NBER WORKING PAPER SERIES

FIRM RESPONSES AND WAGE EFFECTS OF FOREIGN DEMAND SHOCKS WITH FIXED LABOR COSTS AND MONOPSONY

Emmanuel Dhyne
Ayumu Ken Kikkawa
Toshiaki Komatsu
Magne Mogstad
Felix Tintelnot

Working Paper 30447
http://www.nber.org/papers/w30447

NATIONAL BUREAU OF ECONOMIC RESEARCH
1050 Massachusetts Avenue
Cambridge, MA 02138
September 2022, Revised November 2024

The views expressed in this paper are those of the authors and do not necessarily reflect the views of the National Bank of Belgium, nor any other institution with which one of the authors is affiliated, nor those of the National Bureau of Economic Research. A previous version of this paper was titled "Foreign Demand Shocks to Production Networks: Firm Responses and Worker Impacts." We thank the editor (Arnaud Costinot), three anonymous referees, Andrew Atkeson, David Baqaee, Aaron Flaaen, Agustin Gutierrez, Jonathan Vogel, Nicola Pierri, and Trang Hoang for helpful comments.

Firm Responses and Wage Effects of Foreign Demand Shocks with Fixed Labor Costs and Monopsony
Emmanuel Dhyne, Ayumu Ken Kikkawa, Toshiaki Komatsu, Magne Mogstad, and Felix Tintelnot
NBER Working Paper No. 30447
September 2022, Revised November 2024
JEL No. E1, F1, F12, J31, J42, L11

ABSTRACT

We quantify the firm responses and real wage effects of foreign demand shocks. We use Belgian micro data to construct firm-specific measures of demand shocks which capture that firms pass on foreign demand shocks to domestic suppliers. Our estimates of firm responses to these shocks suggest that firms face upward-sloping labor supply curves and have sizable fixed labor costs. We specify a general equilibrium model with these features to quantify the aggregate effects of simulated tariff shocks on wages. We find that ignoring fixed labor costs substantially underestimates aggregate effects on wages, whereas incorporating upward-sloping labor supply appears less consequential.

Emmanuel Dhyne
National Bank of Belgium
Boulevard de Berlaimont, 14
1000 Brussels
Belgium
emmanuel.dhyne@nbb.be

Ayumu Ken Kikkawa
Sauder School of Business
University of British Columbia
2053 Main Mall
Vancouver, BC V6T 1Z2
Canada
and NBER
ken.kikkawa@sauder.ubc.ca

Toshiaki Komatsu
Centre for Research and
Analysis of Migration
Drayton House, 30 Gordon Street
London WC1H 0AX
United Kingdom
komatsu.econ@gmail.com

Magne Mogstad
Department of Economics
University of Chicago
1126 East 59th Street
Chicago, IL 60637
and NBER
magne.mogstad@gmail.com

Felix Tintelnot
Department of Economics
Duke University
213 Social Sciences Bldg.
Box 90097
Durham, NC 27708
and NBER
felix.tintelnot@gmail.com

1 Introduction

In a globalized economy, firms are influenced by fluctuations in foreign market demand, which affect them both directly as exporters and indirectly through their connections in domestic production networks. How firms respond to demand changes shapes the way these effects propagate throughout the economy, influencing workers, suppliers, and domestic consumers. This paper explores the following questions: What insights do firms' responses to demand shocks provide about their cost structures? What impact do these shifts in demand have on workers and wages? How sensitive are the broader economic effects of foreign demand shifts to firms' cost structures and the presence of imperfect competition in labor markets?

We study these questions in the context of Belgium, a small open economy. As discussed in Section 2, our analyses employ a panel dataset of Belgian firms and workers, covering the period 2002-2014. This dataset is based on several micro data sources that we have linked. Annual accounts provide data on input factors and output; customs records and intra-EU declarations give information on imports and exports; a value-added tax (VAT) registry provides information on domestic firm-to-firm transactions; and social security records and employer-employee data give information on workers and their earnings, hourly wages, and work hours.

We establish two empirical facts about the Belgian economy. First, we characterize the relationships in our data between (changes in) firm-level sales, labor costs, and intermediate input purchases. We find that input purchases respond nearly proportionally to changes in sales. In contrast, changes in sales are associated with less than proportionate changes in labor costs. The changes in the labor costs reflect both changes in employment and changes in the average wage, indicating that average wages increase when sales increase. Second, we find that changes in firm-level output prices are more correlated with changes in firm-level input prices than with the changes in the firm-level average wage. These findings are consistent with firms facing upward sloping labor supply curves and fixed overhead costs in labor inputs, whereas intermediate inputs (such as energy and materials) are predominantly variable costs in production.

Motivated and guided by these empirical facts, we next develop, in Section 3, a small open economy model and then analyze the comparative statics properties of the relationships between key variables. One important feature of our model is that we allow for imperfect competition, in the form of monopsonistic competition in the labor market and monopolistic competition in the product market. Another important feature of our model is that we allow the production of goods to depend on both fixed and variable costs of labor and intermediate goods. Fixed labor costs may reflect tasks such as administration, worker management, facility maintenance and any other work that does not translate directly into production and revenue. Examples of fixed intermediate input costs include waste management, accounting services, and electricity payments that occur irrespective of sales. More broadly, fixed costs capture the expense on inputs required for firm activities that do not vary with changes in output.

The model serves three purposes. First, the comparative statics of the model show the elasticities we need to recover to quantify and interpret how firms and workers respond to and are affected by changes in foreign demand. These elasticities include the labor supply elasticity facing the firm as well as the firm's elasticities of labor costs and intermediate input purchases with respect to demand-driven changes in sales. We illustrate that the elasticities of input usage in response to changes in output contain information relevant to determining the share of an input that is used as overhead versus as a variable input. Second, the model helps to make explicit the data, instrument, and assumptions we need to identify and estimate these elasticities. The comparative statics of the model consider a change in the sales of a firm due to an exogenous change in the demand it faces. In the data, however, sales may change for many reasons other than demand, including shifts in input prices, technology, preferences, or amenities. To address this identification challenge, in Section 4, we draw on the work of Hummels et al. (2014) and Dhyne et al. (2021) to construct an instrument that intends to isolate the variation in sales that is induced by a change in foreign demand. We perform a number of robustness checks to examine various threats to the validity of the instrument. Lastly, the model makes it possible to perform counterfactuals to quantify and explain the aggregate welfare implications of changes in foreign demand (or productivity). In this analysis, we consider several counterfactual economies, defined by alternative parameterizations of the model. One of these economies is constructed to mirror the actual Belgian economy. In the other counterfactual economies, we instead assume no fixed costs or perfectly elastic labor supply (or both).

