00	3
22	Utilities	Sectoral price volatility 2000-2019	10	5.45	1.53	0.13	0.08	0.05	8
		Yearly price change from 2020 Q4 to 2021 Q4	10	23.42	1.53	0.56	0.36	0.21	5
		Yearly price change from 2021 Q2 to 2022 Q2	10	26.81	1.53	0.64	0.41	0.23	4
42	Wholesale trade	Sectoral price volatility 2000-2019	3	1.76	4.20	0.13	0.07	0.06	9
		Yearly price change from 2020 Q4 to 2021 Q4	3	9.56	4.20	0.70	0.40	0.30	3
		Yearly price change from 2021 Q2 to 2022 Q2	3	10.97	4.20	0.81	0.46	0.35	2
4A0	Other retail	Sectoral price volatility 2000-2019	42	1.33	5.91	0.08	0.08	0.00	10
		Yearly price change from 2020 Q4 to 2021 Q4	42	6.71	5.91	0.42	0.40	0.02	10
		Yearly price change from 2021 Q2 to 2022 Q2	42	4.12	5.91	0.26	0.24	0.01	15

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
55	Management of companies and enterprises	Sectoral price volatility 2000-2019	6	3.10	0.00	0.08	0.00	0.08	11
		Yearly price change from 2020 Q4 to 2021 Q4	6	0.32	0.00	0.01	0.00	0.01	61
		Yearly price change from 2021 Q2 to 2022 Q2	6	0.27	0.00	0.01	0.00	0.01	63
523	Securities, commodity contracts, and investments	Sectoral price volatility 2000-2019	8	3.46	1.74	0.08	0.06	0.02	12
		Yearly price change from 2020 Q4 to 2021 Q4	8	10.07	1.74	0.22	0.17	0.05	19
		Yearly price change from 2021 Q2 to 2022 Q2	8	-2.47	1.74	-0.06	-0.04	-0.01	71
621	Ambulatory health care services	Sectoral price volatility 2000-2019	62	0.90	7.70	0.07	0.07	0.00	13
		Yearly price change from 2020 Q4 to 2021 Q4	62	3.48	7.70	0.27	0.27	0.00	14
		Yearly price change from 2021 Q2 to 2022 Q2	62	2.24	7.70	0.18	0.17	0.00	21
ORE	Other real estate	Sectoral price volatility 2000-2019	2	1.22	0.05	0.06	0.00	0.05	14
		Yearly price change from 2020 Q4 to 2021 Q4	2	2.68	0.05	0.12	0.00	0.12	28
		Yearly price change from 2021 Q2 to 2022 Q2	2	4.66	0.05	0.21	0.00	0.21	19
481	Air transportation	Sectoral price volatility 2000-2019	47	4.04	1.15	0.05	0.05	0.01	15
		Yearly price change from 2020 Q4 to 2021 Q4	47	14.01	1.15	0.19	0.16	0.03	21
		Yearly price change from 2021 Q2 to 2022 Q2	47	16.92	1.15	0.23	0.19	0.03	17

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
622	Hospitals	Sectoral price volatility 2000-2019	67	0.82	6.49	0.05	0.05	0.00	16
		Yearly price change from 2020 Q4 to 2021 Q4	67	4.30	6.49	0.28	0.28	0.00	13
		Yearly price change from 2021 Q2 to 2022 Q2	67	4.95	6.49	0.32	0.32	0.00	12
331	Primary metals	Sectoral price volatility 2000-2019	13	10.07	0.07	0.05	0.01	0.05	17
		Yearly price change from 2020 Q4 to 2021 Q4	13	50.31	0.07	0.26	0.04	0.23	15
		Yearly price change from 2021 Q2 to 2022 Q2	13	21.48	0.07	0.11	0.01	0.10	29
722	Food services and drinking places	Sectoral price volatility 2000-2019	27	0.77	5.68	0.05	0.04	0.01	18
		Yearly price change from 2020 Q4 to 2021 Q4	27	5.74	5.68	0.37	0.33	0.05	11
		Yearly price change from 2021 Q2 to 2022 Q2	27	7.03	5.68	0.45	0.40	0.06	8
GSLG	State and local general government	Sectoral price volatility 2000-2019	51	1.65	2.84	0.05	0.05	0.00	19
		Yearly price change from 2020 Q4 to 2021 Q4	51	6.98	2.84	0.21	0.20	0.01	20
		Yearly price change from 2021 Q2 to 2022 Q2	51	8.69	2.84	0.26	0.25	0.01	14
452	General merchandise stores	Sectoral price volatility 2000-2019	63	2.89	1.48	0.04	0.04	0.00	20
		Yearly price change from 2020 Q4 to 2021 Q4	63	10.12	1.48	0.15	0.15	0.00	26
		Yearly price change from 2021 Q2 to 2022 Q2	63	10.89	1.48	0.16	0.16	0.00	24

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
524	Insurance carriers and related activities	Sectoral price volatility 2000-2019	5	1.00	2.95	0.04	0.03	0.01	21
		Yearly price change from 2020 Q4 to 2021 Q4	5	-0.79	2.95	-0.03	-0.02	-0.01	70
		Yearly price change from 2021 Q2 to 2022 Q2	5	1.76	2.95	0.08	0.05	0.02	36
GSLE	State and local government enterprises	Sectoral price volatility 2000-2019	30	2.26	1.31	0.04	0.03	0.01	22
		Yearly price change from 2020 Q4 to 2021 Q4	30	12.67	1.31	0.24	0.17	0.07	17
		Yearly price change from 2021 Q2 to 2022 Q2	30	13.48	1.31	0.25	0.18	0.07	16
484	Truck transportation	Sectoral price volatility 2000-2019	20	2.70	0.69	0.04	0.02	0.02	23
		Yearly price change from 2020 Q4 to 2021 Q4	20	17.47	0.69	0.26	0.12	0.14	16
		Yearly price change from 2021 Q2 to 2022 Q2	20	24.46	0.69	0.36	0.17	0.19	10
5412OP	Miscellaneous professional, scientific, and technical services	Sectoral price volatility 2000-2019	1	1.00	0.48	0.04	0.00	0.03	24
		Yearly price change from 2020 Q4 to 2021 Q4	1	1.19	0.48	0.04	0.01	0.04	45
		Yearly price change from 2021 Q2 to 2022 Q2	1	3.73	0.48	0.13	0.02	0.11	27
525	Funds, trusts, and other financial vehicles	Sectoral price volatility 2000-2019	57	3.15	1.08	0.03	0.03	0.00	25
		Yearly price change from 2020 Q4 to 2021 Q4	57	5.06	1.08	0.05	0.05	0.00	38
		Yearly price change from 2021 Q2 to 2022 Q2	57	4.64	1.08	0.05	0.05	0.00	45

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
81	Other services, except government	Sectoral price volatility 2000-2019	17	0.61	4.66	0.03	0.03	0.01	26
		Yearly price change from 2020 Q4 to 2021 Q4	17	5.54	4.66	0.31	0.26	0.05	12
		Yearly price change from 2021 Q2 to 2022 Q2	17	6.16	4.66	0.34	0.29	0.06	11
441	Motor vehicle and parts dealers	Sectoral price volatility 2000-2019	56	2.45	1.14	0.03	0.03	0.00	27
		Yearly price change from 2020 Q4 to 2021 Q4	56	38.02	1.14	0.48	0.43	0.04	8
		Yearly price change from 2021 Q2 to 2022 Q2	56	21.79	1.14	0.27	0.25	0.02	13
445	Food and beverage stores	Sectoral price volatility 2000-2019	65	1.96	1.51	0.03	0.03	0.00	28
		Yearly price change from 2020 Q4 to 2021 Q4	65	4.76	1.51	0.07	0.07	0.00	34
		Yearly price change from 2021 Q2 to 2022 Q2	65	11.94	1.51	0.18	0.18	0.00	20
334	Computer and electronic products	Sectoral price volatility 2000-2019	36	2.98	0.64	0.03	0.02	0.01	29
		Yearly price change from 2020 Q4 to 2021 Q4	36	1.94	0.64	0.02	0.01	0.01	57
		Yearly price change from 2021 Q2 to 2022 Q2	36	4.54	0.64	0.04	0.03	0.01	47
561	Administrative and support services	Sectoral price volatility 2000-2019	4	0.82	0.52	0.03	0.00	0.02	30
		Yearly price change from 2020 Q4 to 2021 Q4	4	4.10	0.52	0.13	0.02	0.11	27
		Yearly price change from 2021 Q2 to 2022 Q2	4	5.30	0.52	0.17	0.03	0.14	22

