EUROPEAN CENTRAL BANK

EUROSYSTEM

Working Paper Series

Chiara Osbat, Yiqiao Sun, Martin Wagner

Sectoral exchange rate pass-through in the Euro Area

No 2634 / December 2021

Abstract

We study exchange rate pass-through (ERPT), i.e., the impact of exchange rate movements on inflation, focusing on euro area import prices at a sectorally disaggregated level. Our estimation strategy is based on VAR-X models, thus incorporating both endogenous and exogenous explanatory variables. The impulse response functions not only allow to study the extent but also the dynamics of ERPT. We find that ERPT is heterogeneous in terms of magnitude across sectors. We further investigate what industry-specific characteristics affect the heterogeneity of ERPT. Across various model specifications including import penetration, market integration, competition and value chain integration, we find that higher market concentration and higher backward integration in global value chains decrease pass-through, in line with previous findings in the literature.

JEL Classification: C50, F30, F40

Keywords: exchange rates, import prices, pass-through, euro area, sectoral disaggregation

Non-technical summary

Exchange rate pass-through (ERPT), i.e., the degree to which exchange rate movements are transmitted to domestic prices, is the focus of many academic studies but it is also a very important concept and quantity for policy makers. The extent and dynamics of ERPT are a key ingredient of forecasting models of prices and of trade balance, with direct implications for monetary policy transmission. In general, and of interest also for academics, the degree to which exchange rate movements shape domestic economic variables is important for understanding macroeconomic dynamics.

In this paper we study exchange rate pass-through on euro area import prices at a sectorally disaggregated level using VAR-X models to incorporate endogenous and exogenous explanatory variables. Our estimated impulse response functions allow to study the extent and the dynamics of ERPT.

We find that ERPT is heterogeneous in terms of magnitude across sectors and, with the literature on drivers of ERPT in mind, we investigate if industry-specific characteristics related to domestic competition and to various dimensions of trade openness affect the heterogeneity of ERPT.

Across various model specifications including market concentration, competition, import penetration, trade integration in general and specifically forward and backward value chain integration, we find that higher market concentration and higher backward integration in global value chains decrease pass-through, in line with previous findings in the literature.

1 Introduction

Exchange rate pass-through (ERPT) is the degree to which exchange rate movements are transmitted to domestic prices. It is a constant focus of interest of policymakers and academics: The former are primarily interested in the extent and dynamics of ERPT as a key ingredient of their forecasting models of prices and of trade balance, with direct implications for monetary policy transmission. Moreover, the degree to which exchange rate movements shape domestic economic variables is important for understanding macroeconomic dynamics. Along with academics, they are also interested in the role of ERPT in understanding the mechanisms of international price adjustment, e.g., in reconciling the observation that the relative stability of import prices does not reflect the high volatility of nominal exchange rates with economic theory. Evidence of the "disconnect" between exchange rates and prices would also imply a greater degree of insulation and thus greater effectiveness of monetary policy. Specifically, the main interest focuses on the notion whether ERPT is *complete*, defined as a one-to-one response of import prices to exchange rate changes, and if so at what time horizon. Existing empirical evidence suggests that pass-through is incomplete even in the long-run and much effort has been made to understand the causes of this incompleteness.

When discussing ERPT, it is important to qualify the prices of reference: While it is natural to expect incomplete ERPT to final consumer price indices, which contain a large share of non-traded goods and services, a much more debated question is what prevents exchange rates from feeding one-to-one into import prices, especially even at medium-term to longer term horizons. In this paper, we study ERPT to import prices at the sectoral level in the euro area, using data on 28 sectors according to NACE Rev.2 classification.[1] Twenty-two sectors are manufacturing sectors, four are mining and quarrying and two are services sectors.

The theoretical literature offers two main standpoints as to why ERPT may be incomplete. One strand points to nominal rigidities as the main cause of the non-responsiveness of

[1] NACE is the statistical classification of economic activities in the European Community and is the subject of legislation at the European Union level, which imposes the use of the classification uniformly within all the Member States. The NACE Rev. 2 is the new revised version of the NACE Rev. 1 and of its minor update NACE Rev. 1.1. NACE Rev. 2 reflects the technological developments and structural changes of the economy. Development of NACE Rev. 2 has benefited from the work preparing the fourth revision of the United Nations International Standard Industrial Classification of All Economic Activities (ISIC Rev. 4). NACE Rev. 2 has been created based on ISIC Rev. 4 and adapted to the European circumstances.

import prices to exchange rate changes, while the other takes a more micro-economic viewpoint and ascribes incomplete ERPT to market and industry characteristics. Key contributions in this spirit are Krugman (1987), Dornbusch (1987) or Baldwin (1988). Exchange rate pass-through is also related to the weight of non-traded inputs in the wholesale and consumer prices of imported goods as discussed, e.g., by Burstein et al. (2003), Burstein et al. (2005), or Goldberg and Verboven (2005). The explanations offered by industrial organization theories hinge on market-specific characteristics, highlighting different mechanisms. In line with this reasoning, ERPT is seen to depend, *inter alia*, on the substitutability between foreign and domestic goods, the competitive structure in the industry both domestically and globally, barriers to trade, import penetration, the relative market size and the degree of integration in global value chains of the firms producing a certain product. If exporters set prices in their own currency, labelled as producer currency pricing (PCP), then ERPT is one in the short run. Conversely, if exporters set prices in the currency of the destination country, labelled as local currency pricing (LCP), then ERPT is zero in the short run. LCP is a particular form of "pricing to market" (PTM), which describes the behaviour of exporting firms that change their mark-ups depending on the destination markets, e.g., offsetting exchange rate movements either completely (LCP) or only to some degree, to maintain market shares. In fact, in a dynamic setting the response pattern may be more complex than suggested by the clear-cut boundary cases of PCP and LCP, with firms adjusting prices in either case over time in response to exchange rate fluctuations. It is also important to note here that a large part of the international trade literature discussing ERPT is based on static models and often places (usually implicitly) exogeneity restrictions on foreign variables and the nominal exchange rate. Therefore, in the empirical assessment of the relationships highlighted by this type of literature, single-equation OLS estimation strategies are usually pursued. If the explanatory variables are, however, endogenous, only a system approach or instrumental variable estimation would allow for consistent estimation of ERPT. Also, these models are often formulated at product-level or at the level of a narrowly defined industry with highly substitutable goods. On the other hand, modern open economy macroeconomic models, e.g., Corsetti et al. (2008), have incorporated more micro-founded explanations in dynamic stochastic general equilibrium (DSGE) models allowing for different degrees of nominal rigidities. This approach has allowed, e.g., Corsetti et al. (2008) to derive structural estimates of ERPT under different assumptions and to use them to quantify potential biases arising from non-observable variables and measurement error in ERPT equations. These models are typically set in a two-country framework and endogenously determine the optimal degree of ERPT as a function of, e.g., the share of distribution costs in the final price of imported goods, the degree of substitutability between goods, and other factors affecting the steady-state mark-ups. These models focus on macroeconomic aggregates and are less amenable to studying the effect of exchange rates on prices of individual goods or in specific industries.

In this paper we follow a somewhat hybrid approach. That is, we use sectorally disaggregated data to study whether pass-through differs across broader industries and to account for endogeneity we use vector autoregressive (VAR) models. Moreover, each sectoral VAR model contains exogenous variables including international commodity prices or some measures of the business cycle to control for economy-wide supply- and demand-side effects to account (at least to some extent) for the fact that prices, quantities and exchange rates are jointly determined in a general equilibrium setting.

Another issue that has spurred quite some discussion in policy and academic circles is whether ERPT has declined over time. The literature proposes two explanations: one is that more stable monetary policy conditions within a credible anti-inflationary regime reduce the degree to which currency changes are transmitted to domestic prices. Taylor (2000) and Engel (2006) provide theoretical analyses of this argument, while Gagnon and Ihrig (2004) and Carrière-Swallow et al. (2021) provide empirical assessments. In the euro area the introduction of the common currency has automatically decreased the proportion of trade exposed to exchange rate movements. The prevalence of micro- or macroeconomic factors in explaining the extent of pass-through has been much debated. A prominent study frequently cited in this regard is that of Campa and Goldberg (2005) who first differentiated microeconomic from macroeconomic explanations for the decline in the responsiveness of import prices to exchange rate movements and found that changes in the composition of imports towards goods whose prices are less sensitive to exchange rate movements, such as differentiated goods in the manufacturing sector, do affect the extent of ERPT across sectors. The results by Campa and Goldberg (2005) are based on differences in ERPT across sectors: a shift in the import composition towards low pass-through sectors may lead to a decline in the observed aggregate pass-through. Our sectoral analysis provides valuable input for this line of research by providing a quantification of the inter-sectoral variability of pass-through.

Yet another proposed explanation for the decline of ERPT, especially in the euro area, is the concentration in invoicing currencies after the introduction of the euro. The currency of invoice for imports of goods and services also determines the degree and dynamics of pass-through, at least in the short to medium run, and can depend on many structural factors. The decision to invoice imports in producer, local or dominant currency can depend on the existence of strategic complementarities as exporters tend to use the currency of the country that dominates their industry or the one that their main competitors use, see (Amiti et al., 2019). More homogeneous goods tend to be priced in US dollars globally. The role of the euro as a currency of invoice has increased in the 21st century, resulting in a larger share of euro area imports invoiced in euro. The expected result would be a lower exchange rate pass-through to domestic euro area prices. Indeed, euro area member states with a higher share of extra-euro area imports invoiced in euro tend to experience a lower degree of exchange rate pass-through. A comprehensive study by Devereux et al. (2015) focuses on the joint determination of ERPT and currency of invoicing in international trade. Using Canadian micro-level import data, they confirm the model predictions that ERPT should be non-monotonic and U-shaped in the market share of exporting firms, but monotonically declining in the market share of importers; exchange rate pass-through should be lower, the higher is local currency invoicing of imports.

For the purposes of informing monetary policy it is of particular interest to study the pricing chain from import to wholesale to consumer prices (as done by Hahn (2003), for instance, for euro area price aggregates). Our paper focuses on the first stage, as rigidities down the pricing chain can only dampen the transmission to final consumer prices. We find sizeable differences in ERPT across the sectors for which we are able to collect all necessary data. Contemporaneous ERPT varies from close to full for mining commodities (around -0.8) to no pass-through for beverages and tobacco but also automotive sectors. One year ahead, for eight out of 28 sectors ERPT is not significantly different from zero. At the same time, ERPT is never complete, meaning that in all cases it is significantly different from -1. In the long run (24 months), in most cases the confidence bands widen so that it is hard to discern significant results: while the point estimate often increases, the widening of uncertainty at two years ahead implies that our ERPT estimates lose statistical significance.

The paper is organized as follows: In Section 2 we provide a brief overview of existing work on (sectoral) ERPT to import prices. Next, in section 3 we describe the data and the modelling framework. The empirical results are presented in section 4 and section 5. Section 6 summarizes the main findings and concludes on insights for policymaking.

2 Previous Studies on Sectoral ERPT

Empirical research for the euro area has confirmed diverse impacts on prices at the industrial sector level since Campa and Goldberg (2005). Differences in exchange rate pass-through can be explained by the import structure. Campa and Goldberg (2005) show that pass-through to import prices is found to be higher in energy and lower in manufacturing across several euro area countries and the United States. Focusing on differences across countries the recent study by Özyurt (2016) finds partial ERPT into euro area import prices for the euro area aggregate and the five largest countries. For the largest euro area countries, she finds striking heterogeneities in the degree but also in the dynamics of ERPT, signalling heterogeneity in domestic market structures.

Campa et al. (2005) also find that exporters price discriminate to a larger extent between markets for manufacturing goods than between those for commodities. Hahn (2003) similarly reports that, among the sub-sectors of industry (excluding construction), exchange rate pass-through is highest in electricity, gas and water supply, as well as in the energy sector. The lowest pass-through is found for capital goods. As mentioned in the introduction, the main reason may lie in the product characteristics: energy products are more homogeneous, entailing a higher degree of competition, and their price is set in international markets. By contrast, capital goods are less homogeneous and less substitutable, leading to less competition; hence they are priced more locally.