In Section 5, we take the model to the data with the goal of quantifying and explaining the firm responses and worker impacts of changes in firm sales that are induced by changes in foreign demand. To do so, we use the instrumental variables approach described in Section 4 to recover the elasticities defined by the comparative statics of the model. We first explore the time series pattern of the foreign demand shock and find it to be close to a permanent shock, with firm sales changes after four years being 76 percent of the initial response in sales. We then investigate how firms' input expenditures respond to changes in sales that are induced by foreign demand shocks. The estimates suggest that in response to a foreign demand shock that increases a firm's sales by 7.6 percent after four years, the total input purchases increase by around 7.8 percent over the same period, whereas labor costs only increase by around 4.1 percent. We also find that roughly one-quarter of the change in labor cost is coming from the change in average wage.[1] Our estimates imply that on average, firms'

[1]The magnitude of the wage effects is comparable to previous findings in other contexts. For example,

input purchases are predominantly variable costs. They also imply that Belgian firms pass on a large share of a foreign demand shock to their domestic suppliers, face upward-sloping labor supply curves and, thus, have wage-setting power, and have sizable fixed overhead costs in labor.

We are not aware of previous studies with directly comparable estimates of the fixed shares of labor or intermediate inputs. The closest comparison is arguably the results in De Loecker et al. (2020). Using data on American firms (from Compustat), they compute the share of total costs that is fixed. They measure fixed costs as the reported spending in the category "Selling, General and Administrative Expenses." They conclude that the share of total costs that are fixed ranges from 18 to 22 percent during the period 2000-2016. Another close comparison is Ederhof et al. (2021), who use U.S. census data for manufacturing plants during 1974-2011. Classifying costs such as fringe benefits, depreciation, and rental payments as fixed costs, they measure that 20 percent of total costs is fixed. By comparison, our estimates suggest that around 29 percent of total costs (including labor and intermediate inputs) are fixed in the Belgian economy.

We consider several alternative explanations but find that none of them plausibly overturns our conclusion that firms face sizable overhead costs that consist predominantly of units of labor. First, we note that our empirical results are consistent with the presence of adjustment costs to firm-level employment. Even in the presence of adjustment costs, if the production function was homothetic and had constant returns to scale, in response to a permanent change in demand, in the long-run firms should increase labor costs proportionally to other inputs. Second, we show that our results are inconsistent with a non-homethetic CES production function (Matsuyama, 2023) that does not incorporate overhead costs of labor.

In Section 6, we analyze the aggregate effects of a five percent increase in foreign tariffs on all Belgian exports. Our results suggest that the increase in foreign tariffs produces a substantial 4.9 percent fall in the average real wage. By comparison, the reduction in real wages would be predicted to be as low as 2.8 percent if we assume the economy had no fixed costs and perfectly elastic labor supply. Thus, we conclude that the way in which the labor market is typically modeled in existing research on foreign demand shocks—with no fixed costs and perfectly elastic labor supply—may grossly understate the decline in real wages due to an increase in foreign tariffs.

The intuition behind how fixed overhead costs in labor amplify real wage declines can be understood by considering that these fixed costs reduce the relative importance of labor in firms' variable costs. When labor constitutes a smaller share of firms' variable costs, output

Garin and Silvério (2023) use linked employer-employee data from Portugal and find that an exogenous output change of 10 percent causes incumbent workers' wages to change proportionally by 1.5 percent in the medium run.

prices become less sensitive to changes in wages. With the aggregate labor supply fixed, the economy responds to a negative demand shock by lowering prices through wage reductions. To achieve the same price decrease, wages must fall further when fixed labor costs are taken into account.

Our paper contributes to several areas of economics. Our first contribution is to the literature that analyzes how foreign demand shocks affect labor market outcomes. A large literature uses worker data at the firm or regional level to analyze the labor market effects of foreign demand shocks (see, e.g., Autor et al., 2013, Autor et al., 2014, Kovak, 2013, Dix-Carneiro, 2014, Dix-Carneiro and Kovak, 2017, Pierce and Schott, 2016, Traiberman, 2019,Kim and Vogel, 2020, 2021, Galle et al., 2022, Costinot et al., 2022, and Garin and Silvério, 2023). Felix (2021) and MacKenzie (2021) study the effects of opening to trade when product and labor markets are imperfect, and find quantitatively small effects of imperfect competition in labor markets, whereas Gutiérrez (2022) estimates larger effects from imperfect competition. Our paper joins a small set of papers that combine information on firm-to-firm transactions with micro data on firms and workers. Demir et al. (2024) document positive assortative matching between buyers and suppliers in terms of wages paid to workers. They analyze how this positive assortative matching affects the wage responses of exporters and their suppliers to a foreign demand shock. Adao et al. (2020) study the impact of trade on inequality in a framework with perfect competition, and Alfaro-Urena et al. (2019) estimate the effects of foreign multinationals on workers. Huneeus et al. (2021) estimate that supply shocks transmitted through the production network can account for around 20 percent of the earnings volatility of Chilean workers.[2]

Another key difference between our study and prior work is that our analysis allows for imperfect competition in the labor market and distinguishes between fixed and variable costs in production. We find this distinction to be empirically important, as it materially affects the conclusions from both partial and general equilibrium analyses of the labor market effects of foreign demand shocks.[3]

Our paper also contributes to the literature on general equilibrium effects in production networks. Baqaee and Farhi (2022) analyze the general equilibrium effects of trade shocks, and Bigio and La'O (2020), Baqaee and Farhi (2019a), and Baqaee and Farhi (2019b) analyze the transmission of shocks in closed economies with and without distortions. Baqaee and Farhi (2020) illustrate how free entry affects the long-run effects of shocks, vom Lehn and Winberry (2021) document the role of the investment network for sectoral comovement along

[2]In other work based on data with firm-to-firm transactions, Huneeus (2018) studies the pass-through of foreign shocks to Chilean firms during the Great Recession.

[3]Our findings do not directly alter the interpretation of prior research that established the reduced form relationship between (regional or industry) labor market outcomes and changes in tariffs or import competition.

the business cycle, and Atalay (2017) quantifies the importance of sectoral shocks along the business cycle.[4] Both Baqaee and Farhi (2020) and Arkolakis et al. (2023) highlight the significance of measuring the input units that contribute to fixed costs. Furthermore, Klenow and Li (2024)'s finding that entry costs increase with growth aligns with the notion that overhead costs are paid in units of labor. To our knowledge, our study is the first to incorporate estimates of fixed overhead costs and imperfect competition in the labor market in a general equilibrium analysis with production networks.[5]

2 Data and motivating empirical facts

Our analyses combine multiple administrative data sources from Belgium for the period 2002-2014. Below we briefly describe our data and sample selection; additional details are given in Appendix A.

2.1 Data on firms

The National Bank of Belgium (NBB) provided us with three datasets on firms, each covering the period 2002-2014. These datasets can be linked through (anonymized) firm identifiers, assigned and recorded by the government for the purpose of collecting value-added taxes (VAT). For details on the linking procedure, we refer to Dhyne et al. (2015) and Dhyne et al. (2021).

The first dataset is the Business-to-Business (B2B) transactions database. Every year, all VAT-liable firms are legally required to report annual sales to every other VAT-liable firm in Belgium. This information must be reported to the tax authority provided that annual sales to a given buyer exceed 250 euro. Thus, the B2B dataset allows us to measure the firms' domestic production networks as well as their purchases from and sales to domestic suppliers and buyers.