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
513	Broadcasting and telecommunications	Sectoral price volatility 2000-2019	12	0.83	2.38	0.03	0.02	0.01	31
		Yearly price change from 2020 Q4 to 2021 Q4	12	-1.19	2.38	-0.04	-0.03	-0.01	71
		Yearly price change from 2021 Q2 to 2022 Q2	12	1.54	2.38	0.05	0.04	0.01	46
326	Plastics and rubber products	Sectoral price volatility 2000-2019	29	2.71	0.29	0.03	0.01	0.02	32
		Yearly price change from 2020 Q4 to 2021 Q4	29	18.93	0.29	0.18	0.06	0.12	22
		Yearly price change from 2021 Q2 to 2022 Q2	29	16.35	0.29	0.16	0.05	0.11	25
332	Fabricated metal products	Sectoral price volatility 2000-2019	11	2.49	0.22	0.02	0.01	0.02	33
		Yearly price change from 2020 Q4 to 2021 Q4	11	19.13	0.22	0.17	0.04	0.13	23
		Yearly price change from 2021 Q2 to 2022 Q2	11	18.84	0.22	0.17	0.04	0.13	23
721	Accommodation	Sectoral price volatility 2000-2019	46	1.59	1.15	0.02	0.02	0.00	34
		Yearly price change from 2020 Q4 to 2021 Q4	46	11.62	1.15	0.16	0.13	0.02	25
		Yearly price change from 2021 Q2 to 2022 Q2	46	16.56	1.15	0.22	0.19	0.03	18
5411	Legal services	Sectoral price volatility 2000-2019	26	1.54	0.76	0.02	0.01	0.01	35
		Yearly price change from 2020 Q4 to 2021 Q4	26	4.66	0.76	0.06	0.04	0.03	37
		Yearly price change from 2021 Q2 to 2022 Q2	26	3.87	0.76	0.05	0.03	0.02	44

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
487OS	Other transportation and support activities	Sectoral price volatility 2000-2019	14	2.07	0.17	0.02	0.00	0.02	36
		Yearly price change from 2020 Q4 to 2021 Q4	14	23.91	0.17	0.23	0.04	0.19	18
		Yearly price change from 2021 Q2 to 2022 Q2	14	15.30	0.17	0.15	0.03	0.12	26
623	Nursing and residential care facilities	Sectoral price volatility 2000-2019	66	1.02	1.79	0.02	0.02	0.00	37
		Yearly price change from 2020 Q4 to 2021 Q4	66	2.90	1.79	0.05	0.05	0.00	39
		Yearly price change from 2021 Q2 to 2022 Q2	66	3.66	1.79	0.07	0.07	0.00	40
532RL	Rental and leasing services and lessors of intangible assets	Sectoral price volatility 2000-2019	16	1.20	0.66	0.02	0.01	0.01	38
		Yearly price change from 2020 Q4 to 2021 Q4	16	7.80	0.66	0.11	0.05	0.06	29
		Yearly price change from 2021 Q2 to 2022 Q2	16	7.22	0.66	0.11	0.05	0.06	32
3361MV	Motor vehicles, bodies and trailers, and parts	Sectoral price volatility 2000-2019	31	0.90	1.73	0.02	0.02	0.00	39
		Yearly price change from 2020 Q4 to 2021 Q4	31	4.99	1.73	0.10	0.09	0.01	31
		Yearly price change from 2021 Q2 to 2022 Q2	31	5.48	1.73	0.11	0.10	0.01	31
61	Educational services	Sectoral price volatility 2000-2019	58	0.83	1.89	0.02	0.02	0.00	40
		Yearly price change from 2020 Q4 to 2021 Q4	58	3.98	1.89	0.08	0.08	0.00	33
		Yearly price change from 2021 Q2 to 2022 Q2	58	3.95	1.89	0.08	0.07	0.00	35

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
322	Paper products	Sectoral price volatility 2000-2019	25	2.51	0.17	0.02	0.00	0.01	41
		Yearly price change from 2020 Q4 to 2021 Q4	25	15.29	0.17	0.10	0.03	0.07	30
		Yearly price change from 2021 Q2 to 2022 Q2	25	17.09	0.17	0.11	0.03	0.08	30
493	Warehousing and storage	Sectoral price volatility 2000-2019	24	1.96	0.00	0.01	0.00	0.01	42
		Yearly price change from 2020 Q4 to 2021 Q4	24	9.65	0.00	0.07	0.00	0.07	36
		Yearly price change from 2021 Q2 to 2022 Q2	24	14.16	0.00	0.10	0.00	0.10	33
212	Mining, except oil and gas	Sectoral price volatility 2000-2019	38	6.77	0.01	0.01	0.00	0.01	43
		Yearly price change from 2020 Q4 to 2021 Q4	38	10.05	0.01	0.02	0.00	0.02	55
		Yearly price change from 2021 Q2 to 2022 Q2	38	17.66	0.01	0.03	0.00	0.03	51
23	Construction	Sectoral price volatility 2000-2019	21	2.27	0.00	0.01	0.00	0.01	44
		Yearly price change from 2020 Q4 to 2021 Q4	21	12.93	0.00	0.07	0.00	0.07	35
		Yearly price change from 2021 Q2 to 2022 Q2	21	16.53	0.00	0.09	0.00	0.09	34
482	Rail transportation	Sectoral price volatility 2000-2019	45	4.14	0.06	0.01	0.00	0.01	45
		Yearly price change from 2020 Q4 to 2021 Q4	45	7.53	0.06	0.02	0.00	0.02	53
		Yearly price change from 2021 Q2 to 2022 Q2	45	9.86	0.06	0.03	0.01	0.02	53

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
483	Water transportation	Sectoral price volatility 2000-2019	60	4.89	0.18	0.01	0.01	0.00	46
		Yearly price change from 2020 Q4 to 2021 Q4	60	19.21	0.18	0.04	0.03	0.01	47
		Yearly price change from 2021 Q2 to 2022 Q2	60	11.31	0.18	0.02	0.02	0.00	55
713	Amusements, gambling, and recreation industries	Sectoral price volatility 2000-2019	64	0.84	1.22	0.01	0.01	0.00	47
		Yearly price change from 2020 Q4 to 2021 Q4	64	3.50	1.22	0.04	0.04	0.00	43
		Yearly price change from 2021 Q2 to 2022 Q2	64	5.63	1.22	0.07	0.07	0.00	38
624	Social assistance	Sectoral price volatility 2000-2019	68	0.59	1.64	0.01	0.01	0.00	48
		Yearly price change from 2020 Q4 to 2021 Q4	68	5.91	1.64	0.10	0.10	0.00	32
		Yearly price change from 2021 Q2 to 2022 Q2	68	4.45	1.64	0.07	0.07	0.00	37
514	Data processing, internet publishing, and other information services	Sectoral price volatility 2000-2019	19	0.73	0.58	0.01	0.00	0.01	49
		Yearly price change from 2020 Q4 to 2021 Q4	19	0.98	0.58	0.01	0.01	0.01	60
		Yearly price change from 2021 Q2 to 2022 Q2	19	0.98	0.58	0.01	0.01	0.01	61
711AS	Performing arts, spectator sports, museums, and related activities	Sectoral price volatility 2000-2019	33	1.08	0.61	0.01	0.01	0.00	50
		Yearly price change from 2020 Q4 to 2021 Q4	33	3.65	0.61	0.03	0.02	0.01	48
		Yearly price change from 2021 Q2 to 2022 Q2	33	-0.27	0.61	0.00	0.00	0.00	69

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
511	Publishing industries, except internet (includes software)	Sectoral price volatility 2000-2019	48	1.00	0.72	0.01	0.01	0.00	51
		Yearly price change from 2020 Q4 to 2021 Q4	48	-1.13	0.72	-0.01	-0.01	0.00	69
		Yearly price change from 2021 Q2 to 2022 Q2	48	-0.21	0.72	0.00	0.00	0.00	68
335	Electrical equipment, appliances, and components	Sectoral price volatility 2000-2019	52	2.42	0.28	0.01	0.01	0.00	52
		Yearly price change from 2020 Q4 to 2021 Q4	52	11.51	0.28	0.04	0.03	0.01	44
		Yearly price change from 2021 Q2 to 2022 Q2	52	15.30	0.28	0.06	0.04	0.01	43
315AL	Apparel and leather and allied products	Sectoral price volatility 2000-2019	61	0.86	1.02	0.01	0.01	0.00	53
		Yearly price change from 2020 Q4 to 2021 Q4	61	4.67	1.02	0.05	0.05	0.00	40
		Yearly price change from 2021 Q2 to 2022 Q2	61	6.65	1.02	0.07	0.07	0.00	39
113FF	Forestry, fishing, and related activities	Sectoral price volatility 2000-2019	34	3.64	0.06	0.01	0.00	0.01	54
		Yearly price change from 2020 Q4 to 2021 Q4	34	6.03	0.06	0.01	0.00	0.01	59
		Yearly price change from 2021 Q2 to 2022 Q2	34	6.14	0.06	0.01	0.00	0.01	60
321	Wood products	Sectoral price volatility 2000-2019	32	4.29	0.04	0.01	0.00	0.01	55
		Yearly price change from 2020 Q4 to 2021 Q4	32	22.69	0.04	0.05	0.01	0.04	41
		Yearly price change from 2021 Q2 to 2022 Q2	32	10.88	0.04	0.02	0.00	0.02	57

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
485	Transit and ground passenger transportation	Sectoral price volatility 2000-2019	53	1.79	0.31	0.01	0.01	0.00	56
		Yearly price change from 2020 Q4 to 2021 Q4	53	1.65	0.31	0.01	0.01	0.00	62
		Yearly price change from 2021 Q2 to 2022 Q2	53	-1.44	0.31	-0.01	0.00	0.00	70
512	Motion picture and sound recording industries	Sectoral price volatility 2000-2019	41	1.81	0.17	0.01	0.00	0.00	57
		Yearly price change from 2020 Q4 to 2021 Q4	41	-2.03	0.17	-0.01	0.00	-0.01	68
		Yearly price change from 2021 Q2 to 2022 Q2	41	3.53	0.17	0.01	0.01	0.01	59
313TT	Textile mills and textile product mills	Sectoral price volatility 2000-2019	40	2.19	0.17	0.01	0.00	0.00	58
		Yearly price change from 2020 Q4 to 2021 Q4	40	12.61	0.17	0.04	0.02	0.02	46
		Yearly price change from 2021 Q2 to 2022 Q2	40	11.55	0.17	0.04	0.02	0.02	50
339	Miscellaneous manufacturing	Sectoral price volatility 2000-2019	54	0.75	0.69	0.01	0.01	0.00	59
		Yearly price change from 2020 Q4 to 2021 Q4	54	3.22	0.69	0.03	0.02	0.01	49
		Yearly price change from 2021 Q2 to 2022 Q2	54	7.13	0.69	0.06	0.05	0.02	41
GFE	Federal government enterprises	Sectoral price volatility 2000-2019	44	1.98	0.09	0.01	0.00	0.00	60
		Yearly price change from 2020 Q4 to 2021 Q4	44	8.53	0.09	0.03	0.01	0.02	50
		Yearly price change from 2021 Q2 to 2022 Q2	44	6.89	0.09	0.02	0.01	0.02	56