We are not the first to conduct an empirical study of ERPT at the sectoral level, although we are, to the best of our knowledge, the first to do it for the euro area as a whole while departing from using a variant of a simple single-equation regression. Previous studies based their empirical analyses on various versions of the equation discussed by Goldberg and Knetter (1997) that relates the price of imports (or exports, depending on the point of view) to the nominal exchange rate, a primary explanatory variable which is a measure of domestic prices, and other variables labelled 'demand shifters' (sometimes proxied by GDP growth). This type of equation is usually estimated in a single equation framework. Knetter (1993) and Yang (1997) are two rather early studies which look at the problem from the point of view of exporting firms. Knetter (1993) used a two-way fixed effects model to study the pricing to market behaviour of US, UK, German and Japanese exporting firms using unit values of exports for very disaggregated (7-digit) industries and found more variation in the degree of ERPT across industries than across countries. He simply regressed the growth rates of prices on those of exchange rates, while exporters' marginal costs were meant to be captured by the time effects in his panel regression.[2] Yang (1997) also looked at ERPT from the point of view of the exporter and studied US manufacturers across industrial sectors (which largely overlap with ours) and finds evidence of incomplete ERPT, with largely varying degrees across industries.

Campa and Goldberg (2005) studied ERPT to import prices in 23 OECD countries both at the aggregate and at a broadly disaggregated level. They looked at food, manufacturing, energy, raw materials and non-manufacturing imports and found evidence of partial ERPT in the short run, in particular in the food and manufacturing sectors. They concluded that the discussed decline in ERPT observed in OECD countries since the 1980-90s was more due to a shift in the composition of imports away from high ERPT sectors like energy and into lower ERPT sectors like manufacturing and food. Campa et al. (2005) used the same methodology and estimated the same equation as Campa and Goldberg (2005) but used data for several euro area countries, both at the aggregate level and for nine sectors.[3] They found evidence of incomplete ERPT both in the short- and long-run across all sectors. They presented also some simple averages of ERPT across euro area countries, but did not analyse euro area aggregates directly.

More recently, Hara et al. (2015) looked at changes in ERPT in Japan and found that it has increased for PPI and CPI since the 2000s, due partly to the increased dependence on imports in production, but also to the increased responsiveness of inflation to marginal costs. Amiti et al. (2014) proposed a theoretical model that accounts for the fact that exporters use imports as intermediate goods in production. Assuming that firms have variable markups, the model predicts that firms that are large in the sense of having large import and market shares, have low exchange rate pass-through. In their empirical analysis using Belgian firm-product-level data on imports and exports they found that indeed large exporters are also large importers and have lower pass-through than small non-importing firms. This finding supports the view that higher integration in supply chains may reduce ERPT.[4]

As mentioned above, a potentially large drawback of the empirical literature surveyed

[2]Using unit values is not equivalent to using actual prices, but sectoral data on prices have become more easily available only in recent years. Furthermore, the more disaggregated the products, the closer unit values are to prices

[3]The sectors are: food and live animals, beverages and tobacco, inedible crude materials, mineral fuels, oils fats and waxes, chemical products, basic manufactures, machines and transport equipment and other manufactured goods.

[4]On the impact of integration in global supply chains see also Ortega and Osbat (2020) and Georgiadis and Graeb (2019).

here is that single-equation OLS estimation of the coefficients is not consistent if any explanatory variable is endogenous. In fact, while our approach is similar to that of the existing literature as regards the choice of variables and its theoretical underpinnings, our choice of the VAR-X modelling framework not only allows us to study the dynamics of ERPT in more detail, but also equips us with the necessary tools to address empirically the question concerning exogeneity of the exchange rate and of domestic and foreign producer prices, which we choose as proxies for the price of substitutes and for foreign costs respectively.

From a more agnostic point of view, our results based on well-specified linear dynamic models can be seen as generators of stylized facts concerning the behaviour of import prices with respect to various shocks. One of these shocks, which we focus on here, is a shock to the nominal effective exchange rate. However, there are other interesting effects that can be studied within the VAR-X framework. These include the effects of oil price or foreign cost/price shocks on import prices or domestic producer prices. In subsequent work we will extend our analysis to estimate models that impose more structure than in the present paper. In this study we focus on Cholesky decompositions for shock identification and perform robustness analysis with respect to the positioning of nominal exchange rate in the VAR-X as well as with respect to modelling the effects of additional explanatory variables, as discussed in Section 3.

3 Data and Modelling Framework

3.1 Data

For our empirical analysis we collect data from various sources to construct sector-level variables for the euro area. We cover up to 28 sectors according to the NACE Rev. 2 classification, as listed in Table 1. Among those, 22 are manufacturing sub-sectors and include the aggregated manufacturing sector as well. We are fortunate to use euro area import prices in contrast to many previous studies that had to resort to other proxies such as unit value index. Our data are monthly and the sample for each sector starts as soon as import prices become available. As shown in Table 1 they mostly start in 2000 or 2005. In Appendix A we provide an overview of all details on the data coverage, description, treatment and sources.

Our choice of variables is quite standard in the empirical literature on ERPT to import prices. Typically, empirical specifications include measures of *foreign cost*, *prices of domestic substitutes* and '*demand shifters*'. We proxy foreign costs by the sector-specific foreign producer price index (ppi^*) and the price of domestic substitutes by the sector-specific domestic producer price index (ppi). Of course, marginal costs are the most relevant unobservable variable while producer price indices comprise both costs and mark-ups and therefore ppi^* is rather a rough measure for cost. On the other hand, our use of sector-specific PPI places us in a better position than most of the literature on sectoral ERPT, where only aggregate PPI variables, or even only CPI, are used. The nominal effective exchange rates are expressed in terms of units of foreign currency per euro. As a consequence, our ERPT estimates are expected to have a negative sign and complete ERPT corresponds to a value of -1. In contrast to the studies mentioned in Section 2, however, we include *all* these variables, while Yang (1997), e.g., omits a measure of exporters' costs and the other studies surveyed do not include a measure of the price of domestic substitutes. Moreover, we include a set of exogenous variables to control for international commodity prices, business cycles and sectoral total demand. For each sector we compute the first principal component of the growth rate of sector-relevant commodity prices. These price variables are relevant in many cases in addition to the oil price alone. A summary is presented in Table AA6 in Appendix A. Business cycle conditions are proxied using the output gap, which we estimate by detrending real GDP[5] data using the HP-filter, M3 growth and the 3-month nominal interest rates[6].

[5]We interpolate real GDP for the euro area with the index of industrial production applying the Chow and Lin (1971) procedure.

[6]We are aware of the problems related to using HP filtered variables, as exposed by Harvey and Jaeger (1993), but empirically this variable turned out systematically to have more explanatory power than the alternative measures of euro area domestic demand that we experimented with.

Table 1: **Data coverage of the VARX estimation by sector**

NACE2	Sector description	start	exog. var.
2B0000	MINING AND QUARRYING	2005m2	*dd*
2B0500	Mining of coal and lignite	2000m2	*dd*
2B0600	Extraction of crude petroleum and natural gas	2005m2	*dd*
2B0700	Mining of metal ores	2000m2	*dd*
2C0000	MANUFACTURING	2005m2	*comm*, *gap*
2C1000	Manufacture of food products	2005m2	*comm*, *gap*
2C1100	Manufacture of beverages	2005m2	*comm*, *gap*
2C1200	Manufacture of tobacco products	2005m2	*comm*
2C1300	Manufacture of textiles	2005m2	*comm*
2C1400	Manufacture of wearing apparel	2005m2	*comm*, *gap*
2C1500	Manufacture of leather and related products	2005m2	*comm*
2C1600	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	2005m2	*dd*
2C1700	Manufacture of paper and paper products	2005m2	*dd*
2C2000	Manufacture of chemicals and chemical products	2005m2	*comm*, *gap*
2C2100	Manufacture of basic pharmaceutical products and pharmaceutical preparations	2005m2	*comm*, *gap*
2C2200	Manufacture of rubber and plastic products	2005m2	*comm*, *gap*
2C2300	Manufacture of other non-metallic mineral products	2005m2	*comm*
2C2400	Manufacture of basic metals	2005m2	*comm*, *gap*
2C2500	Manufacture of fabricated metal products, except machinery and equipment	2005m2	*comm*, *gap*
2C2600	Manufacture of computer, electronic and optical products	2000m2	*comm*, *gap*, *dd*
2C2700	Manufacture of electrical equipment	2000m2	*comm*, *gap*, *dd*
2C2800	Manufacture of machinery and equipment n.e.c.	2000m2	*comm*, *gap*
2C2900	Manufacture of motor vehicles, trailers and semi-trailers	2005m2	*comm*, *gap*, *dd*
2C3000	Manufacture of other transport equipment	2005m2	*comm*, *gap*, *dd*
2C3100	Manufacture of furniture	2005m2	*dd*
2C3200	Other manufacturing	2005m2	*dd*
2C3300	Repair and installation of machinery and equipment	2005m2	*dd*
2D3500	Services: Electricity, gas, steam and air conditioning supply	2005m2	*dd*

Notes: *dd* denotes demand shifter, *gap* denotes cyclical indicator as proxied by output gap, *comm* denotes the first principal component of sector-relevant commodity prices.

"Demand shifters" are taken as the first principal component of sector-specific turnover and production indices. All variables are seasonally adjusted and transformed into growth rates.

Corsetti et al. (2008) provide an assessment of the bias arising in empirical ERPT equations from omitting relevant variables such as marginal costs, or from proxying them with large error. In order to quantify this bias, they simulate data from their calibrated structural model under different sets of assumptions on e.g., the degree of price stickiness and then estimate single equations of the kind discussed in Section 2 on these simulated data. They find that depending on whether the shocks that affect the exchange rate are of a nominal or real nature, different variants of the basic PTM equation based on the discussion in Goldberg and Knetter (1997) perform differently. In particular, they find that versions of this standard PTM equation that use better proxies for demand conditions perform better, in terms of bias, in estimating the ERPT coefficient when shocks are of a monetary nature. Versions using better measures of costs perform better in the presence of real shocks. In our study we have a richer specification compared to most of the literature, because we include in our sectoral VARs *demand shifters*, the price of domestic substitutes and measures of foreign costs, which we proxy by using not only foreign PPI but also global commodity prices. For this reason, the results of Corsetti et al. (2008) tentatively indicate that our approach is less likely to obtain distorted results than previous studies.

3.2 Modelling framework

We next describe our modelling approach in more detail. We estimate a VAR model with an exogenous block for each of the 28 sectors using Cholesky decomposition for shock identification. The endogenous block contains four variables, import prices ($impr$), domestic PPI (ppi), foreign PPI ($ppi*$) and nominal effective exchanges rate ($neer$). In addition, we include an exogenous block which further contains sector-specific sets of the commodity price indices $comm$ and the output gap gap as a measure for euro area business cycle and production and turnover indices as demand shifters . Throughout the paper lower-case letters denote logarithms, except for the gap, the euro area output gap. Δppi^* is the inflation rate of the effective foreign PPI (proxied by the first principal component of all foreign PPI), Δppi is the inflation rate of the euro area PPI, $\Delta neer$ is the rate of change of the effective nominal exchange rate and $\Delta impr$ is the rate of change of the import prices. The joint vector is labelled as $\Delta y = \left[\begin{array}{cccc|ccc} \Delta neer & \Delta ppi^* & \Delta ppi & \Delta impr & \Delta comm & gap & dd \end{array} \right]'$.

Using the growth rates of the variables circumvents unit root nonstationarity issues but of course prevents us from performing structural vector error correction model (VECM) analysis. We do this because cointegration analysis with the logarithms of the level variables has delivered only weak and mixed evidence for interpretable cointegrating relationships and, in some sectors, no evidence of cointegration at all. Furthermore, we do not have a particular structural theoretical model underlying our empirical implementation that generates the type of restrictions required for structural VECM modelling in mind. As a consequence, we focus on VARs in first differences of logarithms (i.e. in growth rates) with identification only achieved by Cholesky decompositions of the reduced-form errors. Lacking a fully specified theoretical model that would lead to a unique (over-)identified structural form to assess the robustness of our findings we report results from placing the nominal effective exchange rate at different positions in the VAR (see Appendix B). We include as exogenous control variables the economy-wide demand shifters and commodity prices, thereby reducing the dimension of the VARs from seven or six to four endogenous variables with two to three exogenous variables depending on the sector.