We merge this dataset with information on the firms' international trade and their annual accounts. The information on international trade comes from the Belgian customs records and the intra-EU trade declarations, which contain the value of imports and exports (disaggregated by the EU's eight-digit coding system for products) and the countries of origin or destination. The annual accounts contain detailed information from the firm's balance sheets on sales, revenues, operating profits, ownership shares in other enterprises, costs of

[4] Several papers analyze endogenous production networks that allow for the creation or destruction of firm-to-firm links in response to economic shocks. See Oberfield (2018), Lim (2018), Taschereau-Dumouchel (2018), Elliott et al. (2021), Acemoglu and Tahbaz-Salehi (2020), Arkolakis et al. (2023), and Dhyne et al. (2023a). For tractability, we abstract from this adjustment mechanism in our model.

[5] A related literature in labor economics examines the rent sharing between firms and workers, exploiting changes in patents, demand, or taxes and subsidies (see, e.g., Van Reenen, 1996, Guiso et al., 2005, Kline et al., 2019, Friedrich et al., 2019, Berger et al., 2022, Kroft et al., 2020, Howell and Brown, 2020, Lamadon et al., 2022, and Chan et al., 2021).

inputs (such as capital, labor, and intermediates), as well as four-digit (NACE) industry codes and geographical identifiers (at the postal code level).

Importantly, the annual accounts also include information about the number of full-time equivalent (FTE) workers. The calculation of FTE is an employee's actual scheduled hours divided by the regular scheduled hours for a full-time workweek. To measure the (average) hourly wage that each firm pays to its workers, we divide the firm's labor cost by the number of FTE workers.

A limitation with the Belgian data is that all the information is recorded at the level of the VAT identifier. This creates a challenge because a firm may have several VAT identifiers (for accounting or tax reasons). If a firm has multiple VAT identifiers, we follow Dhyne et al. (2021) in aggregating the data up to the firm level using information from the annual accounts about the ownership structure. Further details on the aggregation procedure are provided in Appendix A.1.

2.2 Data on individual workers

As described above, the firm data offers information on the number of FTE workers and the wages paid to these workers. This allows us to measure changes over time in the labor cost, hourly wages, and the size of the workforce of a given firm. The firm data do not, however, allow us to follow the same workers over time.

To do so, we add information from matched employer-employee data for the period 2003-2014. The employer-employee data are provided to NBB by the Banque Carrefour de la sécurité sociale (Crossroads Bank for Social Security, BCSS), and then linked by NBB to our firm data (see Appendix A.2 for details.) The linked data consist of a random sample of 500,000 workers, drawn from the population of firms with 10 or more FTE employees at least once during the period 2003-2014. We have to work with this subsample of workers in larger firms because of restrictions imposed by the Belgian social security administration.

As discussed in greater detail later, this subsample of workers is useful for two reasons. First, it lets us perform an analysis of the wage impacts of worker mobility across firms. This allows us to examine if the hourly wage paid to a given worker depends on the firm for which she works. Second, it lets us restrict the estimation sample to stayers, who are observed working for the same firm over several years. This allows us to examine whether changes in a firm's labor cost are a result of changes in the wage that it pays to a given worker or changes in the composition and quality of its workforce.

2.3 Estimation samples

Most of our analyses use only the firm data. In these analyses, we impose a few restrictions to construct a suitable estimation sample. We restrict our analysis to firms in the private, non-financial sectors with at least one FTE employee and positive labor costs and sales. Following De Loecker et al. (2014) and Dhyne et al. (2021), we also restrict our analysis to firms with tangible assets of more than 100 euro and positive total assets in at least one year during our sample period 2002-2014. In the remainder of the paper, we refer to this sample as the main estimation sample.

As evident from Appendix A.3, the main estimation sample covers a large majority of the aggregate value added, gross output, labor costs, exports, and imports in the Belgian economy. In this appendix, we also present the (direct and total) export participation and shares of firms that directly export to those that only export indirectly, building on the work of Dhyne et al. (2021). While few Belgian firms are directly exporting, a majority of the firms are indirectly exporting through sales to domestic buyers that subsequently trade internationally. In fact, even the firms that do not directly export are, on average, selling nearly 10 percent of their output indirectly to foreign markets. These statistics motivate, for example, why we incorporate indirect export through the production network to measure firms' ultimate exposure to foreign demand when constructing our instrument in Section 4.

In a few of our analyses, we will rely on the subsample for which we have additional information from the worker data (i.e., the firms with 10 or more FTE employees at least once from 2002 to 2014). Even though this subsample contains only about a quarter of all firms, it still makes up most of the total sales, inputs, and trade in the Belgian economy.

2.4 Motivating empirical facts

In order to motivate and guide the choices of model and econometric specification, we now present a set of empirical facts on the relationships in our data between firm-level sales, labor costs, and intermediate input purchases.

We begin by describing the cross-sectional relationships between firm-level sales, labor costs, and intermediate input purchases. We pool the cross-sectional data for the entire period 2002-2014. In an attempt to adjust for differences across industries, we first demean the log of each variable using the firm's four-digit industry average. Thus, a firm with reported log sales of zero has the sales of an average firm in its industry. Next, we use local polynomial regressions to non-parametrically estimate the relationships between log labor costs and log sales (panel (a) of Figure 1) and log input purchases and log sales (panel (b) of Figure 1). In these cross-sectional comparisons across firms, we find that both labor and intermediate input purchases are nearly proportionally aligned with sales.

It is admittedly difficult to learn much from such cross-sectional comparisons. For example, large and productive firms may be systematically different from smaller and less productive firms in the production technology they use. A natural way to start addressing this concern is to examine changes over time within firms in sales, labor costs, and intermediate input purchases. In panels (c) and (d) of Figure 1, we perform the same analyses as in the two first panels, except that we now look at changes within firms over a four year period. We find that input purchases respond close to proportionally to changes in sales (a slope coefficient of 0.82). In contrast, changes in sales are associated with less than proportionate changes in labor costs (a slope coefficient of 0.57). Panels (e) and (f) further decompose the changes in labor cost shown in panel (c) into changes in employment and average wages. We find that while much of the changes in labor costs are driven by the changes in employment (a slope coefficient of 0.48), changes in average wage are also correlated with the changes in sales (a slope coefficient of 0.09).