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
327	Nonmetallic mineral products	Sectoral price volatility 2000-2019	39	2.04	0.08	0.01	0.00	0.00	61
		Yearly price change from 2020 Q4 to 2021 Q4	39	9.57	0.08	0.02	0.01	0.02	52
		Yearly price change from 2021 Q2 to 2022 Q2	39	10.58	0.08	0.03	0.01	0.02	52
5415	Computer systems design and related services	Sectoral price volatility 2000-2019	28	0.97	0.00	0.00	0.00	0.00	62
		Yearly price change from 2020 Q4 to 2021 Q4	28	-0.68	0.00	0.00	0.00	0.00	67
		Yearly price change from 2021 Q2 to 2022 Q2	28	0.32	0.00	0.00	0.00	0.00	64
486	Pipeline transportation	Sectoral price volatility 2000-2019	49	2.57	0.02	0.00	0.00	0.00	63
		Yearly price change from 2020 Q4 to 2021 Q4	49	9.67	0.02	0.02	0.00	0.02	58
		Yearly price change from 2021 Q2 to 2022 Q2	49	12.14	0.02	0.02	0.00	0.02	58
323	Printing and related support activities	Sectoral price volatility 2000-2019	50	1.54	0.06	0.00	0.00	0.00	64
		Yearly price change from 2020 Q4 to 2021 Q4	50	6.82	0.06	0.02	0.00	0.02	54
		Yearly price change from 2021 Q2 to 2022 Q2	50	13.11	0.06	0.04	0.01	0.03	49
562	Waste management and remediation services	Sectoral price volatility 2000-2019	37	0.95	0.23	0.00	0.00	0.00	65
		Yearly price change from 2020 Q4 to 2021 Q4	37	3.91	0.23	0.02	0.01	0.01	56
		Yearly price change from 2021 Q2 to 2022 Q2	37	5.53	0.23	0.03	0.01	0.01	54

Table 3: Inflation impact simulation results for all industries *(continued)*

Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
337	Furniture and related products	Sectoral price volatility 2000-2019	59	0.96	0.38	0.00	0.00	0.00	66
		Yearly price change from 2020 Q4 to 2021 Q4	59	11.21	0.38	0.05	0.04	0.00	42
		Yearly price change from 2021 Q2 to 2022 Q2	59	14.05	0.38	0.06	0.05	0.00	42
333	Machinery	Sectoral price volatility 2000-2019	35	1.19	0.09	0.00	0.00	0.00	67
		Yearly price change from 2020 Q4 to 2021 Q4	35	8.36	0.09	0.02	0.01	0.02	51
		Yearly price change from 2021 Q2 to 2022 Q2	35	13.42	0.09	0.04	0.01	0.03	48
3364OT	Other transportation equipment	Sectoral price volatility 2000-2019	43	0.88	0.16	0.00	0.00	0.00	68
		Yearly price change from 2020 Q4 to 2021 Q4	43	2.25	0.16	0.00	0.00	0.00	63
		Yearly price change from 2021 Q2 to 2022 Q2	43	5.41	0.16	0.01	0.01	0.00	62
213	Support activities for mining	Sectoral price volatility 2000-2019	55	3.47	0.00	0.00	0.00	0.00	69
		Yearly price change from 2020 Q4 to 2021 Q4	55	5.81	0.00	0.00	0.00	0.00	64
		Yearly price change from 2021 Q2 to 2022 Q2	55	10.34	0.00	0.00	0.00	0.00	65
GFGD	Federal general government (defense)	Sectoral price volatility 2000-2019	69	1.78	0.00	0.00	0.00	0.00	70
		Yearly price change from 2020 Q4 to 2021 Q4	69	4.77	0.00	0.00	0.00	0.00	65
		Yearly price change from 2021 Q2 to 2022 Q2	69	5.72	0.00	0.00	0.00	0.00	66

Table 3: Inflation impact simulation results for all industries *(continued)*

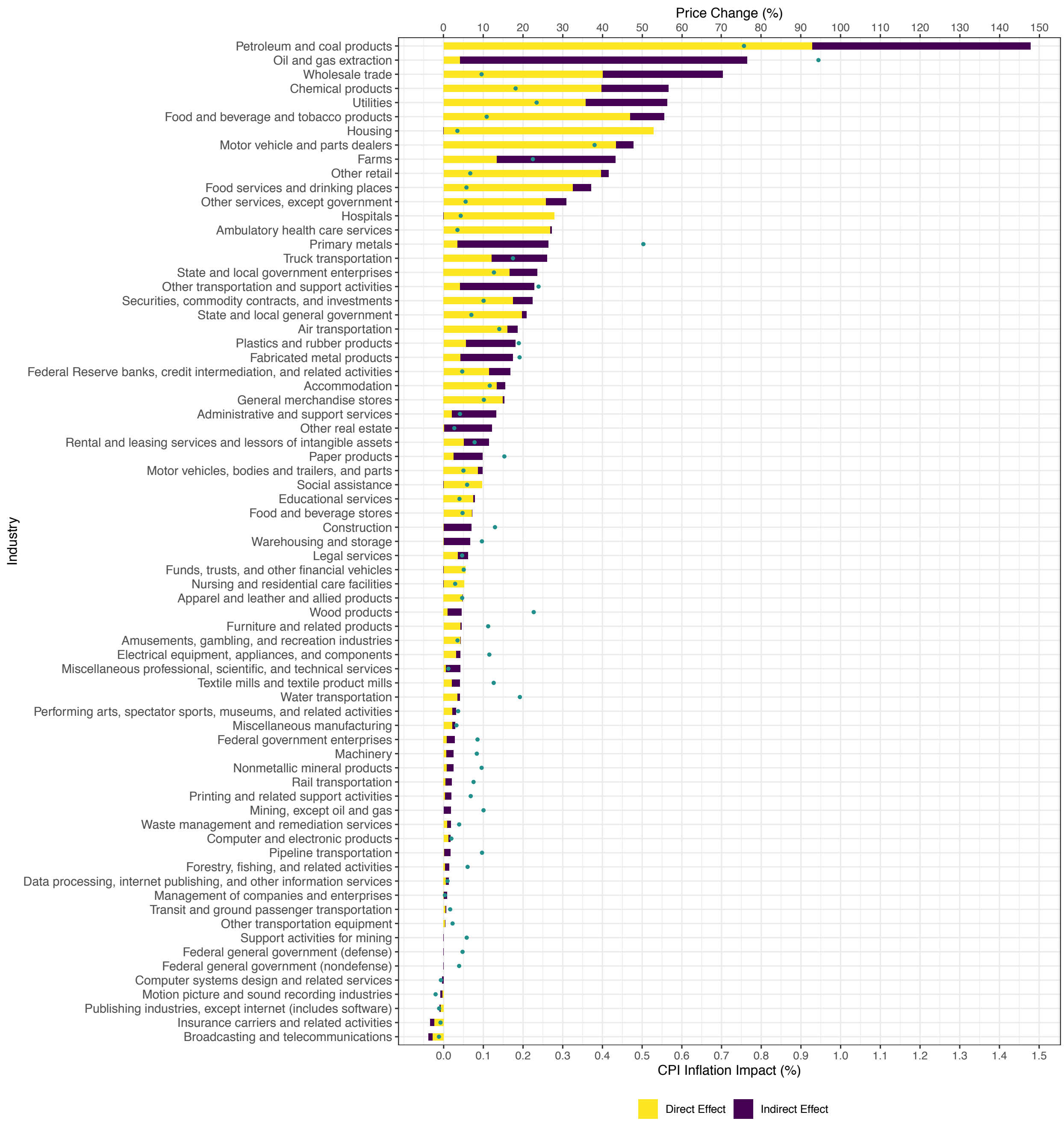
Code	Description	Period of Price Change	Rank Forward Linkages	Yearly Price Change (%)	Share of Personal Consumption	CPI Total	CPI Direct	CPI Indirect	Rank CPI Impact
GFGN	Federal general government (nondefense)	Sectoral price volatility 2000-2019	71	1.14	0.00	0.00	0.00	0.00	71
		Yearly price change from 2020 Q4 to 2021 Q4	71	3.90	0.00	0.00	0.00	0.00	66
		Yearly price change from 2021 Q2 to 2022 Q2	71	4.95	0.00	0.00	0.00	0.00	67

Note:
This table summarizes the main results of simulated price shocks using the Leontief price model for all industries. Each row provides the overall inflation impact (total, direct, and indirect) resulting from a simulated price shock to an individual industry. For each industry, three different magnitudes of price shocks are used: (1) the average sectoral price volatility of the industry over the period 2000-2019, (2) the annual price change of the industry from 2020-Q4 to 2021-Q4 (the post-shudown period), and (3) the annual price change of the industry from 2021-Q2 to 2022-Q2 (the period which includes the 2022-Q2 price shock resulting from the beginning of the war in Ukraine). The magnitude of the price shocks for each of the three scenarios is given. In addition, each industry's ranking among the 71 industries in terms of forward linkages is provided, as is the industry's ranking in terms of the overall inflation impact for each of the three price shocks. The industries are arranged in descending order according to their inflation impact when we simulate the sectoral price volatility as a shock to the industry.