4 Results

This section reports accumulated impulse response functions (IRF) over a two-year horizon to the exchange rate shock as identified in the VAR-X estimation. We present the results from our baseline specification with *neer* ordered first among the endogenous variables, such that it is "most exogenous", with all the other endogenous variables allowed to contemporaneously respond to the exchange rate. We find that ERPT to import prices is never complete but at most approximately -0.8. ERPT is heterogeneous in terms of magnitude across manufacturing sectors. For non-manufacturing sectors ERPT is highly uncertain and statistically insignificant at all horizons.

Figure 1 plots the IRFs for the aggregate sectors Mining and Manufacturing. Across all mining and quarrying subsectors, of which the results are shown in Appendix B, the IRFs look similar and are highly uncertain, with fast and quite complete ERPT within a quarter. This is typically true for all mining of primary commodities that are traded on globally integrated markets. For the overall manufacturing industry ERPT takes place over a horizon of three quarters but only up to a magnitude of -0.3. For the services-related sector of repair and installation of machinery and the only services sector in our sample, electricity and gas supply, the results are also insignificant. Services sectors are typically non-tradable and do not appear to respond in a statistically significant way to exchange rate fluctuations, see Figure 2.

We now turn to the subsectors of manufacturing. There is some evidence of heterogeneity of ERPT across sectors. We would consider ERPT "complete" at a given horizon if the corresponding confidence bounds around the impulse response function point estimate

Figure 1: Accumulated impulse response functions for imp from a unit shock to $neer$. The dashed lines are 68% bootstrapped confidence bounds. The ordering of the endogenous variables is $\Delta neer$, Δppi^*, Δppi and Δimp.

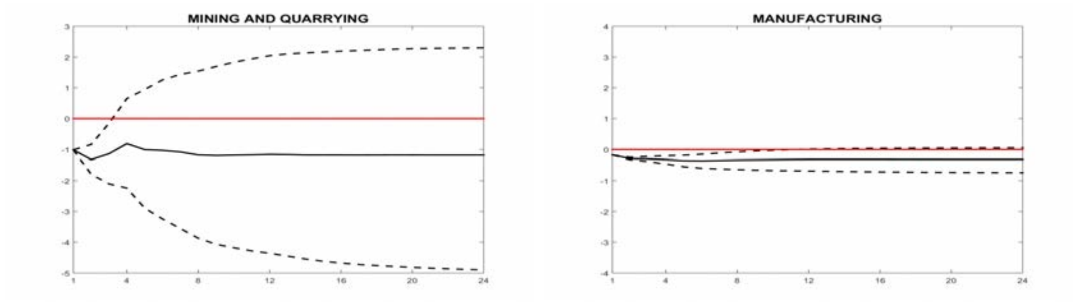
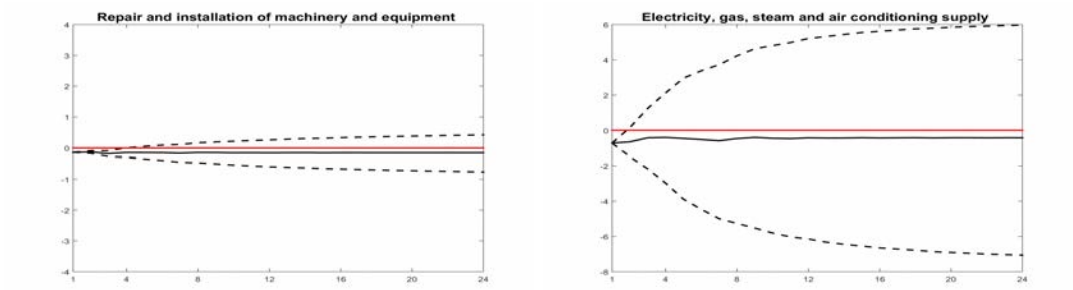


Figure 2: Accumulated impulse response functions for imp from a unit shock to $neer$. The dashed lines are 68% bootstrapped confidence bounds. The ordering of the endogenous variables is $\Delta neer$, Δppi^*, Δppi and Δimp.



contain -1 but exclude 0. This does not happen for any sector. In Table 2 we can see that highest ERPT up to -0.60 and above -0.50 at a two-year horizon can be found in the sectors of pharmaceuticals, rubber and plastics and computers. On average, ERPT after 24 months is around -0.4. Generally, the shape of the impulse responses indicates rather fast adjustment, which is basically completed after 10 to 12 months. However, the size of both the short-run ERPT and the long-run ($h = 24$) ERPT differ substantially across sectors. This is an interesting observation since it indicates that heterogeneous ERPT dynamics across sectors have to be taken into account when assessing the impacts of exchange rate changes on the euro area, see also the results in Tables 2 and 3. For $h = 0$ the point estimates range around -0.2 on average across the manufacturing sector and double their magnitude at $h = 24$ over time. These differences in both the shape and magnitude of the accumulated impulse response functions indicate that a sectoral analysis is indeed important for understanding ERPT in the euro area.

Suggested as a robustness check in case of lack of rigorous theoretical guidance by Sims (1981), we display the results of four orderings both in table format for horizons $h = 0$ and $h = 24$ in Tables 2 and 3 and graphically in Figures B1 and B2 in Appendix B. Looking at the other three orderings we see that it makes hardly any difference where $\Delta neer$ is placed. For the sectors of textiles, wearing apparel, paper, pharmaceuticals, computers and other manufacturing, it is always the fourth ordering which deviates most from the other three orderings.

Figure 3: Accumulated impulse response functions for imp from a unit shock to $neer$. The dashed lines are 64% bootstrap confidence bounds. The ordering of the endogenous variables is Δppi^*, Δppi, $\Delta neer$ and Δimp.

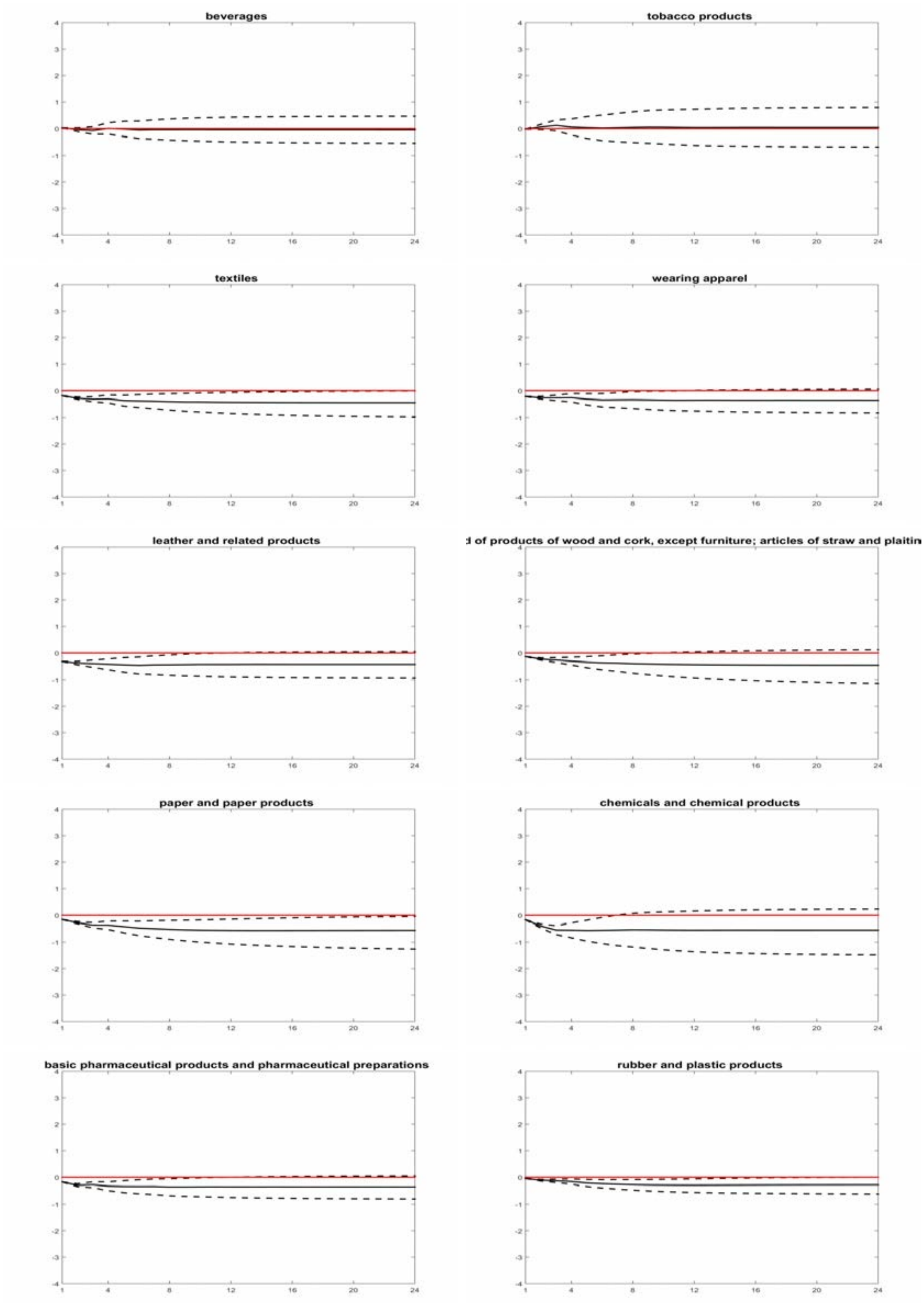
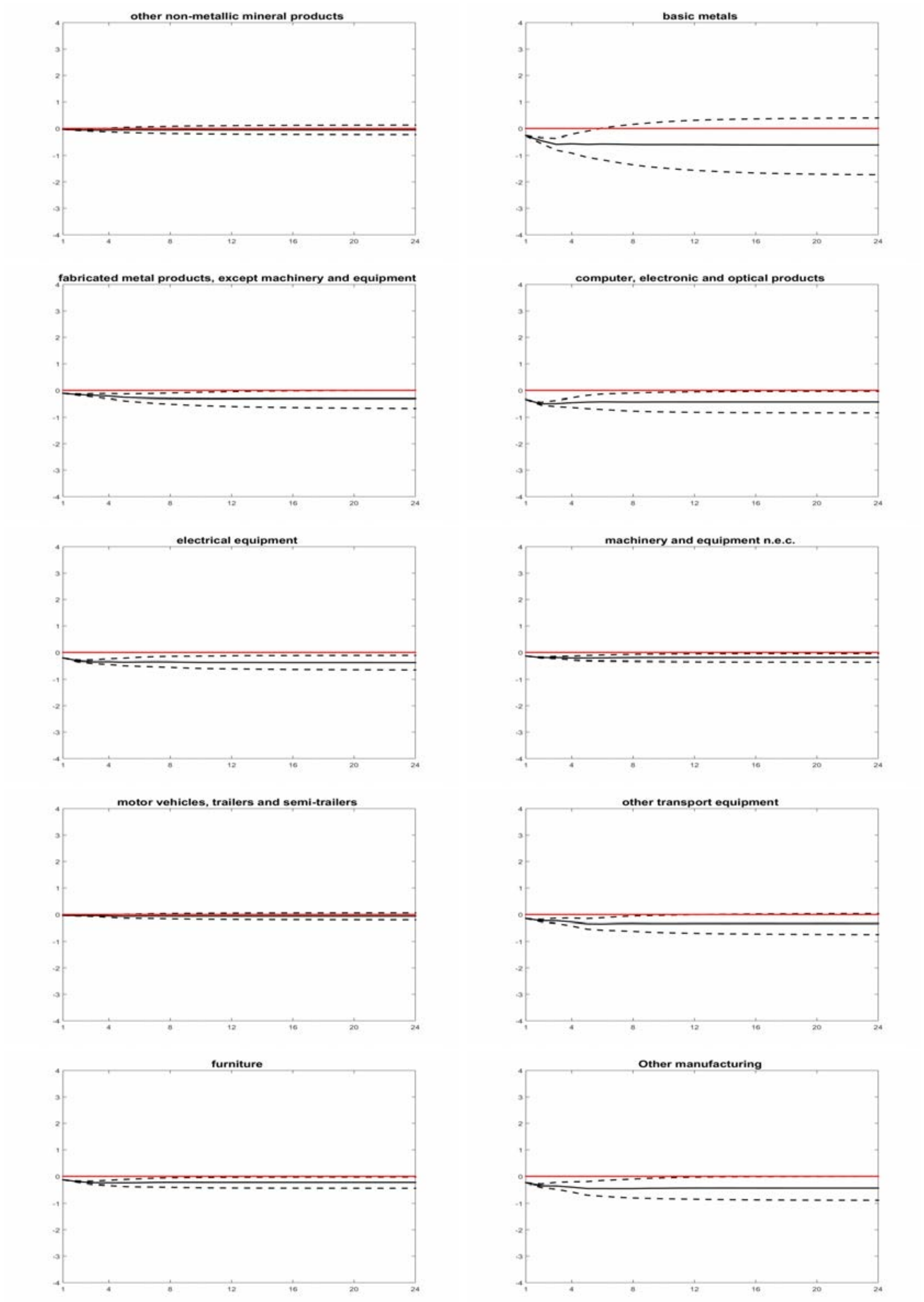