These results are suggestive of two things. First, the fact that changes in labor costs are less than proportional to the changes in sales suggest that there are sizable fixed overhead costs in labor. In Appendix C.1 we examine different cuts of the data to explore whether any group of firms have significantly lower correlation between changes in labor cost and sales than other firms. We find that groups of firms that are often associated with having larger fixed costs, such as exporters and importers, have significantly lower correlation between changes in labor cost and sales, suggesting that fixed labor cost shares are higher for those firms. Second, the fact that wages change along with sales suggest that firms face upward sloping labor supply curve.[6]

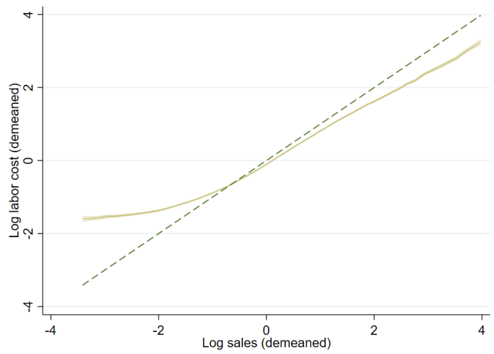
We further investigate firms' input composition by looking at the relationship between the changes in prices of their inputs and outputs. In Appendix C.3, we illustrate the differential pass-through rates of changes in wages and input prices on firm-level output prices. We use additional information on unit values provided by Duprez and Magerman (2018), which is based on Prodcom data that contains output values and quantities at the 8-digit level for large firms in the mining and quarrying, and manufacturing sectors. We find that changes in output prices are more correlated with the changes in input prices than with the changes in average wage. This fact is consistent with labor cost having a smaller share than input purchases in firms' variable costs.

However, one needs to be cautious in drawing conclusions from these facts. Input costs and sales are simultaneously determined and may be affected by many omitted variables. Similarly, the changes in input and output prices may be affected by measurement errors or driven by changes in other firm-level outcomes that generate omitted variable biases. To

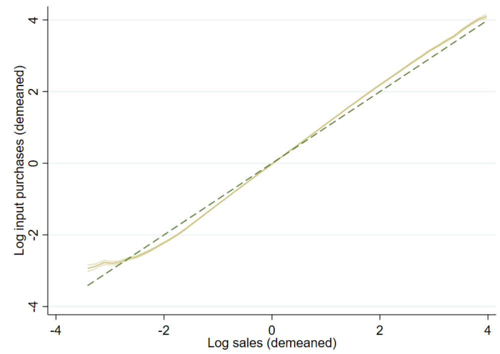
[6]We further investigate the relationship between wage and firm size in Appendix C.2. We first show that firms that are more exposed to foreign markets are larger, more productive, and pay higher wages, and then that these wage differentials cannot be entirely explained by observed or unobserved differences across workers. These results showing wage premium for exporters are documented for many other countries (see for example, Irarrazabal et al. (2013) for Norway, Egger et al. (2020) for Germany, Frías et al. (2024) for Mexico, and Helpman et al. (2016) for Brazil), and motivate our departure in Section 3 from the canonical model of a competitive labor market where wages depend only on the marginal product of workers and not the firm that employs them.

Figure 1: Relationship between firm-level sales, labor costs, and input purchases

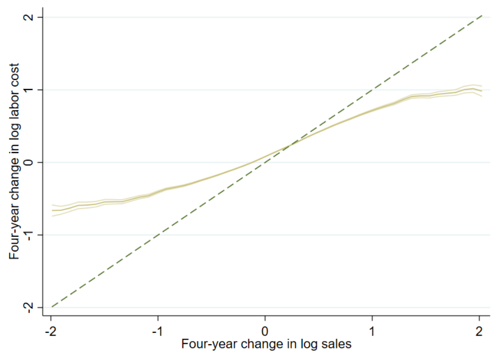
(a) Sales and labor costs



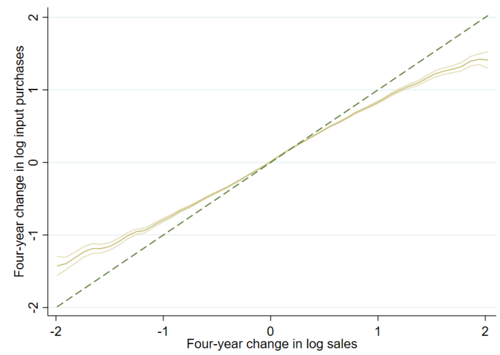
(b) Sales and input purchases



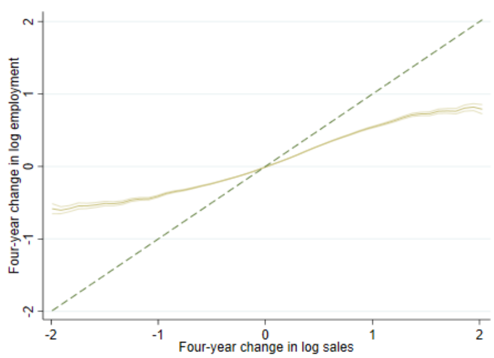
(c) Sales and labor costs (four-year change)



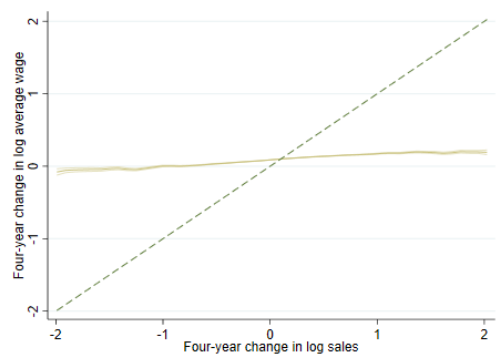
(d) Sales and input purchases (four-year change)



(e) Sales and employment (four-year change)



(f) Sales and average wage (four-year change)



Notes: The figures use the main estimation sample of private-sector firms in Belgium from 2002 to 2014 (see Section 2.3 for details). They display the relationship between firm-level sales, labor costs, input purchases, employment, and average wage using the smoothed values of kernel-weighted local polynomial regression estimates with 95 percent confidence intervals. We use the Epanechnikov kernel function with kernel bandwidth of 0.05. In panels (a) and (b), each variable is demeaned with four-digit industry-year fixed effects. Log sales and four-year changes in log sales are trimmed at the top and bottom 1 percentiles.

draw conclusions about fixed versus variable costs we therefore will, in Section 3, develop an explicit model and construct an instrument that isolates the variation in sales that is induced by an exogenous change in demand. The insight from the model is that how firms' labor costs respond to changes in sales induced from exogenous demand shocks map to their fixed labor cost shares only when the labor supply curve is flat. As we demonstrate in Section 5, our IV estimates suggest a broadly comparable relationship between changes in labor costs and sales for firms that trade internationally and those that do not. This suggests that firms that trade internationally may have higher fixed costs (as they are larger), but comparable fixed share of costs. Furthermore, when firms face an upward sloping labor supply curve, responses of labor costs to sales change and the elasticity of the labor supply curve jointly determine the fixed labor cost shares. To determine the elasticity of the labor supply curve that individual firms face, we turn to the estimating equation derived from the model in Section 3.

3 Model

Motivated and guided by the empirical evidence presented in the previous section, we now develop a model and then analyze the comparative statics properties of the relationship between key variables.[7]

3.1 Model environment

We model Belgium as a small open economy where firms take the prices in the foreign market as given. Our model is parsimonious and restrictive in several ways. For example, we take all buyer-supplier relationships as given, in terms of both the domestic firm-to-firm links and the firms' direct export and import participation. However, in other important ways, the model is rich and flexible as compared to much of the existing work on production networks.