Figure A1a: Inflation impact. Sectoral price volatility 2000-2019

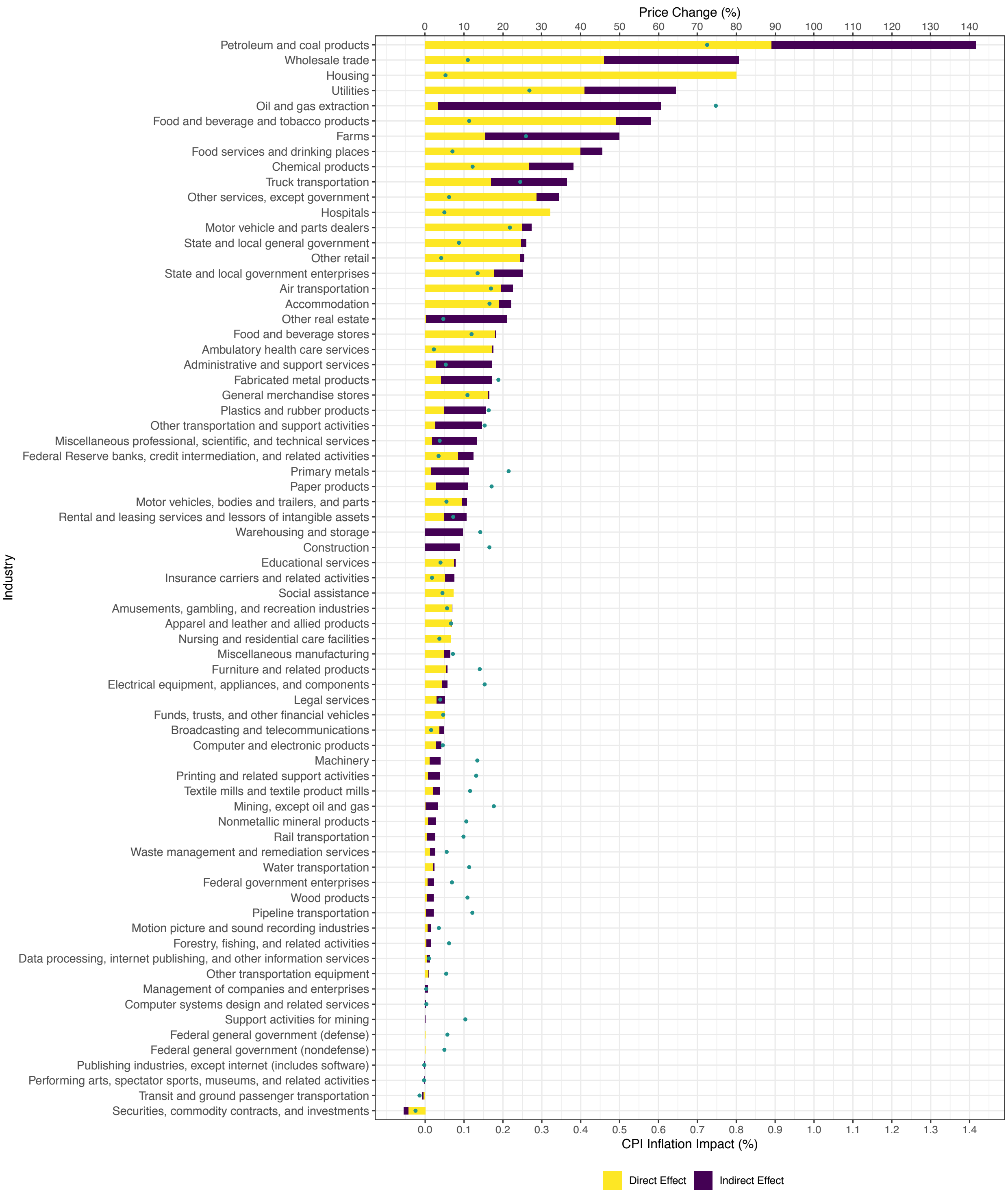
Notes: The results of price-shock simulations for each individual industry using the Leontief price model. The combined length of the purple and yellow bars represents the total inflation impact on a synthetic CPI generated by a price shock to each industry. The magnitudes of the price shocks to each industry (indicated by a green dot) are the average annual price change of each industry between 2000-2019, which we call the "sectoral price volatility" of the industry. The purple bar represents the indirect and the yellow bar the direct inflation impact. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

Figure A1b: Inflation impact. Yearly price change from 2020 Q4 to 2021 Q4



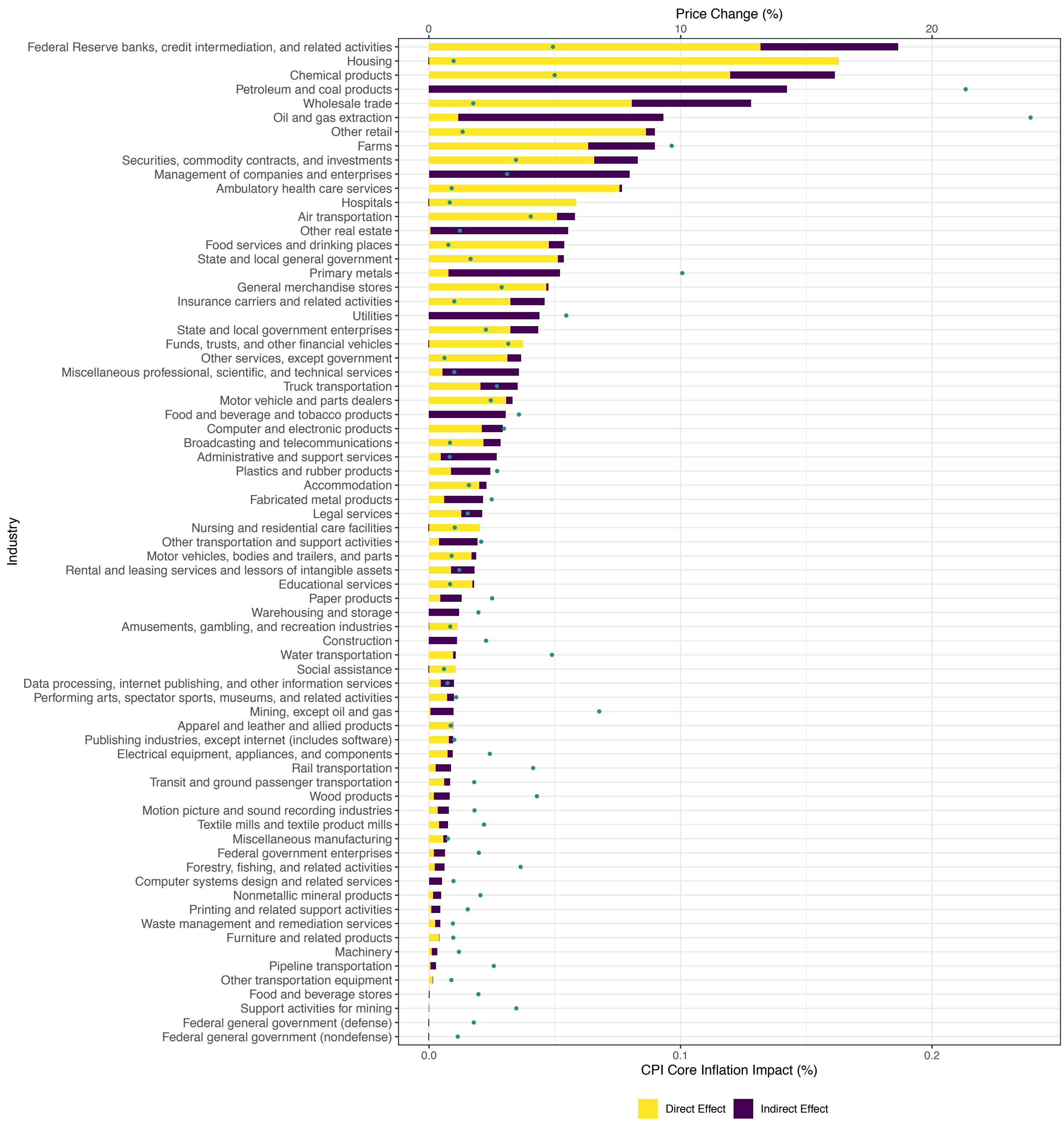
Notes: The results of price-shock simulations for each individual industry using the Leontief price model. The combined length of the purple and yellow bars represents the total inflation impact on a synthetic CPI generated by a price shock to each industry. The magnitudes of the price shocks to each industry (indicated by a green dot) are the annual price change of each industry between 2020-Q4 and 2021-Q4. The purple bar represents the indirect and the yellow bar the direct inflation impact. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