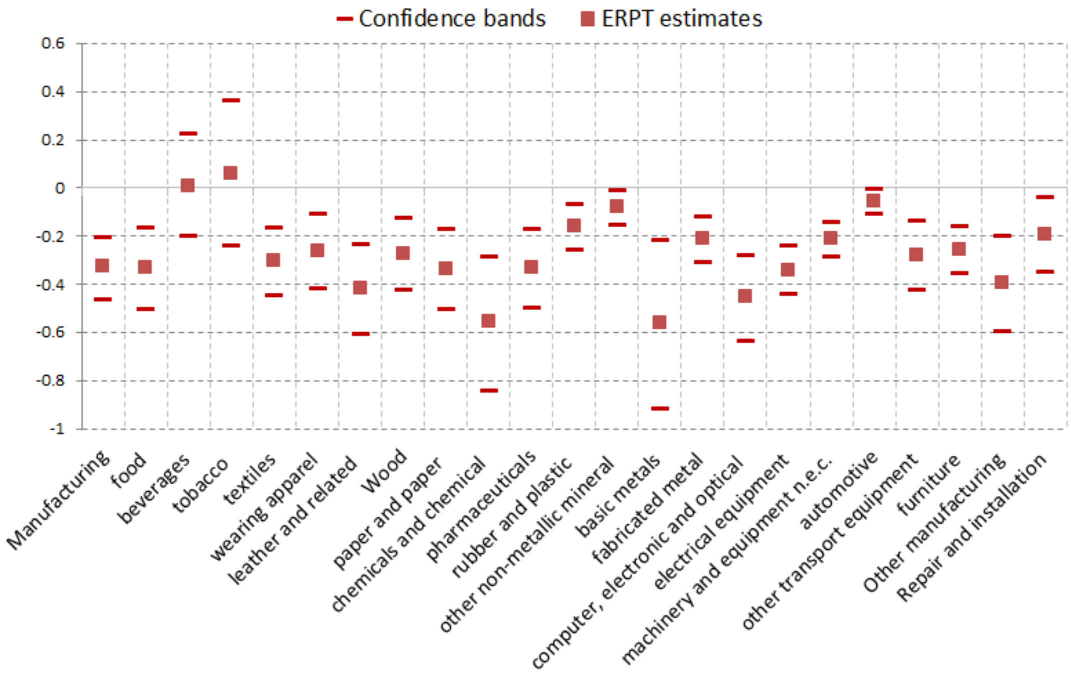
Figure 4: Accumulated impulse response functions for *imp* from a unit shock to *neer*. The dashed lines are 64% bootstrap confidence bounds. The ordering of the endogenous variables is Δppi^{*}, Δppi, $\Delta neer$ and Δimp.



5 Potential causes of ERPT heterogeneity

As mentioned in the introduction, the degree of EPRT in highly stylized models is related to industry characteristics that are difficult to measure. Nevertheless, we make an attempt to compute proxies for characteristics of the domestic market, such as concentration and the level of competition, and of integration in international trade fo each sector. We then conduct cross-section regressions of ERPT point estimates on sets of industry-specific determinants. Our dependent variable, 24-month ahead point ERPT estimates obtained from the VAR-X models by sector, are shown in Figure 5.[7]

Figure 5: EPRT point estimates by NACE Rev. 2 sectors



Note: ERPT $= -1$ means complete pass-through. Confidence intervals have coverage probability of 68%.

As our measure for domestic *competition* we use the ratio of net operating surplus to gross turnover (labelled operating surplus). As an alternative measure of competition we also considered gross operating surplus as a fraction of total turnover (called gross operating rate). *Market concentration* is measured using the average value added produced

[7] We choose the 24-month-ahead estimate because this medium-term horizon leaves some time for the dynamics of ERPT to work their way.

Table 2: Accumulated impulse response functions for $\Delta impr$ from a unit shock to $\Delta neer$ at horizons h = 0 and h = 24

	neer = 1						neer = 2					
	h = 0			h = 24			h = 0			h = 24		
sector	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower	mean	upper
2B0000	-1.013	-1.013	-1.013	-4.897	-1.182	2.301	-0.737	-0.737	-0.737	-4.371	-0.683	2.574
2B0500	-0.912	-0.912	-0.912	-2.296	-0.377	1.897	-0.881	-0.881	-0.881	-2.188	-0.205	2.101
2B0600	-0.882	-0.882	-0.882	-4.933	-0.472	3.795	-1.146	-1.146	-1.146	-5.588	-0.948	3.259
2B0700	-0.835	-0.835	-0.835	-3.221	-1.410	0.282	-0.827	-0.827	-0.827	-3.325	-1.426	0.184
2B0800	-0.164	-0.164	-0.164	-2.042	-0.223	1.581	-0.164	-0.164	-0.164	-2.033	-0.227	1.588
2C1100	-0.177	-0.177	-0.177	-0.745	-0.319	0.054	-0.168	-0.168	-0.168	-0.731	-0.314	0.050
2C1200	-0.204	-0.204	-0.204	-0.872	-0.302	0.225	-0.208	-0.208	-0.208	-0.975	-0.355	0.154
2C1300	0.029	0.029	0.029	-0.542	-0.045	0.467	0.028	0.028	0.028	-0.533	-0.046	0.440
2C1400	-0.019	-0.019	-0.019	-0.689	0.044	0.794	-0.018	-0.018	-0.018	-0.713	0.050	0.780
2C1500	-0.186	-0.186	-0.186	-0.972	-0.443	-0.009	-0.185	-0.185	-0.185	-0.970	-0.442	-0.019
2C1600	-0.212	-0.212	-0.212	-0.826	-0.356	0.055	-0.206	-0.206	-0.206	-0.861	-0.365	0.079
2C1700	-0.315	-0.315	-0.315	-0.930	-0.421	0.045	-0.284	-0.284	-0.284	-0.911	-0.417	0.052
2C2000	-0.133	-0.133	-0.133	-1.139	-0.452	0.116	-0.118	-0.118	-0.118	-1.044	-0.349	0.201
2C2100	-0.157	-0.157	-0.157	-1.263	-0.562	-0.049	-0.159	-0.159	-0.159	-1.240	-0.552	-0.035
2C2200	-0.168	-0.168	-0.168	-1.478	-0.554	0.230	-0.129	-0.129	-0.129	-1.424	-0.456	0.355
2C2300	-0.173	-0.173	-0.173	-0.806	-0.354	0.047	-0.174	-0.174	-0.174	-0.777	-0.337	0.065
2C2400	-0.047	-0.047	-0.047	-0.620	-0.280	-0.001	-0.047	-0.047	-0.047	-0.644	-0.280	-0.001
2C2500	-0.035	-0.035	-0.035	-0.235	-0.056	0.125	-0.035	-0.035	-0.035	-0.244	-0.057	0.130
2C2600	-0.265	-0.265	-0.265	-1.730	-0.604	0.395	-0.229	-0.229	-0.229	-1.611	-0.471	0.498
2C2700	-0.112	-0.112	-0.112	-0.670	-0.302	0.002	-0.108	-0.108	-0.108	-0.689	-0.317	0.005
2C2800	-0.336	-0.336	-0.336	-0.832	-0.420	-0.036	-0.332	-0.332	-0.332	-0.814	-0.415	-0.014
2C2900	-0.211	-0.211	-0.211	-0.644	-0.366	-0.115	-0.211	-0.211	-0.211	-0.645	-0.366	-0.123
2C3000	-0.138	-0.138	-0.138	-0.354	-0.195	-0.047	-0.137	-0.137	-0.137	-0.348	-0.193	-0.050
2C3100	-0.038	-0.038	-0.038	-0.200	-0.064	0.062	-0.027	-0.027	-0.027	-0.176	-0.045	0.079
2C3200	-0.151	-0.151	-0.151	-0.746	-0.334	0.035	-0.134	-0.134	-0.134	-0.668	-0.271	0.090
2C3300	-0.133	-0.133	-0.133	-0.433	-0.231	-0.028	-0.134	-0.134	-0.134	-0.433	-0.232	-0.041
2D3500	-0.240	-0.240	-0.240	-0.886	-0.425	-0.002	-0.247	-0.247	-0.247	-0.879	-0.428	-0.011
2C3300	-0.142	-0.142	-0.142	-0.765	-0.156	0.423	-0.142	-0.142	-0.142	-0.788	-0.154	0.456
2D3500	-0.726	-0.726	-0.726	-7.056	-0.428	5.971	-0.791	-0.791	-0.791	-7.079	-0.474	5.980

Table 3: Accumulated impulse response functions for $\Delta impr$ from a unit shock to $\Delta neer$ at horizons h = 0 and h = 24

	neer = 3						neer = 4					
	h = 0			h = 24			h = 0			h = 24		
sector	lower	mean	upper	lower	mean	upper	lower	mean	upper	lower bound	mean	upper
2B0000	-0.800	-0.800	-0.800	-4.549	-0.841	2.418	0	0	0	-3.319	0.131	3.287
2B0500	-0.943	-0.943	-0.943	-2.649	-0.605	1.608	0	0	0	-1.260	0.687	3.044
2B0600	-1.185	-1.185	-1.185	-5.705	-1.042	3.200	0	0	0	-4.198	0.420	4.623
2B0700	-0.663	-0.663	-0.663	-2.912	-1.095	0.621	0	0	0	-1.607	0.134	1.868
2B0800	-0.157	-0.157	-0.157	-2.003	-0.226	1.556	0	0	0	-1.848	-0.114	1.662
2C1100	-0.154	-0.154	-0.154	-0.664	-0.272	0.080	0	0	0	-0.285	0.045	0.397
2C1200	-0.225	-0.225	-0.225	-1.056	-0.420	0.089	0	0	0	-0.398	0.162	0.790
2C1300	0.028	0.028	0.028	-0.554	-0.047	0.458	0	0	0	-0.586	-0.076	0.419
2C1400	-0.012	-0.012	-0.012	-0.696	0.045	0.784	0	0	0	-0.695	0.061	0.815
2C1500	-0.173	-0.173	-0.173	-0.910	-0.403	0.037	0	0	0	-0.396	0.020	0.470
2C1600	-0.206	-0.206	-0.206	-0.840	-0.360	0.057	0	0	0	-0.402	0.017	0.467
2C1700	-0.285	-0.285	-0.285	-0.923	-0.421	0.031	0	0	0	-0.574	-0.099	0.376
2C2000	-0.126	-0.126	-0.126	-1.140	-0.412	0.160	0	0	0	-0.757	-0.130	0.426
2C2100	-0.136	-0.136	-0.136	-1.114	-0.458	0.036	0	0	0	-0.560	-0.047	0.402
2C2200	-0.093	-0.093	-0.093	-1.223	-0.338	0.422	0	0	0	-1.046	-0.210	0.544
2C2300	-0.173	-0.173	-0.173	-0.785	-0.343	0.059	0	0	0	-0.568	-0.130	0.282
2C2400	-0.045	-0.045	-0.045	-0.607	-0.267	0.010	0	0	0	-0.522	-0.200	0.074
2C2500	-0.037	-0.037	-0.037	-0.245	-0.061	0.123	0	0	0	-0.225	-0.038	0.153
2C2600	-0.192	-0.192	-0.192	-1.461	-0.379	0.626	0	0	0	-0.825	0.207	1.166
2C2700	-0.109	-0.109	-0.109	-0.716	-0.324	-0.013	0	0	0	-0.438	-0.122	0.162
2C2800	-0.336	-0.336	-0.336	-0.825	-0.414	-0.018	0	0	0	-0.245	0.159	0.599
2C2900	-0.208	-0.208	-0.208	-0.607	-0.335	-0.092	0	0	0	-0.370	-0.117	0.114
2C3000	-0.133	-0.133	-0.133	-0.338	-0.187	-0.045	0	0	0	-0.173	-0.032	0.112
2C3100	-0.027	-0.027	-0.027	-0.165	-0.042	0.079	0	0	0	-0.136	-0.008	0.119
2C3200	-0.134	-0.134	-0.134	-0.674	-0.271	0.094	0	0	0	-0.541	-0.160	0.203
2C3300	-0.130	-0.130	-0.130	-0.430	-0.229	-0.034	0	0	0	-0.311	-0.101	0.096
2D3500	-0.242	-0.242	-0.242	-0.881	-0.431	-0.008	0	0	0	-0.615	-0.163	0.268
2C3300	-0.133	-0.133	-0.133	-0.748	-0.148	0.437	0	0	0	-0.636	-0.031	0.571
2D3500	-0.564	-0.564	-0.564	-6.846	-0.159	6.544	0	0	0	-6.496	0.162	6.741