One important feature of our model is that we allow for imperfect competition, in the form of monopsonistic competition in the labor market and monopolistic competition in the product market. To let the labor supply facing the firm be imperfectly elastic, we assume that many firms compete with one another for workers who have heterogeneous preferences over amenities. This assumption gives rise to firms having an increasing marginal cost of labor, consistent both with the descriptive evidence in Appendix C.2 and with recent empirical findings from countries other than Belgium (see, e.g., Almunia et al., 2021, Lamadon et al., 2022, and Kroft et al., 2020). In the product market, we assume a market structure in which firms have many competitors, but each one sells a single differentiated good. As a

[7]The model is similar to the one in Huneeus et al. (2021), with a key distinction being that the cost structure of firms differs, and our model incorporates fixed overhead costs that lead to increasing returns to scale in production. We also consider a small open economy, whereas their model considers a closed economy.

result, the product demand facing the firm may be imperfectly elastic. The firms may sell to households with heterogeneous preferences, to other domestic firms, and directly to foreign markets. Intermediate inputs may be purchased from other domestic firms or imported directly from abroad.

Another important feature of our model is that we allow the production of goods to depend on both fixed and variable costs of labor and intermediate goods. The reason we allow for fixed overhead costs is that both the descriptive evidence in Section 2.4 as well as previous studies indicate that such expenses can be important in matching key moments of the data on firms and workers in developed countries, at least in the short or medium run (see, e.g., Bartelsman et al., 2013, Traina, 2018, and Autor et al., 2020).

Product demand. The households in the economy consist of workers and firm owners. All households have the same preferences for goods. The utility of a household from final good consumption is denoted by C, which is a CES aggregator of the household's purchases of each firm's goods, q_{kH}:

$$C = \left(\sum_{k \in \Omega} \left(\beta_{kH} q_{kH} \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where Ω denotes the set of all available products and H denotes domestic final demand from households. With the CES structure, one can write $P = \left(\sum_{k \in \Omega} \beta_{kH}^{\sigma-1} p_k^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$ as the aggregate price index. The demand for product k (which is produced by firm k) can be expressed as

$$q_{kH} = \beta_{kH}^{\sigma-1} \frac{p_k^{-\sigma}}{P^{1-\sigma}} E_H, \tag{2}$$

with E_H being the aggregate income of workers and firm owners, and similarly for exports, we have

$$q_{kF} = p_k^{-\sigma} D_{kF}, \tag{3}$$

where D_{kF} is the exogenous foreign demand shifter for firm k.

Labor supply. We consider an environment where labor is hired in a spot market, and each worker has idiosyncratic preferences over firms that are private information. Because of this information asymmetry, a firm cannot price-discriminate with respect to workers' reservation wages. Each worker n supplies one unit of labor and has the following preference for working at firm k:

$$v_{nk} = \log w_k + \log \delta_k - \log P + \nu_{nk}, \tag{4}$$

where w_k denotes the wage at firm k, δ_k denotes the firm-specific amenity that is common to all workers, P is the aggregate price index, and ν_{nk} denotes worker n's idiosyncratic taste for the non-wage attributes or amenities of firm k.

This specification of preferences allows for the possibility that workers are heterogeneous in their preferences over the same firm. The importance of this source of horizontal differentiation is governed by the variance of ν_{nk}. For empirical tractability, we assume that ν_{nk} is distributed according to a Type-1 Extreme Value distribution with parameter ε.

Given the set of offered wages by all firms, worker n chooses a firm k to maximize her utility. Due to the distributional assumption on ν_{nk}, we obtain the following firm-specific labor supply curve:

$$\ell_k = A_k w_k^{\varepsilon}, \tag{5}$$

where $A_k = \frac{\delta_k^{\varepsilon}}{\sum_j \delta_k^{\varepsilon} w_j^{\varepsilon}} L$. The term L is the aggregate labor supply.

Firms' production technology. Each firm produces a unique differentiated product and has a firm-specific production technology to convert variable labor, domestic inputs, and foreign inputs into output. It also has firm-specific fixed overhead input requirements for labor and inputs purchased from other firms. Finally, each firm has an exogenous set of domestic suppliers as well as exogenous access to the import or export market. We denote variables associated with variable inputs with superscript v and variables associated with fixed overhead inputs with superscript f.

Let the fixed overhead input requirement of firm k be denoted by $\bar{q}_k^f$. This fixed overhead input requirement can be fulfilled via a CES production technology by choosing inputs from a set of domestic suppliers Z_k as well as imports. The technology parameters ω_{jk}^f and ω_{Fk}^f are given. For all firms that do not directly import to fulfill the fixed input requirement, we have $\omega_{Fk}^f = 0$. Specifically, firm k's technology to fulfill its exogenous fixed overhead input requirements is as follows:

$$\bar{q}_k^f = \left(\sum_{j \in Z_k} \omega_{jk}^f \left(q_{jk}^f \right)^{\frac{\sigma-1}{\sigma}} + \omega_{Fk}^f \left(q_{Fk}^f \right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}. \tag{6}$$

Note that the term on the left-hand side is exogenously given, whereas the inputs on the right-hand side, q_{jk}^f and q_{Fk}^f, can be endogenously chosen. In addition, firm k has a fixed overhead labor input requirement $\bar{\ell}_k^f$. By letting the fixed overhead input requirements be firm-specific, our specification is flexible enough to capture that large firms may have higher overhead costs, as suggested by Traina (2018) and De Loecker et al. (2020).

After fulfilling the fixed overhead requirements, the output production function has constant returns to scale. Firms combine variable labor inputs and a variable intermediate input bundle in a Cobb-Douglas fashion. The variable intermediate input bundle is a CES aggregate of variable inputs purchased from their suppliers and variable imports. We write the output production function of firm k as follows:

$$q_k = \phi_k \left(q_k^v\right)^{1-\alpha_{\ell k}} \left(\ell_k^v\right)^{\alpha_{\ell k}}$$
$$q_k^v = \left(\sum_{j \in Z_k} \omega_{jk}^v \left(q_{jk}^v\right)^{\frac{\sigma-1}{\sigma}} + \omega_{Fk}^v \left(q_{Fk}^v\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}, \tag{7}$$

where $\alpha_{\ell k}$, ω_{jk}^v, and ω_{Fk}^v are the saliency parameters for labor inputs, inputs from individual suppliers, and imports. The term ϕ_k represents the exogenous Hicks-neutral productivity term of firm k. The left-hand side of equation (7), the total output of firm k, is an endogenous variable. Note that the CES substitutability parameters in firms' production technology are restricted to be the same as the substitutability parameter in final demand. This assumption, which is common in the literature (see Huneeus et al., 2021 and Demir et al., 2024 for example), implies that firms face the same demand elasticity regardless of who they sell their output to, and, thus, charge common markups under monopolistic competition.