Figure A1c: Inflation impact. Yearly price change from 2021 Q2 to 2022 Q2



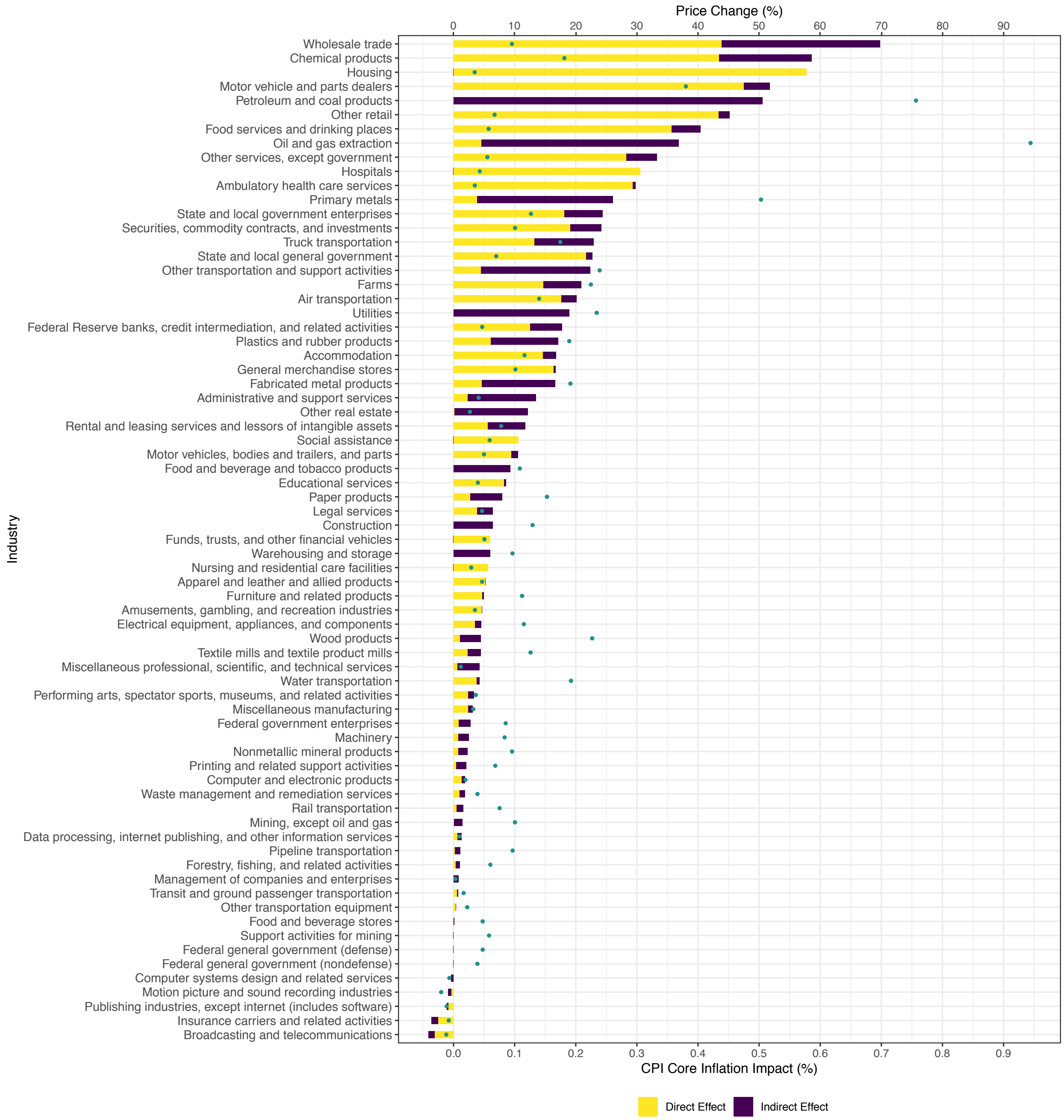
Notes: The results of price-shock simulations for each individual industry using the Leontief price model. The combined length of the purple and yellow bars represents the total inflation impact on a synthetic CPI generated by a price shock to each industry. The magnitudes of the price shocks to each industry (indicated by a green dot) are the annual price change of each industry between 2021-Q2 and 2022-Q2.. The purple bar represents the indirect and the yellow bar the direct inflation impact. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

Figure A2a: Core inflation impact. Sectoral price volatility 2000-2019



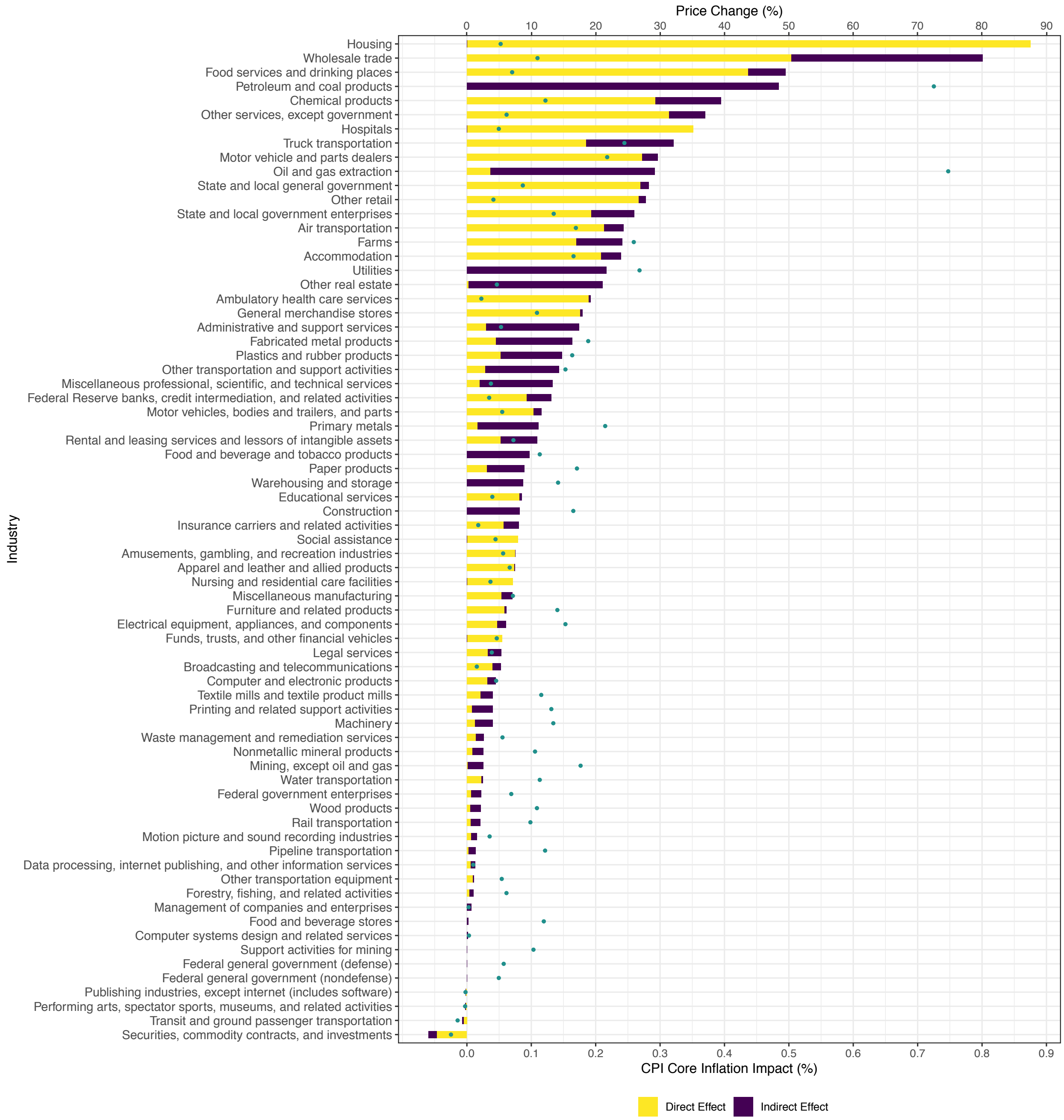
Notes: The results of price-shock simulations for each individual industry using the Leontief price model, excluding certain industries to simulate core inflation. The combined length of the purple and yellow bars represents the total inflation impact on a synthetic core CPI generated by a price shock to each industry. The magnitudes of the price shocks to each industry (indicated by a green dot) are the average annual price change of each industry between 2000-2019, which we call the "sectoral price volatility" of the industry. The purple bar represents the indirect and the yellow bar the direct inflation impact. The industries excluded from the calculation of the core CPI are "Utilities", "Food and beverage and tobacco products", "Petroleum and coal products", "Food and beverage stores". Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