per enterprise in the sector (sectoral total production value added/total number of the enterprises of the sector).[8] Turning to the measures of integration in international trade, we proxy the ratio of foreign to domestic firms that are active on the domestic market by the ratio of imports to value added in each sector, referred to as *import penetration*. The greater the market penetration by foreign firms, the higher we expect ERPT to be. Our proxy for *market integration* is given by the ratio of exports plus imports over valued added. These data at a detailed level of disaggregation can downloaded from the Prodcom database provided by Eurostat, which we aggregate to broader 2-digit sector-level data according to the NACE Rev. 2 sector classification. This is a comprehensive measure of openness of the industry. To compute the euro area-level data aggregates by sector, we take averages across the years from 2000 to 2015. The explanatory variable data are plotted in Figure 6 below.

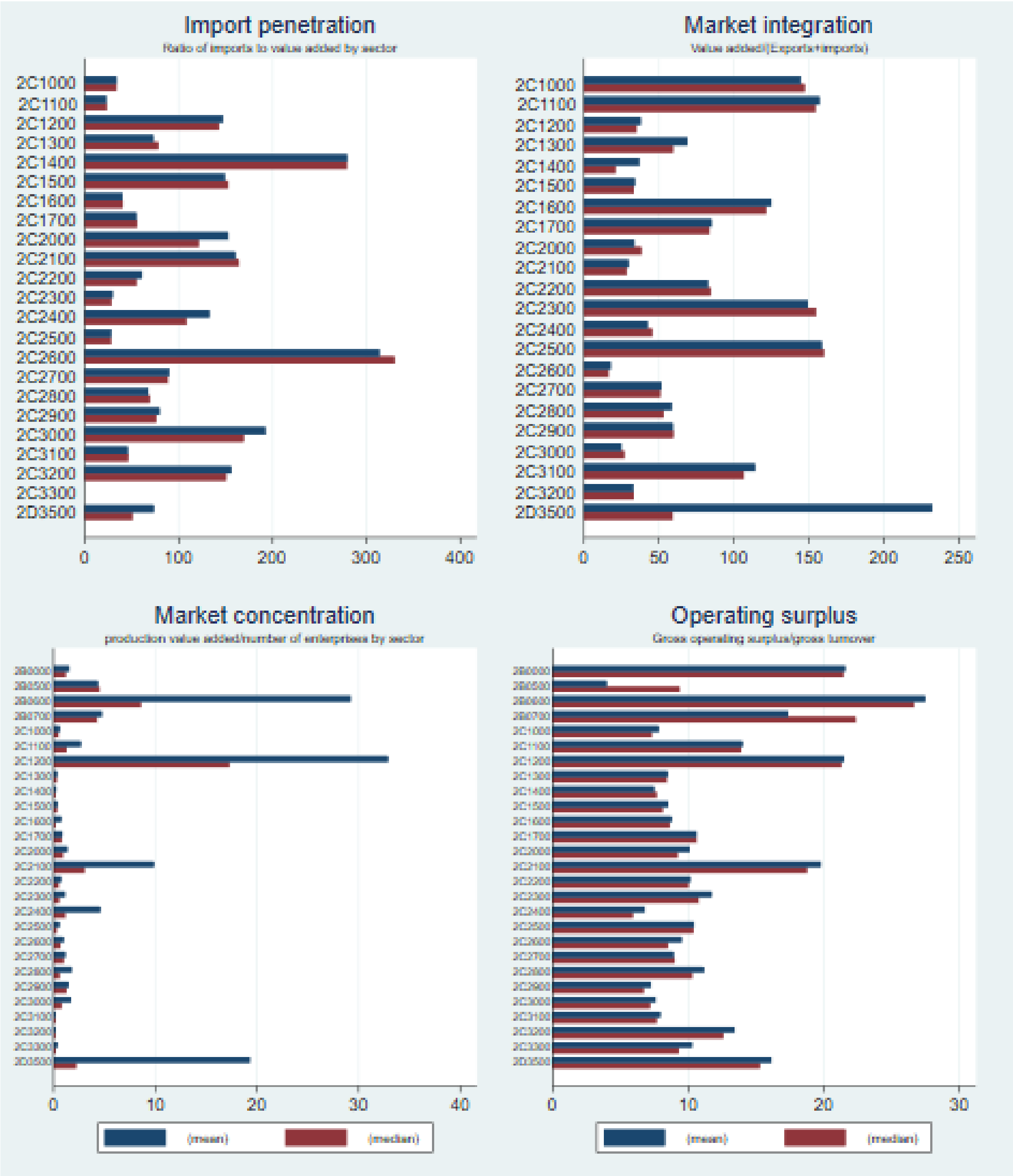
In Figure 7 we see that different sectors engage more or less intensively in international trade. Moreover, international production is increasingly organised within global value chains (GVCs) where the different stages of the production process are located across different countries. Participation in GVCs is measured by distinguishing a "backward-looking" measure that tracks foreign value added included in a country's exports from a "forward-looking" measure based on a country's domestic value added that is contained in the exports of other countries. The participation pattern in GVCs by sector as a percentage of total gross trade is shown in Figure 7. In the last panel the total GVC in percent of gross trade is simply the sum of forward- and backward-looking GVC integration.

We regress the point estimates of EPRT (as shown in Figure 5) on these explanatory variables.[9] We present the cross-section regression results in Table 4. The dependent variable is -ERPT for ease of interpretation. We use the point estimate 24 months ahead. The regression is a simple OLS with robust standard errors and the number of observations is smaller when the openness variables are included due to data availability. Taking the domestic structural variables, market concentration and each of the two measures of competition, as explanatory variables in the first regression, only market concentration is statistically significant (see specifications I and II in Table 4). We then run two more specifications that also include measures of trade openness: in specification III we add to the regression with competitions proxied by gross operating rate also market integration

[8] We acknowledge that this is only a rough proxy: accurate measures of concentration would require firm-level data.

[9] We present the cross-correlations between the explanatory variables in our database in AA7 in Appendix A.

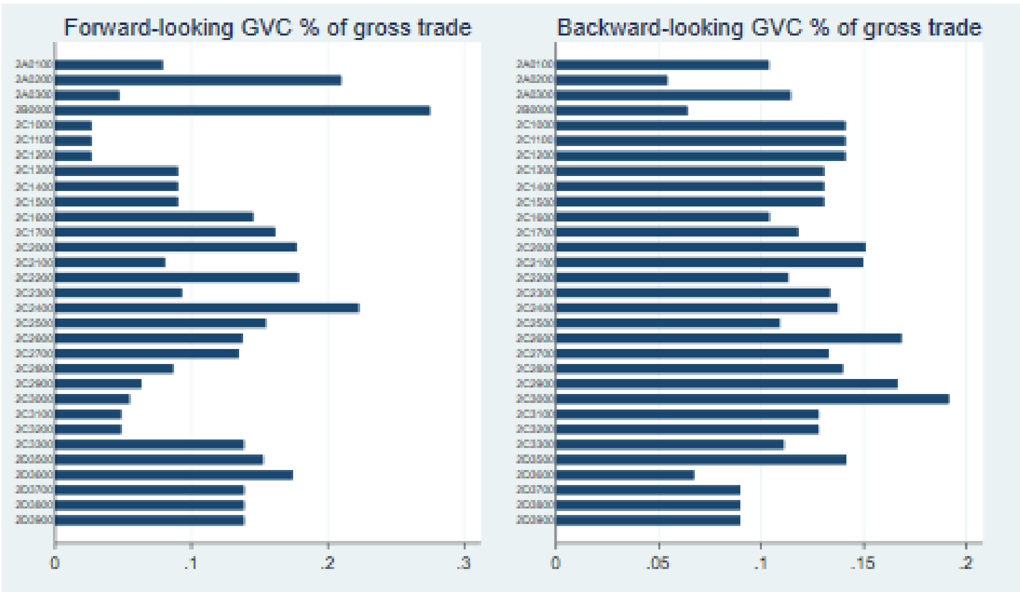
Figure 6: Sector characteristics in mean and median values by explanatory variable



Note: Mean and median values are calculated using annual data starting from 2000, which is the earliest start of the data sample for the VAR estimation with the exception of 2B0900 (sample start from 1999), and ending in 2015. *Source:* Eurostat Prodcom, Short term statistics.

and import penetration. In this specification with more variables all the coefficients are statistically significant. Market concentration and import penetration reduce import price pass-through as also found by Amiti et al. (2019). Market integration, which is a more general measure of openness, increases ERPT. In the last specification we also add the two measures of GVC integraton. When we do this the estimated coefficients of the more general measures of openness become insignificant, while those of the GVC measures are significant. Backward integration in GVC, also in line with the theory by Amiti et al. (2014), reduces ERPT. The coefficient of forward GVC integration is significant and positive, meaning that if a sector's exports are included in exports of other countries then the import price pass-through is larger. This does not have a clear theoretical explanation, but it could be due to a reduced price elasticity in sectors that are globally integrated upstream, meaning that exports are in turn re-exported. This might have to do with the role of multinationals, but a more precise explanation would require firm-level information.

Figure 7: Sector characteristics in mean values by explanatory variable



Note: Mean values are calculated using annual data from 2000, which is the earliest start of the data sample for the VAR estimation with the exception of 2B0900 (sample start from 1999), to 2016. *Source:* World Input-Output Database (WIOD), conversion of sector classification from ISIC v.4 to NACE Rev. 2

Table 4: Cross-section regression results: sector-specific determinants of ERPT

VARIABLES	(1) Domestic - I	(2) Domestic - II	(3) Openness	(4) Openness - GVC
market_concentration	-0.145**	-0.218*	-0.274***	-0.172***
	(0.0602)	(0.116)	(0.0898)	(0.0439)
gross_operating_rate		0.130	0.426*	0.232**
		(0.122)	(0.213)	(0.103)
market_integration			0.618**	0.183
			(0.241)	(0.206)
import_penetration			-0.810**	-0.363
			(0.283)	(0.208)
GVC_forward				0.0729*
				(0.0397)
GVC_backward				-0.129*
				(0.0645)
operating_surplus	0.0791			
	(0.0688)			
Constant	0.304***	0.304***	0.435***	0.414***
	(0.0716)	(0.0699)	(0.0770)	(0.0427)
Observations	28	28	22	22
R-squared	0.178	0.215	0.621	0.821

Robust standard errors in parentheses. N.B. The dependent variable is -ERPT at 24 months.
*** p<0.01, ** p<0.05, * p<0.1

6 Conclusions and future work

In this paper we estimate ERPT to euro area manufacturing import prices at the sectorally disaggregated level as well as for the manufacturing aggregate. Using a VAR-X framework including exogenous explanatory variables allows to derive well-specified dynamic models that take into account that important explanatory variables (in particular domestic and foreign PPI and the nominal effective exchange rate) are endogenous. A second advantage of a VAR-X system approach is that it allows to not only study the extent of ERPT, but also its dynamics. The dynamic measure of ERPT over h periods is given by the cumulated impulse response function of import prices to a shock in the nominal effective exchange rate. Using this quantity as our dynamic measure we find that in general ERPT adjustment is essentially completed after one year.