Firm k's use of labor inputs, ℓ_k, inputs from supplier j, q_{jk}, and imports q_{Fk} are equal to the sum of their usage as variable and fixed inputs:

$$\ell_k = \ell_k^v + \bar{\ell}_k^f$$
$$q_{jk} = q_{jk}^v + q_{jk}^f \; \forall j \in Z_k$$
$$q_{Fk} = q_{Fk}^v + q_{Fk}^f. \tag{8}$$

Firm's problem. We now turn to the firm's profit maximization problem. Recall that the idiosyncratic preferences of workers are private information and thus unobserved to the firm. However, the firm knows the distribution of the idiosyncratic preferences. The firm views itself as infinitesimal within both the product and labor markets, acting monopolistically competitive in the output market and monopsonistic in the labor market. Firm k maximizes its profits by taking as given the labor supply curve (as in $w_k(\ell_k)$), the required fixed costs of $\bar{q}_k^f$ and $\bar{\ell}_k^f$, the intermediate input prices, as well as the price of imports p_{Fk}.

Given this environment, each firm k chooses demand for inputs and its output price to solve

$$\max_{\left\{q_{jk}^v\right\}, q_{Fk}^v, \left\{q_{jk}^f\right\}, q_{Fk}^f, \ell_k^v, p_k} p_k q_k\left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right) - w_k\left(\ell_k\right)\ell_k - \sum_{j \in Z_k} p_j q_{jk} - p_{Fk} q_{Fk}, \tag{9}$$

such that equations (5) to (8) hold.

Price. The first-order condition with respect to the firm's output price yields that firm k charges a firm-level markup of $\frac{\sigma}{\sigma-1}$ over its marginal cost, as it faces a common residual demand elasticity of σ. This result is a consequence of the assumption of firms engaging in monopolistic competition when they sell to other firms or sell to final demand.

Labor costs. The first-order condition with respect to variable labor inputs yields the following expression for firm k's variable labor cost share out of its total sales:

$$\frac{\ell_k^v w_k(\ell_k)}{p_k q_k\left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)} = \frac{\varepsilon}{\varepsilon+1} \frac{\partial \log q_k\left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)}{\partial \log \ell_k^v}\left(1+\frac{d\log p_k}{d\log q_k}\right). \tag{10}$$

The first term in equation (10) represents the markdown of labor cost, which comes from the upward-sloping supply curve that has a constant elasticity of ε. The steeper the slope of the labor supply curve (low ε), the greater the markdown. The second term is the output elasticity with respect to variable labor inputs, which is summarized by the parameter $\alpha_{\ell k}$. The third term captures the inverse of the demand elasticity, which can be written as a constant term of $1+\frac{d\log p_k}{d\log q_k}=\frac{\sigma-1}{\sigma}$.

Intermediate input purchases. We now turn our attention to intermediate input purchases. Similar to equation (10), the first-order condition of firm k for variable input purchases from supplier j yields the following equation for the share of intermediate inputs from supplier j out of firm k's total sales:[8]

$$\frac{p_j q_{jk}^v}{p_k q_k\left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)} = \frac{\partial \log q_k\left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)}{\partial \log q_{jk}^v}\left(1+\frac{d\log p_k}{d\log q_k}\right). \tag{14}$$

The share of variable inputs from supplier j depends on two parameters. The first is the output elasticity with respect to the variable input, and the second is the inverse of the demand elasticity the firm faces.

[8] The profit maximization problem of (9) also yields the following relationships for the fixed input bundle. Firms minimize the cost of their fixed input purchases, $\sum_{j\in Z_k} p_j q_{jk}^f + p_{Fk} q_{Fk}^f$, such that equation (6) holds. We obtain the price index for the fixed input bundle:

$$c_k^f = \left(\sum_{j\in Z_k}\left(\omega_{jk}^f\right)^\sigma p_j^{1-\sigma} + \left(\omega_{Fk}^f\right)^\sigma p_{Fk}^{1-\sigma}\right)^{\frac{1}{1-\sigma}}. \tag{11}$$

The individual demand for the fixed inputs is expressed as

$$q_{jk}^f = \left(\omega_{jk}^f\right)^\sigma p_j^{-\sigma}\left(c_k^f\right)^\sigma \bar{q}_k^f \tag{12}$$

$$q_{Fk}^f = \left(\omega_{Fk}^f\right)^\sigma p_{Fk}^{-\sigma}\left(c_k^f\right)^\sigma \bar{q}_k^f. \tag{13}$$

General equilibrium. Equations for aggregate trade balance, labor market clearing, and aggregate income are presented in Appendix B.1. The general equilibrium features a set of firms' wages, $\{w_k\}$, and aggregate expenditure, E_H, such that firms and workers optimize and markets clear (see Appendix B.1 for details).

3.2 Comparative statics and target parameters

We now analyze the comparative statics properties of the relationship between key variables in the model. These comparative statics show the elasticities we need to recover to quantify and interpret how firms and workers respond to and are affected by exogenous changes in demand.

Elasticity of labor cost with respect to a demand-driven change in a firm's output. The change in the labor cost in response to a demand-driven change in a firm's output is informative about the share of labor inputs that is used for fixed overhead costs. Using equation (8) and taking the total derivative of equation (10) while holding firms' labor-specific technology parameter $\alpha_{\ell k}$, labor supply elasticity ε, and worker amenity draws $\{\nu_{nk}\}$ fixed, we obtain[9]

$$\frac{d\log\left(\ell_k w_k\left(\ell_k\right)\right)}{d\log\left(p_k q_k\left(\ell_k^v,\left\{q_{jk}^v\right\},q_{Fk}^v\right)\right)} = \frac{\ell_k^v}{\ell_k}\frac{\varepsilon+1}{\frac{\ell_k^v}{\ell_k}+\varepsilon}. \tag{15}$$

Equation (15) illustrates that the labor cost elasticity of firm k is a function of its variable share of labor inputs $\left(\frac{\ell_k^v}{\ell_k}\right)$ and the labor supply elasticity ε it faces. One extreme case is that all labor inputs are fixed $\left(\frac{\ell_k^v}{\ell_k}=0\right)$, so that changes in sales do not get passed on to labor costs. The other extreme case is that all labor inputs are variable $\left(\frac{\ell_k^v}{\ell_k}=1\right)$. Labor costs are then changing proportionally to changes in sales. Between these two extremes cases, some but not all labor is fixed. The response of labor costs to changes in sales is monotonically increasing in variable share of labor inputs (until the labor cost elasticity is equal to one).

More generally, the labor cost elasticity depends on both the variable share of labor inputs and the labor supply elasticity ε. If there is perfect competition in the labor market ($\varepsilon=\infty$), the labor cost elasticity increases linearly with the variable share of labor inputs. However, if firms face upward-sloping labor supply curves, they pay lower wages than they otherwise would by hiring fewer workers, which effectively amplifies the share of labor inputs that is fixed. Thus, for a given variable share of labor inputs, the elasticity of labor costs

[9] See Appendix B.2 for the derivation. Note that both a firm's foreign demand parameter, D_{kF}, and its productivity parameter ϕ_k are allowed to vary. Equation (15) is therefore consistent with both a demand-driven and a TFP-driven change in sales.

is declining in ε (i.e., as the labor supply curve gets flatter and labor markets become more competitive).