Figure A2b: Core inflation impact. Yearly price change from 2020 Q4 to 2021 Q4



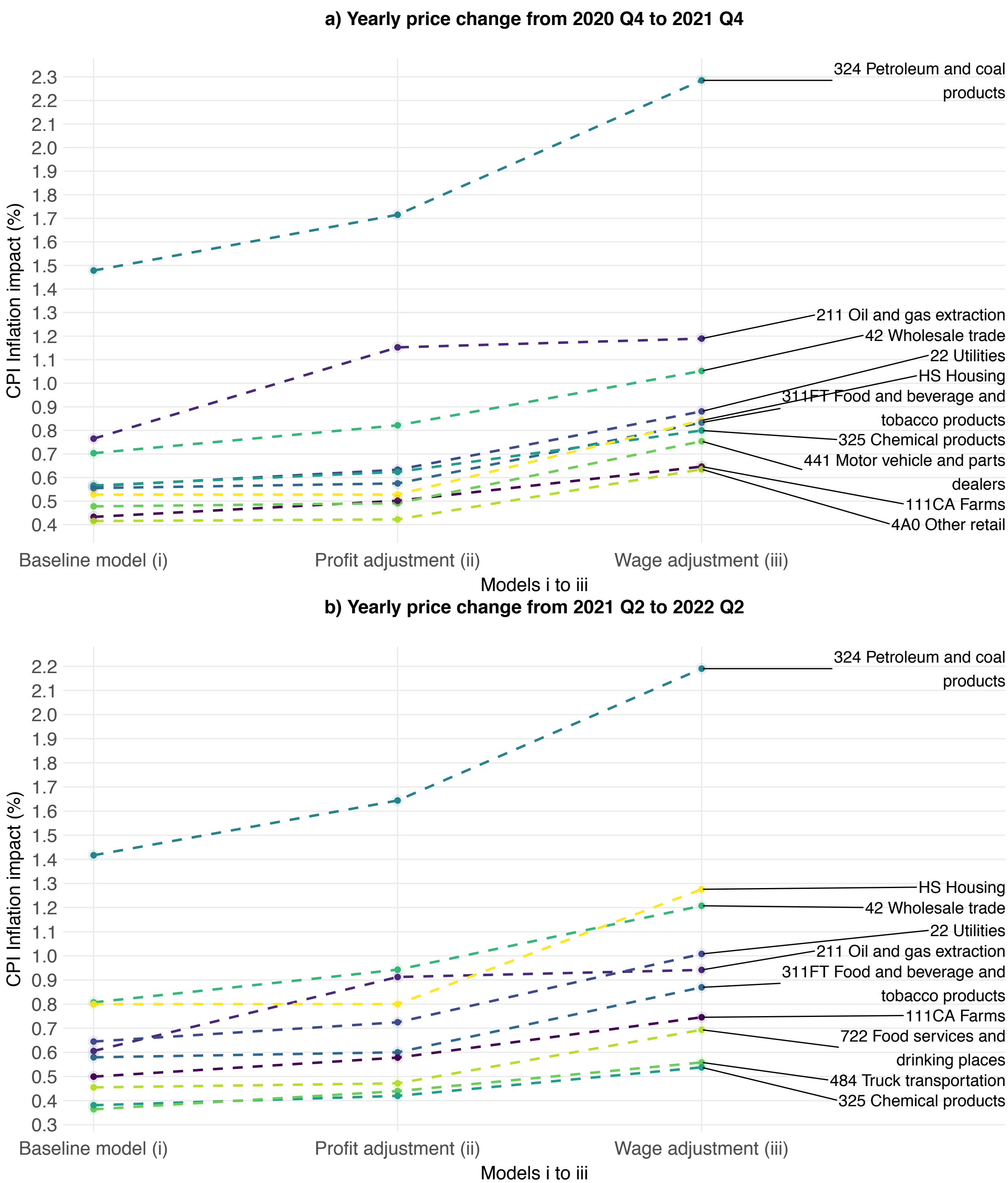
Notes: The results of price-shock simulations for each individual industry using the Leontief price model, excluding certain industries to simulate core inflation. The combined length of the purple and yellow bars represents the total inflation impact on a synthetic core CPI generated by a price shock to each industry. The magnitudes of the price shocks to each industry (indicated by a green dot) are the annual price change of each industry between 2020-Q4 and 2021-Q4. The purple bar represents the indirect and the yellow bar the direct inflation impact. The industries excluded from the calculation of the core CPI are "Utilities", "Food and beverage and tobacco products", "Petroleum and coal products", "Food and beverage stores". Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

Figure A2c: Core inflation impact. Yearly price change from 2021 Q2 to 2022 Q2



Notes: The results of price-shock simulations for each individual industry using the Leontief price model, excluding certain industries to simulate core inflation. The combined length of the purple and yellow bars represents the total inflation impact on a synthetic core CPI generated by a price shock to each industry. The magnitudes of the price shocks to each industry (indicated by a green dot) are the annual price change of each industry between 2021-Q2 and 2022-Q2. The purple bar represents the indirect and the yellow bar the direct inflation impact. The industries excluded from the calculation of the core CPI are "Utilities", "Food and beverage and tobacco products", "Petroleum and coal products", "Food and beverage stores". Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables. Sources: BEA chain-type price indexes for gross output by industry, and the BEA Input-Output accounts, after-redefinitions 2019 tables.

Figure A3: Conflict inflation impact. Yearly price change from 2020 Q4 to 2021 Q4



Notes: Each point represents the total inflation impact on a synthetic CPI generated by the actual price change of each industry from (a) 2020 Q4 to 2021 Q4 and (b) from 2021 Q2 to 2022 Q2 across three specifications of the price model: i) Wages and other income factors fixed: ii) Profits adjusting to increase profit shares back to initial level: iii) Wages adjusting to compensate for real wage loss, other income factors fixed. Sources: BEA chain-type price indexes for gross output by industry, and BEA Input-Output accounts, after redifinitions 2019 tables.