We find heterogeneous results across sectors, for immediate responses, to a certain extent for the dynamics and also for the long-run response. These results point to the importance of studying ERPT at a disaggregated level to understand the inflationary impact of exchange rate changes. To understand the sectoral differences requires knowledge about industry-specific characteristics such as openness, degree of competition and global value chain integration that may well influence the extent of ERPT. Similarly to a sectoral disaggregation, an intra-euro area country disaggregation may lead to sharpened insights concerning euro area price adjustment in response to exchange rate fluctuations. Given that the shares of imports in total imports to the euro area by broad industries have been mostly stable, our results are therefore also reliable over time when estimating ERPT at more aggregate level.

References

Amiti, M., O. Itskhoki, and J. Konings (2014): "Importers, Exporters, and Exchange Rate Disconnect," *American Economic Review*, 104, 1942–78.

——— (2019): "International Shocks, Variable Markups, and Domestic Prices," *The Review of Economic Studies*, 86, 2356–2402.

Baldwin, R. (1988): "Hysteresis in Import Prices: The Beachhead Effect," *The American Economic Review*, 773–785.

Burstein, A., M. Eichenbaum, and S. Rebelo (2005): "Large Devaluations and the Real Exchange Rate," *Journal of Political Economy*, 113, 742–784.

Burstein, A. T., J. C. Neves, and S. Rebelo (2003): "Distribution Costs and Real Exchange Rate Dynamics During Exchange-Rate-Based Stabilizations," *Journal of Monetary Economics*, 50, 1189–1214.

Campa, J. M. and L. S. Goldberg (2005): "Exchange Rate Pass-Through Into Import Prices," *Review of Economics and Statistics*, 87, 679–690.

Campa, J. M., L. S. Goldberg, and J. M. González-Mínguez (2005): "Exchange-rate pass-through to import prices in the euro area," *National Bureau of Economic Research Working Paper No. w11632.*

Carrière-Swallow, Y., B. Gruss, N. E. Magud, and F. Valencia (2021): "Monetary Policy Credibility and Exchange Rate Pass-Through," *International Journal of Central Banking*, 17, 61–94.

Chow, G. and A. L. Lin (1971): "Best Linear Unbiased Distribution and Extrapolation of Economic Time Series by Related Series," *Review of Economics and Statistics*, 53, 372–375.

Corsetti, G., L. Dedola, and S. Leduc (2008): "High Exchange-Rate Volatility and Low Pass-Through," *Journal of Monetary Economics*, 55, 1113–1128.

Devereux, M. B., B. Tomlin, and W. Dong (2015): "Exchange Rate Pass-Through, Currency of Invoicing and Market Share," Working Paper 21413, National Bureau of Economic Research.

Dornbusch, R. (1987): "Exchange Rates and Prices," *American Economic Review*, 77, 93–106.

Engel, C. (2006): "Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Export Pricing," *Journal of the European Economic Association*, 4, 1249–1260.

Gagnon, J. E. and J. Ihrig (2004): "Monetary Policy and Exchange Rate Pass-Through," *International Journal of Finance and Economics*, 9, 315–338.

Georgiadis, G. and J. Graeb (2019): "Global Value Chain Participation and Exchange Rate Pass-Through to Export and Import Prices," *Economic Bulletin Articles*, 5.

Goldberg, P. K. and M. M. Knetter (1997): "Goods Prices and Exchange Rates: What Have We Learned?" *Journal of Economic Literature*, 35, 1243–1272.

Goldberg, P. K. and F. Verboven (2005): "Market Integration and Convergence to the Law of One Price: Evidence from the European Car Market," *Journal of International Economics*, 65, 49–73.

Hahn, E. (2003): "Pass-Through of External Shocks to Euro Area Inflation," *ECB Working Paper No. 243*.

Hara, N., K. Hiraki, and Y. Ichise (2015): "Changing Exchange Rate Pass-Through in Japan: Does It Indicate Changing Pricing Behavior?" Bank of Japan Working Paper Series 15-E-4, Bank of Japan.

Harvey, A. and A. Jaeger (1993): "Detrending, Stylized Facts and the Business Cycle," *Journal of Applied Econometrics*, 8, 231–247.

Knetter, M. M. (1993): "International Comparisons of Pricing-to-Market Behavior," *American Economic Review*, 83, 473–486.

Krugman, P. K. (1987): "Pricing to Market When the Exchange Rate Changes," in *Real-Financial Linkages among Open Economies*, ed. by S. W. Arndt and J. D. Richardson, MIT Press.

Ortega, E. and C. Osbat (2020): "Exchange rate pass-through in the euro area and EU countries," Occasional Paper Series 241, European Central Bank.

Özyurt, S. (2016): "Has the Exchange Rate Pass-Through Recently Declined in the Euro Area?" *Working Paper Series No. 1955.*

Sims, C. A. (1981): "An Autoregressive Index Model for the U.S. 1948-1975," in *Large-Scale Macro-Econometric Models*, ed. by J. Kmenta and J. Ramsey, North-Holland, Amsterdam, 283–327.

Taylor, J. B. (2000): "Low Inflation, Pass-Through, and the Pricing Power of Firms," *European Economic Review*, 44, 1389–1408.

Yang, J. (1997): "Exchange Rate Pass-Through in US Manufacturing Industries," *The Review of Economics and Statistics*, 79, 95–104.

Appendix A Data

For our empirical analysis we collect sector-level as well as macroeconomic data from several sources. Our main object of study, the nominal effective exchange rate (NEER), is computed by the ECB (SDW code: EXR.M.E7.EUR.EN00.A). It is the nominal effective exchange rate of the euro (euro area-19 countries) against the 38-country group of trading partners (AU, CA, DK, HK, JP, NO, SG, KR, SE, CH, GB, US, BG, CZ, HU, PL, RO, CN, DZ, AR, BR, CL, HR, IS, IN, ID, IL, MY, MX, MA, NZ, PH, RU, ZA, TW, TH, TR and VE).

To construct PPI* we take the first principal component of the PPI of *sector-specific and relevant trading partners* of the euro area. To select the country composition, we apply a few rules:

1. For each sector we include countries that altogether cover at least 80% of euro area imports in the sector.
2. Countries whose PPI data series start later than the euro area import price index or stop before December 2016 or with shorter than three years of data are excluded.

To what extent individual trading partner's export (in descending order) to the euro area in each of the sectors is shown in Table AA1.

Table AA1: Import share in total euro area import by trading partner and by broader sectors

country	Food	country	Beverages & Tabacco	country	Crude ex fuels	country	Mineral fuels	country	Fats	country	Chemicals	country	Manufactured goods	country	Machinery	country	Miscellaneous	country	Others
UK	0.1397	UK	0.3288	Brazil	0.1514	Russia	0.4238	Indonesia	0.3529	United States	0.0030	China	0.1319	China	0.2003	China	0.3234	Russia	0.2919
Brazil	0.1116	US	0.0261	US	0.0351	UK	0.1380	Malaysia	0.2006	UK	0.2003	UK	0.1174	US	0.0008	US	0.0021	Norway	0.2342
Denmark	0.0904	Poland	0.0922	Sweden	0.0693	Norway	0.1291	UK	0.0647	Switzerland	0.1656	Poland	0.0748	Japan	0.0947	Switzerland	0.0817	Switzerland	0.1110
Poland	0.0901	Denmark	0.0641	UK	0.0610	Algeria	0.1070	Argentina	0.0472	China	0.0510	Sweden	0.0703	Czech Republic	0.0786	Poland	0.0592	US	0.0068
Argentina	0.0647	Czech Republic	0.0567	Canada	0.0557	US	0.0000	Hungary	0.0361	Sweden	0.0390	Czech Republic	0.0629	Poland	0.0563	Turkey	0.0491	Algeria	0.0506
US	0.0201	Switzerland	0.0470	Russia	0.0534	Mexico	0.0173	India	0.0343	Japan	0.0353	Russia	0.0622	Hungary	0.0543	Czech Rep	0.0420	South Africa	0.0305
China	0.0399	Brazil	0.0439	China	0.0373	Sweden	0.0160	Brazil	0.0306	Poland	0.0311	US	0.0211	Sweden	0.0486	Japan	0.0397	Denmark	0.0222
Turkey	0.0388	Romania	0.0310	Australia	0.0372	Poland	0.0126	US	0.0023	Singapore	0.0297	Switzerland	0.0507	South Korea	0.0455	Romania	0.0315	Czech Republic	0.0174
Switzerland	0.0358	Chile	0.0261	Czech Republic	0.0357	Australia	0.0115	Russia	0.0271	Denmark	0.0287	Turkey	0.0416	Switzerland	0.0392	India	0.0313	Sweden	0.0137
Hungary	0.0356	South Africa	0.0208	Chile	0.0351	Denmark	0.0111	Poland	0.0269	Russia	0.0209	India	0.0370	Taiwan	0.0305	Denmark	0.0289	Poland	0.0134
Sweden	0.0323	Turkey	0.0182	Poland	0.0349	Czech Rep	0.0111	Denmark	0.0212	Czech Rep	0.0212	Hungary	0.0243	Turkey	0.0288	Sweden	0.0235	China	0.0133
Czech Rep	0.0316	Australia	0.0168	South Africa	0.0295	India	0.0108	Czech Republic	0.0192	India	0.0185	Norway	0.0231	Malaysia	0.0209	Hungary	0.0226	Canada	0.0129
Morocco	0.0289	Sweden	0.0151	Indonesia	0.0243	South Africa	0.0088	Sweden	0.0149	Hungary	0.0171	Chile	0.0211	Denmark	0.0179	Indonesia	0.0179	Japan	0.0111
Thailand	0.0221	Mexico	0.0147	Denmark	0.0237	Switzerland	0.0084	Thailand	0.0093	Israel	0.0168	Japan	0.0212	Romania	0.0180	Morocco	0.0161	Australia	0.0096
India	0.0213	Hungary	0.0133	Switzerland	0.0217	Brazil	0.0074	Norway	0.0091	South Korea	0.0119	South Africa		Singapore	0.0161	Thailand	0.0144	Brazil	0.0089
Chile	0.0198	Argentina	0.0130	Hungary	0.0201	Canada	0.0066	Canada	0.0091	Canada	0.0102	Brazil	0.0183	Thailand	0.0134	Hong Kong	0.0142	Singapore	0.0081
South Africa	0.0187	Indonesia	0.0100	Argentina	0.0180	South Korea	0.0044	Turkey	0.0088	Norway	0.0101	South Korea	0.0179	Mexico	0.0109	Taiwan	0.0126	Malaysia	0.0077
Canada	0.0149	Bulgaria	0.0088	Norway	0.0157	Indonesia	0.0041	Morocco	0.0091	Brazil	0.0090	Romania	0.0179	Canada	0.0100	South Korea	0.0116	Hungary	0.0072
Indonesia	0.0128	India	0.0088	Turkey	0.0145	Hungary	0.0040	Bulgaria	0.0090	Turkey	0.0076	Denmark	0.0170	Hong Kong	0.0089	Bulgaria	0.0106	Chile	0.0069
Russia	0.0117	China	0.0085	Romania	0.0128	Israel	0.0038	China	0.0086	Mexico	0.0054	Taiwan	0.0148	India	0.0073	Malaysia	0.0104	Mexico	0.0067
Bulgaria	0.0100	Russia	0.0055	Malaysia	0.0123	Singapore	0.0037	Romania	0.0073	Indonesia	0.0048	Israel	0.0129	Brazil	0.0064	Mexico	0.0078	Israel	0.0051
Norway	0.0099	Croatia	0.0034	India	0.0113	Turkey	0.0034	Singapore	0.0031	Taiwan	0.0047	Bulgaria	0.0119	South Africa	0.0064	Singapore	0.0062	Turkey	0.0042
Romania	0.0000	Canada	0.0030	Thailand	0.0094	China	0.0026	Japan	0.0029	Romania	0.0040	Canada	0.0093	Morocco	0.0053	Croatia	0.0061	India	0.0037
Israel	0.0097	Thailand	0.0023	Bulgaria	0.0093	Bulgaria	0.0020	Switzerland	0.0026	Malaysia	0.0038	Indonesia	0.0087	Israel	0.0047	Israel	0.0056	Hong Kong	0.0033
Mexico	0.0071	Japan	0.0018	Morocco	0.0086	Croatia	0.0018	Mexico	0.0024	Argentina	0.0036	Thailand	0.0084	Norway	0.0039	Canada	0.0049	Taiwan	0.0032
Australia	0.0052	Israel	0.0014	Croatia	0.0083	Romania	0.0017	Chile	0.0023	South Africa	0.0034	Hong Kong	0.0061	Indonesia	0.0038	Brazil	0.0037	South Korea	0.0030
Croatia	0.0050	Taiwan	0.0014	Japan	0.0082	Japan	0.0011	Croatia	0.0018	Australia	0.0030	Croatia	0.0046	Bulgaria	0.0033	Norway	0.0025	Thailand	0.0030
Malaysia	0.0037	Morocco	0.0013	Mexico	0.0077	Morocco	0.0010	South Africa	0.0013	Chile	0.0030	Australia	0.0044	Croatia	0.0026	Chile	0.0022	Morocco	0.0029
South Korea	0.0019	Singapore	0.0011	Israel	0.0065	Malaysia	0.0009	Australia	0.0013	Morocco	0.0029	Malaysia	0.0038	Russia	0.0025	South Africa	0.0021	United Kingdom	0.0027
Japan	0.0016	South Korea	0.0010	South Korea	0.0060	Taiwan	0.0007	Israel	0.0009	Thailand	0.0028	Mexico	0.0029	Australia	0.0014	Russia	0.0020	Croatia	0.0027
Singapore	0.0011	Norway	0.0010	Taiwan	0.0041	Argentina	0.0002	Taiwan	0.0007	Bulgaria	0.0027	Morocco	0.0024	Argentina	0.0008	Australia	0.0018	Romania	0.0025
Algeria	0.0009	Malaysia	0.0005	Singapore	0.0017	Thailand	0.0002	Hong Kong	0.0005	Croatia	0.0026	Argentina	0.0023	Chile	0.0008	United Kingdom	0.0008	Bulgaria	0.0016
Taiwan	0.0008	Algeria	0.0004	Algeria	0.0013	Chile	0.0000	South Korea	0.0002	Algeria	0.0022	Singapore	0.0017	Algeria	0.0003	Argentina	0.0003	Argentina	0.0012
Hong Kong	0.0003	Hong Kong	0.0002	Hong Kong	0.0004	Hong Kong	0.0000	Algeria	0.0002	Hong Kong	0.0005	Algeria	0.0005	United Kingdom	0.0003	Algeria	0.0000	Indonesia	0.0011
sum	**0.8562**		**0.8285**		**0.7121**		**0.8095**		**0.5796**		**0.7101**		**0.8305**		**0.7848**		**0.8004**		**0.8172**