Elasticity of input purchases with respect to a demand-driven change in a firm's output. The change in intermediate input purchases in response to a demand-driven change in a firm's output is informative about the share of input purchases that is used for fixed overhead costs. Using equation (8) and taking the total derivative of equation (14) while holding firms' input-factor-specific technology parameters $\left(\left\{\alpha_{\ell k}, \omega_{jk}^{v}, \omega_{Fk}^{v}, \omega_{jk}^{f}, \omega_{Fk}^{f}\right\}, \sigma\right)$ and relative prices of the suppliers fixed, we obtain[10]

$$\frac{d \log \left(p_j q_{jk}\right)}{d \log \left(p_k q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)\right)} = \frac{q_{jk}^v}{q_{jk}}. \tag{16}$$

Equation (16) implies a one-to-one relationship between the share of the firm's intermediate inputs that is variable costs in the production and the elasticity of intermediate purchases in response to a demand-driven change in the firm's output.

Labor supply elasticity and demand-driven changes in a firm's output. The firm-specific labor supply elasticity governs how much the firm's employment increases if it raises the wage it is paying. Leveraging equation (5), we obtain the following relationship between the labor supply elasticity and the ratio of the average response of labor costs and employment to an increase in sales:

$$\sum_k \frac{d \log \left(\ell_k w_k \left(\ell_k\right)\right)}{d \log \left(p_k q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)\right)} \Bigg/ \sum_k \frac{d \log \ell_k}{d \log \left(p_k q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)\right)} = \frac{\varepsilon + 1}{\varepsilon}. \tag{17}$$

Equation (17) provides the basis for estimating the labor supply elasticity in Section 5. The labor supply elasticity also determines the firm's wage-setting power and its markdown of wages relative to the marginal revenue product of labor.

Worker rents. In our model, worker rents are due to the idiosyncratic taste component ν_{nk}, giving rise to upward sloping labor supply curves and employer wage-setting power. We assumed that employers do not observe the idiosyncratic taste for amenities of any given worker. This information asymmetry implies that firms cannot price-discriminate with respect to workers' reservation wages. As a result, the equilibrium allocation of workers to firms creates surpluses or rents for inframarginal workers, defined as the excess return over that required to change a decision, as in Rosen (1986).

Intuitively, the area above the labor supply curve constitutes the rents of workers. These

[10] See Appendix B.2 for the derivation.

rents represent the willingness-to-pay to stay at the current firm which, on average, is greater when the labor supply curve is steeper. Following Lamadon et al. (2022) and Kroft et al. (2020), the additional rents of workers due to a demand-driven increase in sales can be expressed as:

$$\begin{aligned}\frac{d\left(\ell_k w_k\left(\ell_k\right)\right)}{1+\varepsilon} = & \underbrace{\ell_k dw_k\left(\ell_k\right)}_{\text{incumbent workers}} \\ & + \underbrace{\left(w_k\left(\ell_k\right)+dw_k\left(\ell_k\right)\right)\left(\frac{\ell_k+d\ell_k}{1+\varepsilon}-\ell_k\right)+\frac{\varepsilon}{1+\varepsilon}\ell_k w_k\left(\ell_k\right)}_{\text{new workers}}. \qquad (18)\end{aligned}$$

The additional rents for incumbents is the wage change multiplied by the number of incumbent workers. The additional rents for new hires is the wage bill of new hires minus the wage bill required to make them indifferent between the new and initial firm choices.

3.3 Key modeling choices and alternative interpretations of worker impacts and firm responses to foreign demand shocks

The comparative statistics in the previous subsection connected unknown model parameters to quantifiable worker impacts and firm responses to foreign demand shocks. Of course, these connections depend on our modeling choices, and there admittedly exists alternative economic interpretations of these impacts and responses. We now discuss a few key modeling choices and alternative interpretations of worker impacts and firm responses to foreign demand shocks.

Production function with variable and fixed inputs. Our model uses a non-homothetic production function where optimal combination of total (i.e. flexible and fixed) labor inputs and intermediate inputs vary with the scale of the production.[11] The fixed overhead costs in labor (intermediate inputs) can be identified by examining whether labor costs (input purchases) respond less than proportionally to a change in sales induced by a permanent demand shock.

A natural question is whether such non-proportional responses could be rationalized by a non-homothetic production function without fixed costs. In Appendix B.3, we examine this by deriving the labor cost and input purchase elasticities to sales under an isoelastic nonhomothetic CES production function without fixed overhead costs, as in Hanoch (1975), Comin et al. (2021), and Matsuyama (2023). We show that such a production function allows

[11]Our specification of the production function mirrors the main analysis in De Loecker et al. (2020) where overhear costs are treated as a fixed input in production. However, they also consider an interpretation of the production function where overhead costs are included as a variable, dynamic factor of production. This interpretation requires observing overhead costs directly in the data. Our data do not allow us to do that.

labor costs and input purchases to respond non-proportionally to a change in sales induced by a permanent demand shock. However, it does so in a highly restrictive way: if one elasticity is lower than one, the other elasticity needs to be above one, which, we show in the next section, is at odds with our data. In contrast, our specification of the production function with flexible and fixed (labor and intermediate) input does not constrain the elasticities in such a way.

Adjustment costs. Our comparative statics assume that firms are shifted along their labor demand curves in response to the foreign demand shocks. A possible concern is that firms may face labor adjustment costs. In Appendix B.4, we add adjustments costs to the model. We consider two alternative types of labor adjustment costs: a quadratic adjustment cost, or labor adjustment à la Calvo (1983). In each case, the presence of adjustment costs would lead the firms to adjust inputs more slowly over time rather than immediately when the demand shock occurs. However, we show that fixed costs in labor can still be identified by examining whether labor costs in the long(er) run respond less than proportionally to the changes in sales induced by a permanent demand shock.

Motivated by this identification result, our empirical analysis will be centered around the changes in labor costs over the course of four years. Although we admittedly cannot rule out that the adjustment to shocks may take even longer, we do find that the firm responses to the foreign demand shocks changes relatively little after the first couple of years.

Modeling of the labor market. Our model treats Belgium as a single labor market in which each firm is faced with a homogeneous iso-elastic labor supply curve, resulting in a constant markdown of wages. As a result, the only wedge or distortion it creates is the firm's choice between labor and intermediate inputs in the production. In Appendix D.2, we consider an extension of the model where Belgium is no longer a single labor market, and markdowns are allowed to vary across markets. Therefore, imperfect competition could give misallocation of labor across firms, not only distort the choice between labor and intermediate inputs in the production.

Our model extension follows Lamadon et al. (2022) in letting the labor supply curve to differ across markets by extending the preference specification of the workers (from the current logit specification) to a nested logit. This structure allows the preferences of a given worker to be correlated across alternatives within each nest. In the empirical analysis, we specify the nest as the combination of industry and region, and refer to it as a market. We show how we can identify and estimate the market-specific parameter governing the degree of independence in a worker's taste for the alternative firms within a given market. Empirically, we find that our key findings are robust to this model extension.