Figure A4 Part 1: Input vs Output prices

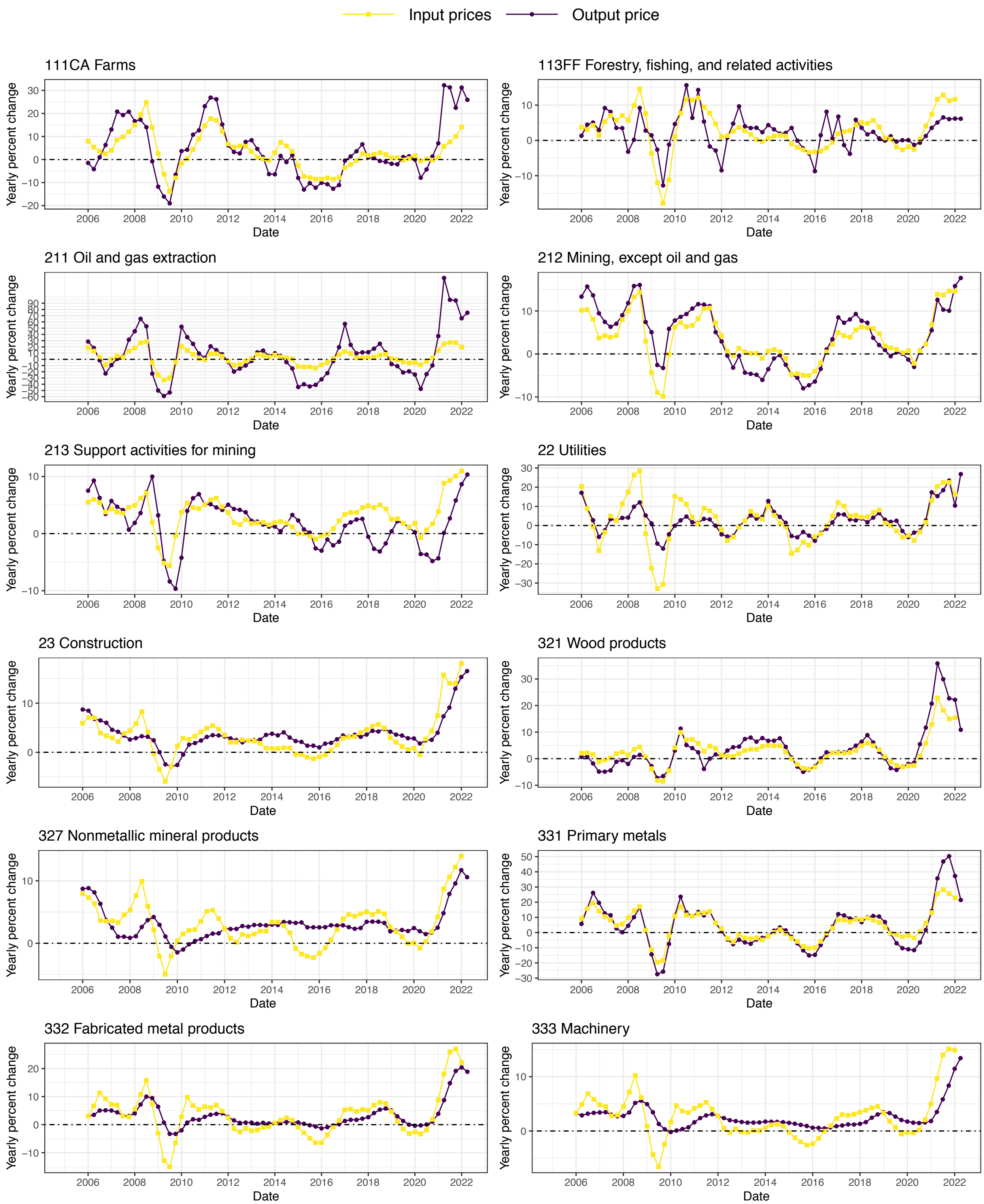


Figure A4 Part 2: Input vs Output prices

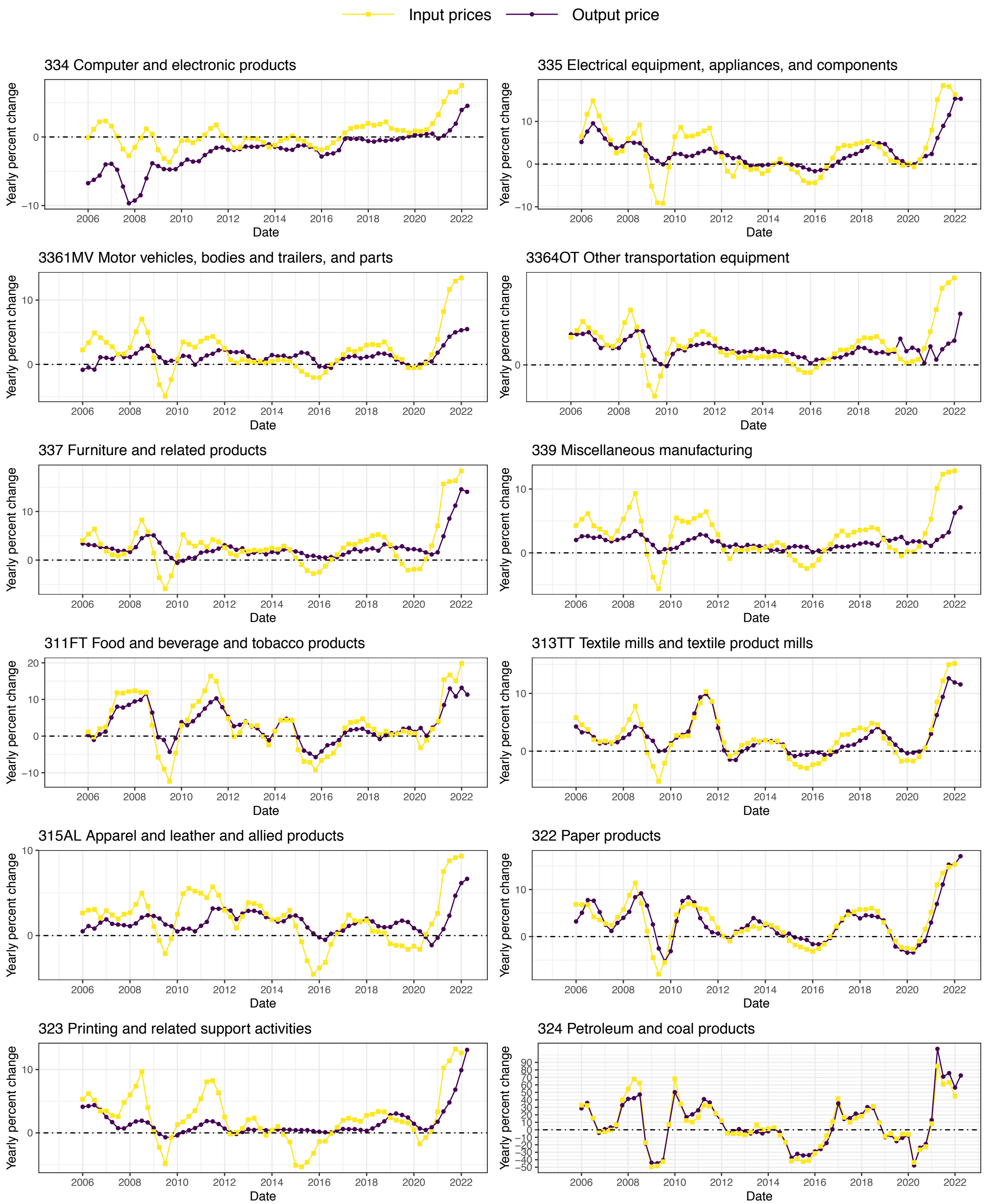


Figure A4 Part 3: Input vs Output prices

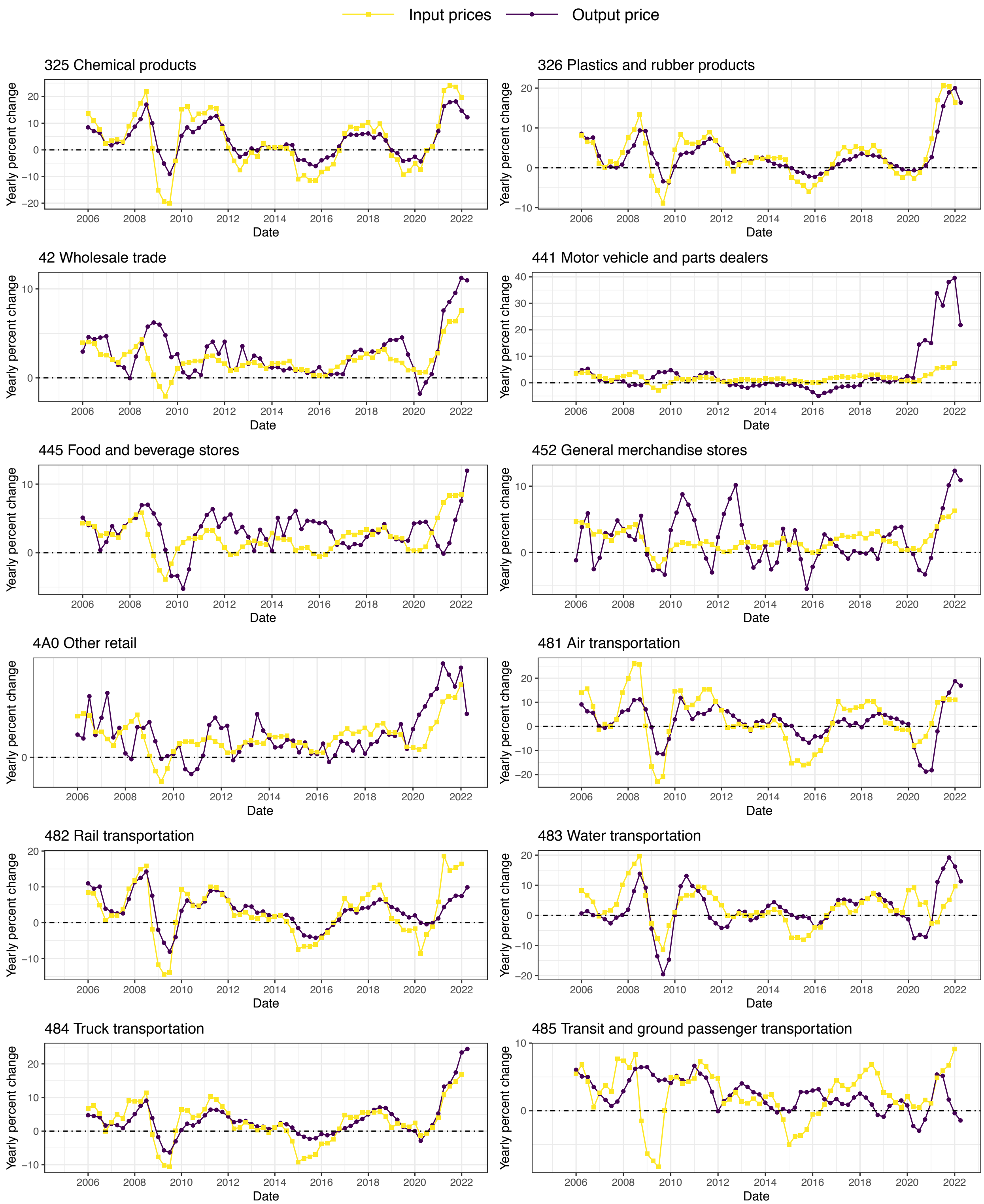


Figure A4 Part 4: Input vs Output prices

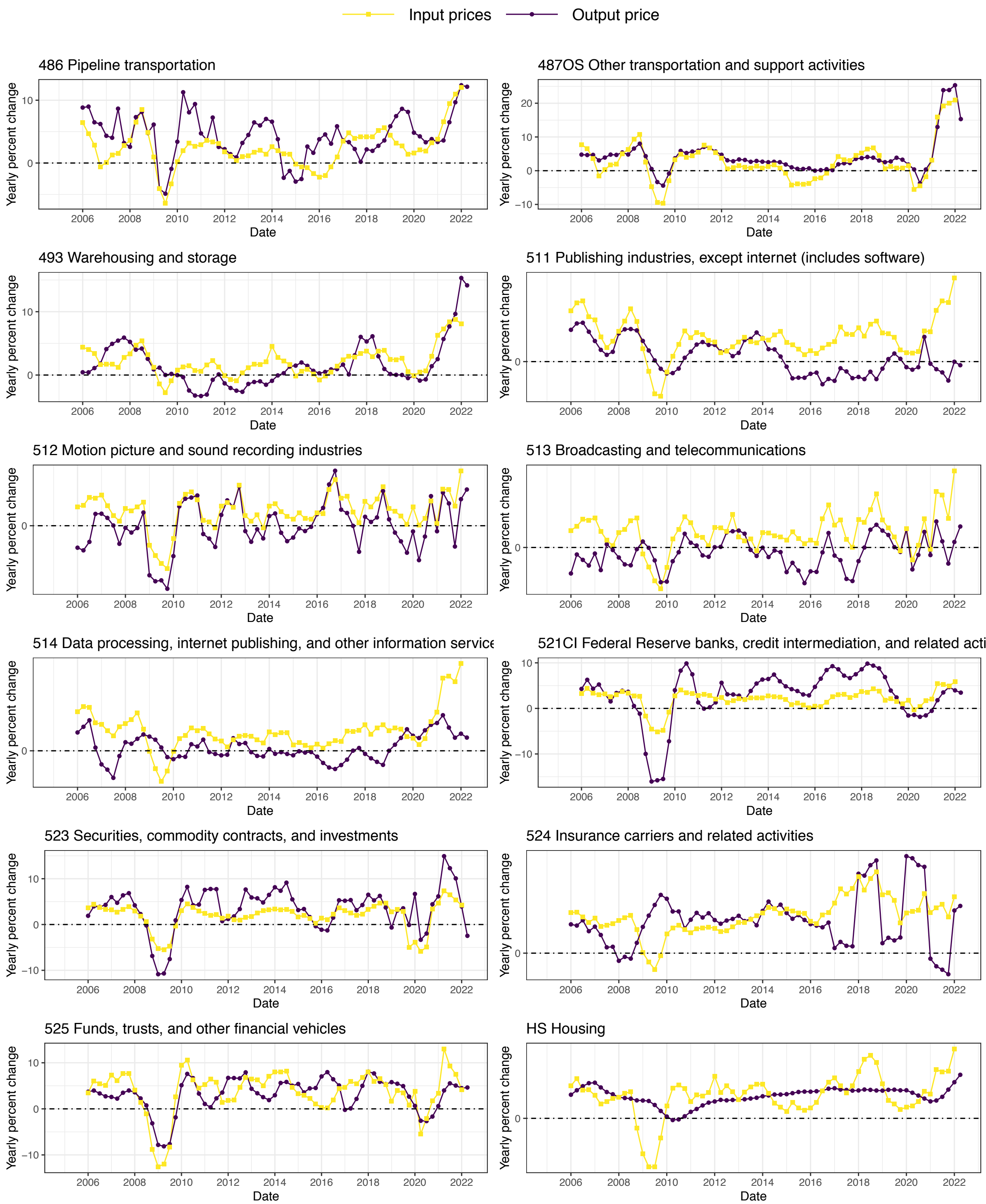


Figure A4 Part 5: Input vs Output prices