Notes: The shares of imports by trading partner in the euro area total imports are computed as time series averages over the period from 2000-2016 in the respective sectors. *Source:* Eurostat

Table AA2: Explained part of total variance by the first principal component (PC) and non-explained part by the first two principal components (PCs) of total (foreign) PPI* variations

NACE2 sector code	Explained by 1^{st} PC	Non-explained by first 2 PCs
2B0000	37.3	36.9
2B0500	73.2	0
2B0800	18.9	63.09
2C0000	31.4	41.7
2C1000	51.3	37.61
2C1100	25.8	50.9
2C1200	51.5	23.3
2C1300	35.3	46.9
2C1400	27.0	48.9
2C1500	29.2	51.6
2C1600	25.9	51.5
2C1700	43.7	42.65
2C1800	38.0	38.45
2C1900	59.6	25.6
2C2000	33.4	39.2
2C2100	33.0	38.2
2C2200	27.2	53.7
2C2300	26.2	57.4
2C2400	40.1	38.7
2C2500	26.5	55.8
2C2600	35.6	42.5
2C2700	54.6	34.7
2C2800	39.7	43.8
2C2900	52.5	33.4
2C3000	32.4	42.7
2C3100	44.9	40.4
2C3200	40.9	27.7
2C3300	94.5	1.4
2D0000	88.6	5.1
2D3500	88.6	5.1

From **Eurostat's STS database** we take the monthly time series of import prices, PPI data, industrial production and turnover index (both domestic and non-domestic market) for the 19 euro area countries for each of the sectors included in our estimation.

Table AA3: Data taken from the Eurostat Short Term Statistics (STS) database

variable	**SDW code**	**variable label**	**source**
impr	IMPR	import price index	Eurostat STS
ppi	PRIN	producer prices index, domestic sales	Eurostat STS
ind	PROD	industrial production index	Eurostat STS
dd	TOVD	turnover index, domestic market	Eurostat STS
dd*	TOVE	turnover index, non-domestic market	Eurostat STS
dd_total	TOVT	total turnover index	Eurostat STS

From the same data source we retrieve euro area-level data of commodity price indices as tabulated below.

Table AA4: Commodity price index taken from the Eurostat Short Term Statistics (STS) database

Commodity price index	**SDW code**
Agricultural raw materials	STS.M.I8.N.UWID.CAGRMT.3.000
Beverages, sugar and tobacco	STS.M.I8.N.UWID.CBEVST.3.000
Cereals price 100 kilos	STS.M.I8.N.UWID.CCEREA.3.000
Food	STS.M.I8.N.UWID.CFOOD0.3.000
Iron ore and steel scrap	STS.M.I8.N.UWID.CIOSCR.3.000
Meat price 100 kilos	STS.M.I8.N.UWID.CMEAT0.3.000
Metals	STS.M.I8.N.UWID.CMETAL.3.000
Non-food	STS.M.I8.N.UWID.CNFOOD.3.000
Non-ferrous metals	STS.M.I8.N.UWID.CNFRMT.3.000
Oils price 100 kilos	STS.M.I8.N.UWID.COILS0.3.000
Seeds	STS.M.I8.N.UWID.CSEEDS.3.000
Total non-energy commodity	STS.M.I8.N.UWID.CTOTNE.3.000

Euro area real GDP (SDW code: MNA.Q.N.I8.W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.LR.N) and output gap from the ECB projection database are transformed from quarterly to monthly frequency using Chow-Lin interpolation, whereby the observable states for real GDP are industrial production excluding construction (SDW code: STS.M.I8.Y.PROD.NS0020.4.000) and for euro area output gap euro area unemployment rate (SDW code: STS.M.I8.S.UNEH.RTT000.4.000).

Table AA5: Commodity prices considered as an exogenous factor by NACE Rev.2 sector

NACE2 label	**Code**	Agri raw materials	Beverages sugar & tobacco	Cereals	Food	Iron & steel	Meat	Metals	Non-food	Non-ferrous	Oils	Seeds	Non- energy
MINING AND QUARRYING	2B0000	0	0	0	0	1	0	1	1	1	1	0	0
Mining of coal and lignite	2B0500	0	0	0	0	1	0	1	1	1	1	0	0
Extraction of crude petroleum and natural gas	2B0600	0	0	0	0	1	0	1	1	1	0	0	0
Mining of metal ores	2B0700	0	0	0	0	1	0	1	1	1	0	0	0
Other mining and quarrying	2B0800	0	0	0	0	1	0	1	1	1	0	0	0
MANUFACTURING	2C0000	1	1	1	1	1	1	1	1	1	0	1	1
food products	2C1000	1	1	1	1	0	1	0	0	0	1	1	1
beverages	2C1100	1	1	1	1	0	0	0	0	0	0	1	0
tobacco products	2C1200	1	1	0	0	0	0	0	0	0	0	0	1
textiles	2C1300	0	0	0	0	0	0	0	1	0	0	0	1
wearing apparel	2C1400	0	0	0	0	0	0	0	1	0	0	0	1
leather and related products	2C1500	0	0	0	0	0	0	0	1	0	0	0	1
wood and of products of wood and cork	2C1600	1	0	0	0	0	0	0	1	0	0	0	1
paper and paper products	2C1700	1	0	0	0	0	0	0	1	0	0	0	1
chemicals and chemical products	2C2000	1	0	0	0	1	0	0	1	0	0	0	1
basic pharmaceutical products and pharmaceutical preparations	2C2100	1	0	0	0	0	0	0	1	0	0	0	1
rubber and plastic products	2C2200	0	0	0	0	0	0	0	1	0	0	0	1
other non-metallic mineral products	2C2300	0	0	0	0	1	0	1	1	1	0	0	1
basic metals	2C2400	0	0	0	0	1	0	1	0	1	0	0	0
fabricated metal products, except machinery and equipment	2C2500	0	0	0	0	1	0	1	0	1	0	0	0
computer, electronic and optical products	2C2600	0	0	0	0	0	0	1	0	1	0	0	0
electrical equipment	2C2700	0	0	0	0	0	0	1	0	1	0	0	0
machinery and equipment n.e.c.	2C2800	0	0	0	0	1	0	1	0	1	0	0	0
motor vehicles, trailers and semi-trailers	2C2900	0	0	0	0	1	0	1	0	1	0	0	0
other transport equipment	2C3000	0	0	0	0	1	0	1	0	1	0	0	0
furniture	2C3100	0	0	0	0	1	0	1	0	1	0	0	0
Other manufacturing	2C3200	0	0	0	0	1	0	1	0	1	0	0	0
Repair and installation of machinery and equipment	2C3300	0	0	0	0	0	0	1	1	0	0	0	1
Electricity, gas, steam and air conditioning supply	2D3500	0	0	0	0	1	0	0	1	0	0	0	0

Note: 1 indicates that the series is taken into account when computing the 1st principal component of international commodity prices as an exogenous variable for the sector, otherwise 0. The results of the computation exercise are detailed in Table AA6 on next page.

Table AA6: Explained part of the total variance by the first principal component (PC) and non-explained part by the first two principal components (PCs) of the total commodity prices variations

NACE2 sector code	Explained by 1^{st} PC	Non-explained by first 2 PCs
2B0000	55.5	18.7
2B0500	55.5	18.7
2B0600	71.2	1.7
2B0700	71.2	1.7
2B0800	71.2	1.7
2B0900	71.2	1.7
2C0000	40.2	32.9
2C1000	51.2	28.7
2C1100	63.4	16.8
2C1200	65.0	9.0
2C1300	93.6	0.0
2C1400	93.6	0.0
2C1500	93.6	0.0
2C1600	83.5	4.2
2C1700	83.5	4.2
2C1800	93.6	0.0
2C2000	73.2	6.0
2C2100	83.5	4.2
2C2200	93.6	0.0
2C2300	70.4	3.4
2C2400	70.0	0.5
2C2500	70.0	0.5
2C2600	95.6	0.0
2C2700	95.6	0.0
2C2800	70.0	0.5
2C2900	70.0	0.5
2C3000	70.0	0.5
2C3100	70.0	0.5
2C3200	70.0	0.5
2C3300	93.0	2.0
2D3500	86.5	0.0

Table AA7: Cross-correlations of sector-specific characteristics

	mkt_con	**os**	**gor**	**mkt_int**	**imp_pen**	**GVC_fwd**	**GVC_bwd**
market_concentration	1.00						
operating_surplus	-0.06	1.00					
gross_operating_rate	0.53*	0.32	1.00				
market_integration	-0.20	0.27	-0.02	1.00			
import_penetration	-0.19	0.25	0.05	0.98*	1.00		
GVC_forward	-0.26	0.27	0.14	-0.20	-0.22	1.00	
GVC_backward	0.11	-0.19	-0.07	-0.21	-0.17	-0.54*	1.00

Note: * indicates significance at 5%.