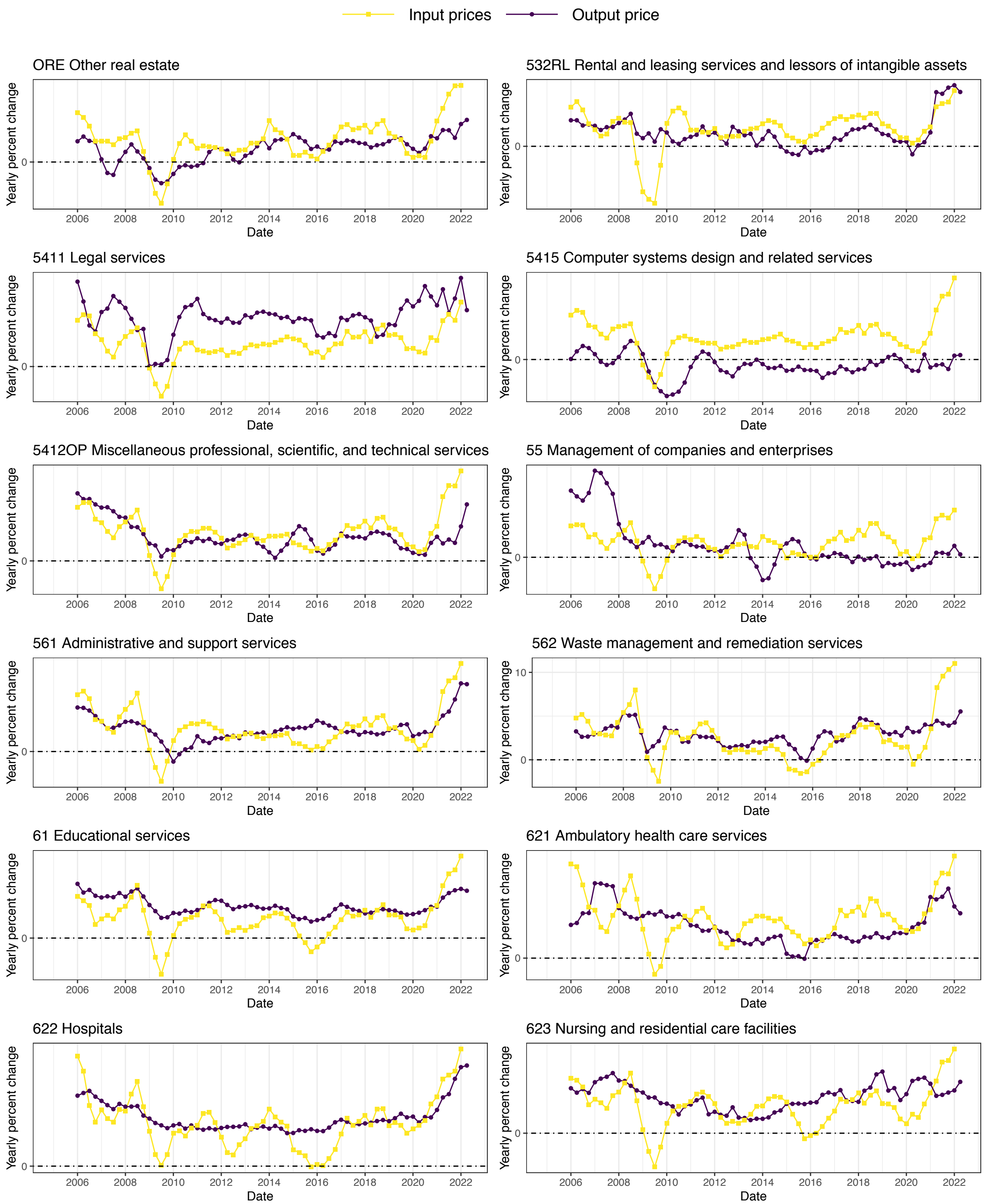
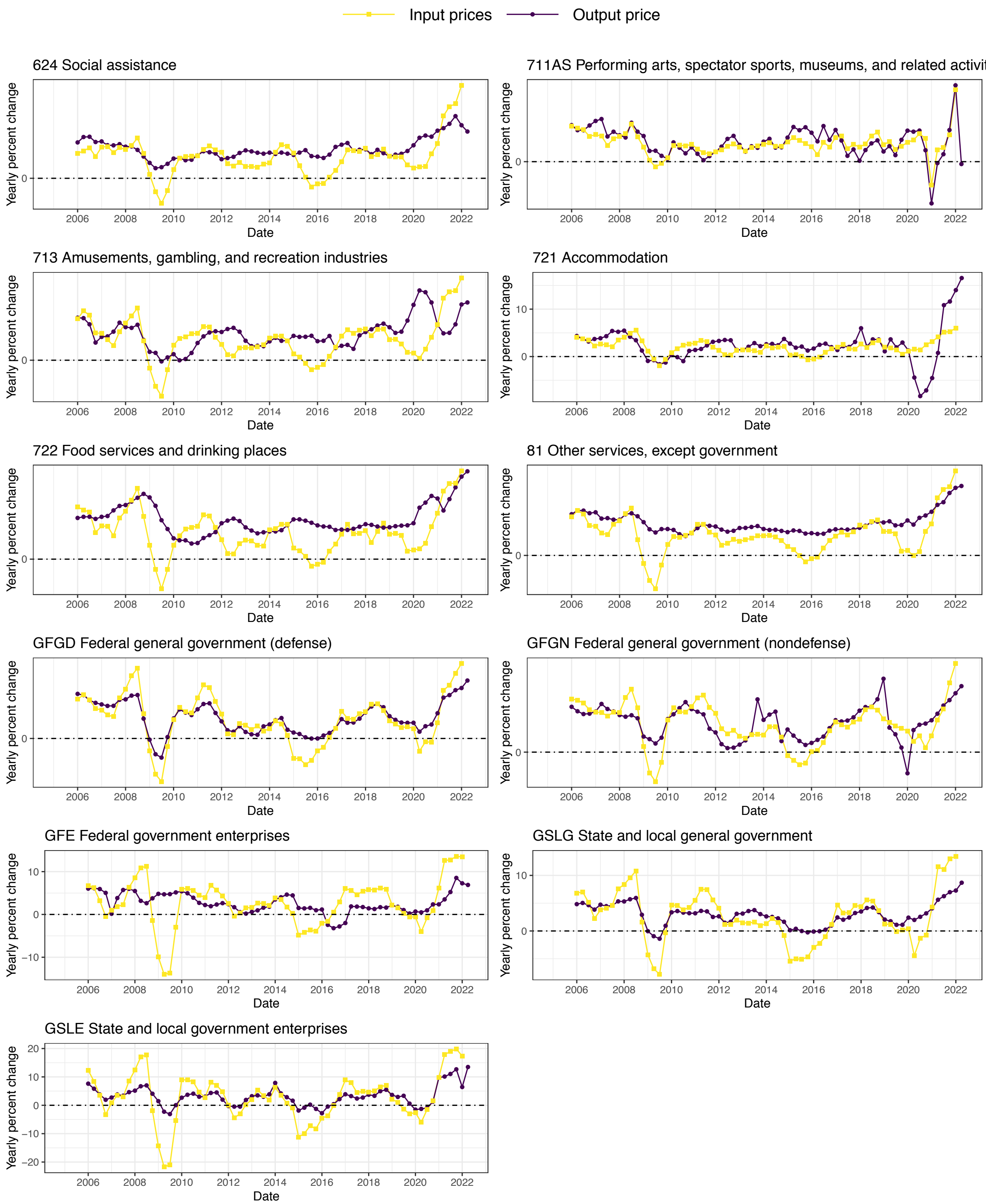


Figure A4 Part 6: Input vs Output prices



Notes: Yearly input (yellow) and output (purple) price change of each industry, from 2006 to the first quarter of 2022. Sources: BEA chain-type price indexes for gross output and for intermediate inputs by industry.