Appendix B Additional Empirical Results

Figure B1: Accumulated impulse response functions for *imp* from a unit shock to *neer*, with *neer* at different positions. The dashed lines are 68% bootstrap confidence bounds.

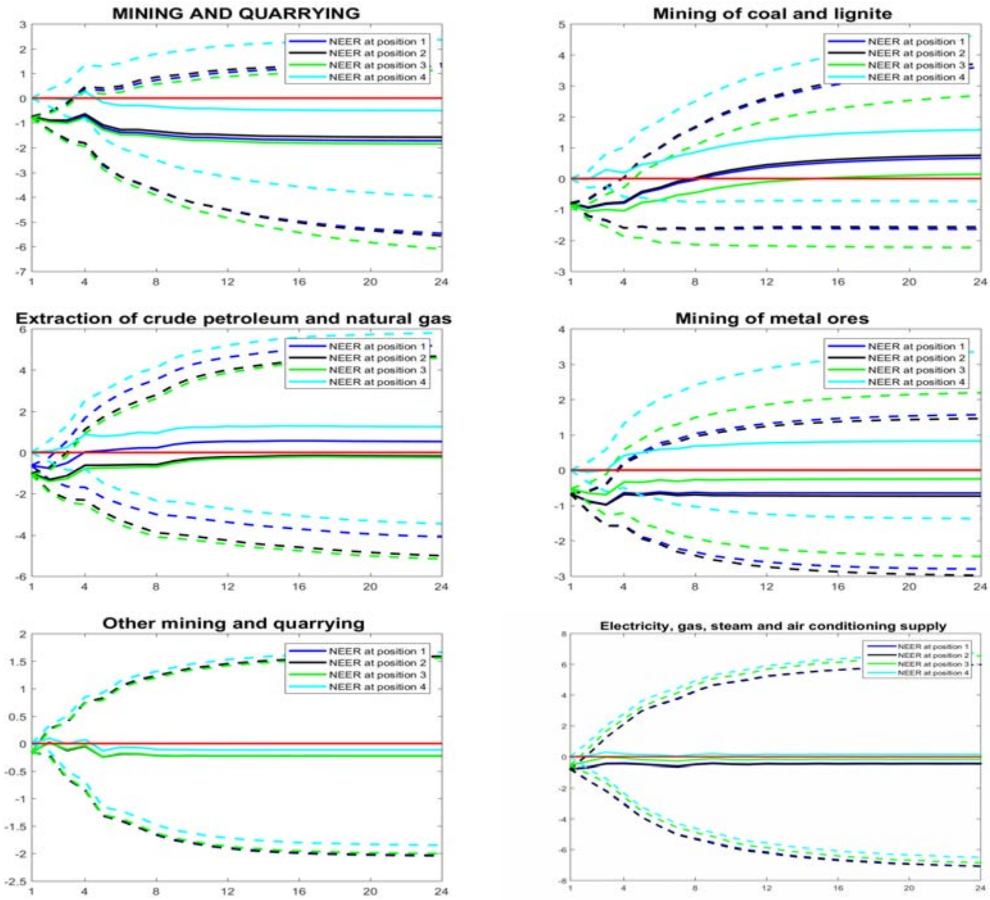


Figure B2: Accumulated impulse response functions for *imp* from a unit shock to *neer*, with *neer* at different positions. The dashed lines are 68% bootstrap confidence bounds.

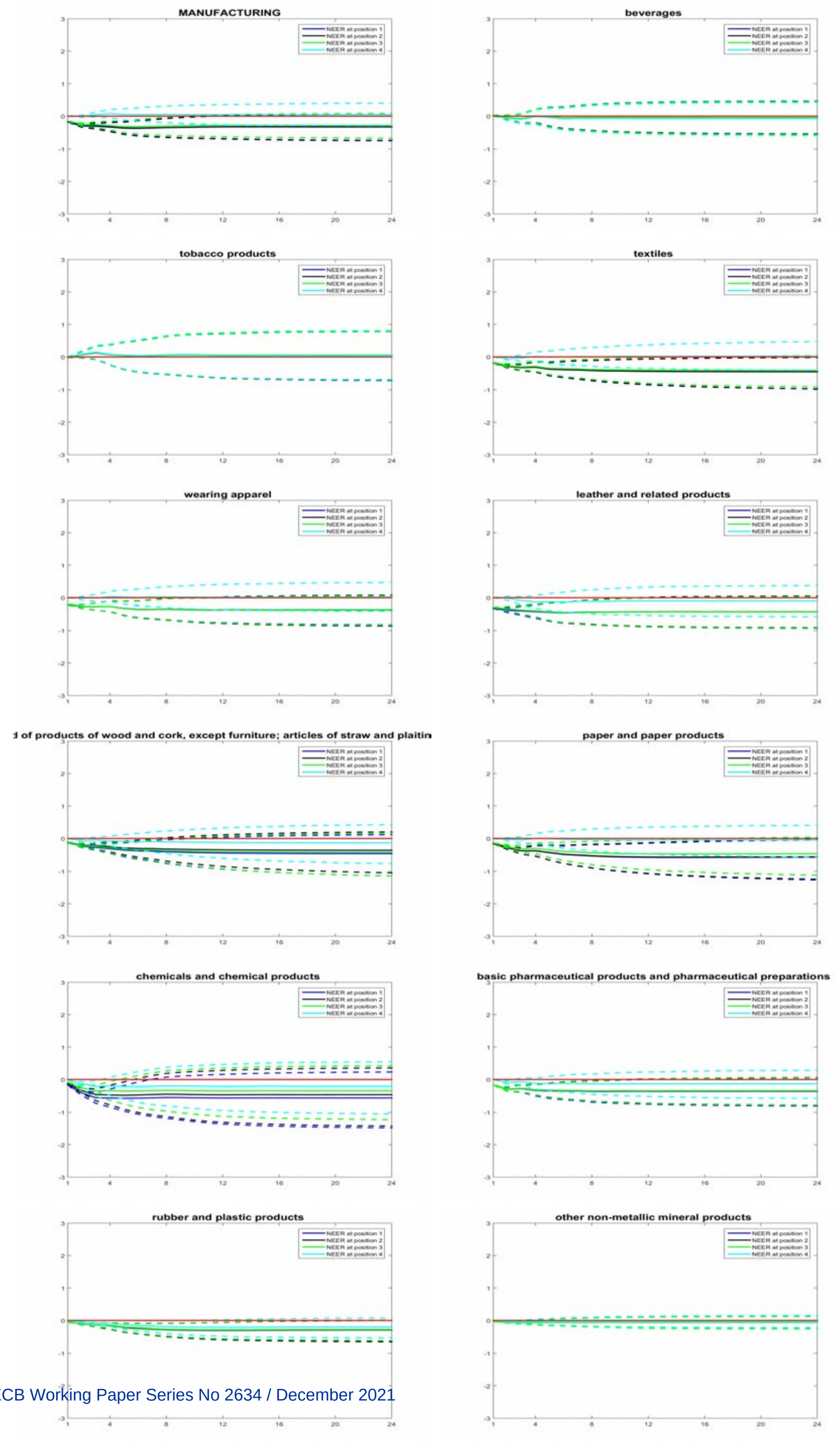
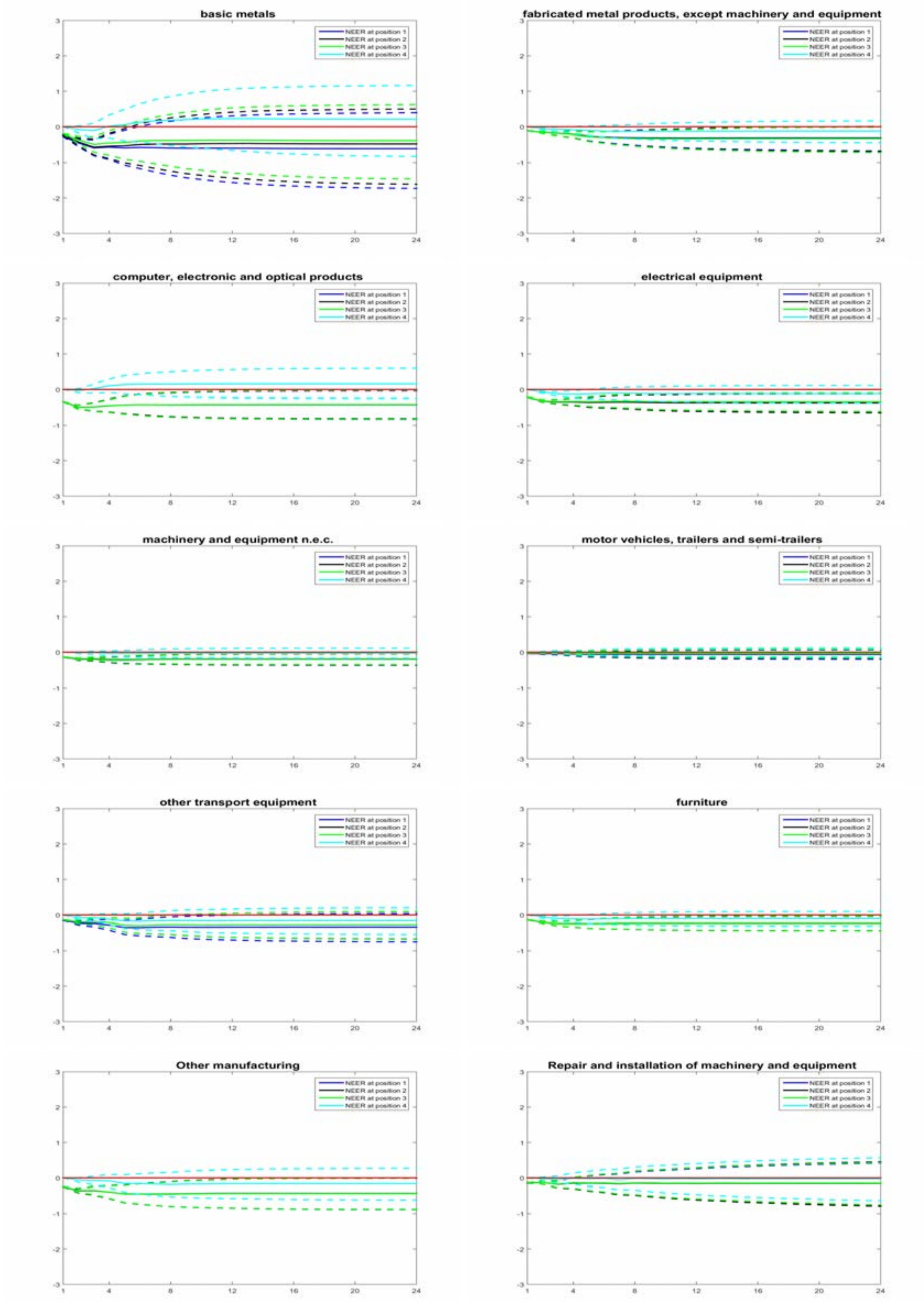


Figure B3: Accumulated impulse response functions for *imp* from a unit shock to *neer*, with *neer* at different positions. The dashed lines are 68% bootstrap confidence bounds.



Acknowledgements

We thank Rob Vigfusson, Matthieu Bussière, Luca Dedola and Stelios Makrydakis for valuable discussions and comments.
The views expressed are those of the authors only and do not necessarily reflect those of the European Central Bank, the Bank of Slovenia or the Eurosystem.

Chiara Osbat
European Central Bank, Frankfurt am Main, Germany; email: chiara.osbat@ecb.europa.eu

Yiqiao Sun
European Central Bank, Frankfurt am Main, Germany; email: yiqiao.sun@ecb.europa.eu

Martin Wagner
University of Klagenfurt, Klagenfurt, Austria; Bank of Slovenia, Ljubljana, Slovenia; Institute for Advanced Studies, Vienna, Austria; email: martin.wagner@aau.at

Postal address 60640 Frankfurt am Main, Germany
Telephone +49 69 1344 0
Website www.ecb.europa.eu

PDF ISBN 978-92-899-4921-7 ISSN 1725-2806 doi:10.2866/102470 QB-AR-21-125-EN-N