As in Lamadon et al. (2022), our model extension assumes that each firm views itself as infinitesimal within the market. This assumption is motivated by the fact that very few firms in Belgium has a large share of the local labor market (as captured by our nests). Thus, optimizing firms would essentially ignore the negligible effect of changing their own wages on the overall supply of workers to the market as a whole. However, if labor markets were sufficiently segmented (geographically or by industry), it is possible that strategic interactions can play an important role (see, e.g., Berger et al., 2022). However, identification is difficult in models with strategic interactions in the wage-setting. Recent papers by Roussille and Scuderi (2024) and Sharma (2024) test for strategic interactions in wage-setting, but do not find evidence of such interaction.

Exogenous production network. Our model assumes the production network is exogenous in the sense that buyer-supplier links do not change in response to the foreign demand shock. Although this assumption is admittedly restrictive, allowing for endogenous networks would both complicate the model, and make identification of the key parameters very difficult.

The results from two recent papers suggests the assumption of exogenous networks may not be critical for the model counterfactuals we will consider in Section 6. One of these papers is our recent work that examines how endogenous production networks can alter the aggregate responses to foreign trade shocks (Dhyne et al., 2023a). Although the model in this paper does not nest the model in the current paper (since allowing for endogenous networks forces us to make other strong assumptions), our main finding is that the aggregate impact of foreign trade shocks through the changes in the network is quantitatively small, especially when looking at the magnitudes of foreign trade shocks that we consider in this paper.

The other paper is the recent work by Arkolakis et al. (2023) on the role of endogenous production networks. Their analysis suggests that the units of overhead costs that firms pay are critical for the first-order welfare effects. If firms' overhead costs are paid in terms of intermediate goods, the welfare effects of endogenous networks are quantitatively large, while if firms' overhead costs are paid in terms of labor units, the welfare effects of endogenous networks are quantitatively small. Our empirical finding that overhead costs are mostly paid in terms of labor units suggests that allowing for endogenous networks would have quantitatively small aggregate effects.

Alternative interpretation of pass-through to wages. In our model, we recover the labor supply curve from the pass-through of foreign demand shocks to employment and wages. An alternative interpretation of the pass-through to wages is that it reflects insurance that firms provide to their workers (see, e.g., Guiso et al., 2005). The basic argument is that it may be optimal for risk neutral firms to offer workers some insurance against idiosyncratic shocks to worker productivity. As a result, the firm may bear some of the costs of an idiosyncratic shock to worker productivity. However, the shocks we study are changes to the demand of the firm, not to the productivity of the worker. In a large class of frictionless labor market models (including ours), the workers only bear the risk of shocks to their own productivity. If the firm tried to pass on a demand shock, the worker would leave the firm and find a new employer.

There exist, however, models that would rationalize a risk-sharing interpretation of the estimated pass-through. For example, Balke and Lamadon (2022) develop a structural model with directed job search that offers a theoretical model for understanding the role of firm-level shocks for worker outcomes. A low pass-through of firm shocks would then suggests more insurance and risk sharing between workers and firms. The empirical relevance of risk sharing between workers and firms may vary depending on the way wages are set (see, e.g., Juhn et al., 2018) and the progressivity of the tax-transfer system (see, e.g., Balke and Lamadon, 2022).

No changes in markup. The comparative statics above hold the markups fixed. If one instead assumes that firms increase the markup on the goods that they sell in response to an increase in foreign demand, the elasticities of labor cost and input purchases would be lower than one, even in the absence of fixed costs. In this case, however, all elasticities would be uniformly lower than one, and there should be no differences between the elasticities of labor cost and total input purchases. The estimates we present in the next section are grossly at odds with this prediction.

4 Research design

The comparative statics of the model consider a change in the sales of a firm due to an exogenous change in the demand it faces. In the data, however, sales may change for many reasons other than demand, including shifts in input prices, technology, preferences, or amenities. To address this identification challenge, we now construct and critically examine an instrument that intends to isolate the variation in sales that is induced by a change in foreign demand.

Instrument for changes in firms' sales To obtain plausibly exogenous variation in each firm's foreign demand, we follow Hummels et al. (2014) and Dhyne et al. (2021) and take the weighted average of the changes in the world import demand for each firm. We denote the firm-level change from period $t-1$ to t in the world import demand by $\Delta_{t-1}^{t} \log X_{kF}^{shock}$, and construct this firm-level shock as below.[12]

$$\Delta_{t-1}^{t} \log X_{kF}^{shock} = \sum_{c,p} r_{k,c,p,t-1}^{\mathrm{EX}} \Delta_{t-1}^{t} \log WID_{c,p}, \tag{19}$$

where c denotes countries and p denotes products. We denote the lagged share of firm k's exports to country-product c, p in k's total exports with $r_{k,c,p,t-1}^{\mathrm{EX}}$. The term $WID_{c,p,t}$ represents country c's imports of product p from all other countries excluding Belgium. We define firm k's direct foreign demand shock on its total sales using the lagged export share, $r_{kF,t-1}\Delta_{t-1}^{t} \log X_{kF}^{shock}$. We further define the firm's total foreign demand shock, which includes its own direct foreign demand shock as well as takes into account the firm's indirect exposure to the direct foreign demand shocks through its buyers, as $\sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock}$. The term $\tilde{H}_{kn,t-1}$ captures the share of firm k's total sales that are purchased by firm n directly and indirectly through firm k's buyers and their buyers, and so on.[13]

Given this measure of total foreign demand shock, we can construct our first stage regression equation, which instruments the change in sales of a firm with its foreign demand shock:

$$\Delta_{t-1}^{t} \log X_k = \alpha + \beta_{Et} \sum_n \tilde{H}_{kn,t-1} r_{nH,t-1} + \beta \sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock} + \varphi_{k,t}. \tag{20}$$

The goal of this first-difference specification is to isolate plausibly exogenous, demand-driven variation in sales that we can use to identify the elasticities derived out above. The basic idea of our research design is to compare firms that get a large foreign demand shock (treatment group) to those that get a small or no foreign demand shock (control group), in a period before the shock and a period after the shock. Unobserved time-invariant heterogeneity across firms (e.g., in technology, amenities or input prices) is eliminated by looking at changes over time within firms. The inclusion of an intercept in the specification controls for changes over time in the firms' outcomes that are unrelated to the trade shock. In the absent of other control variables, the identifying assumption would be that these changes are common for the treatment and control groups.

To weaken the identifying assumption, we include several control variables. First of all, we include industry-year fixed effects and firm fixed-effects as controls in our specification. As a result, we allow for differential time trends in the outcomes of interest across firms

[12]By applying log, the changes we use are entirely coming from the intensive margin adjustments in the world import demand. Empirically, there are little changes over time at the extensive margin, and the combinations of importing countries and products that existed in the previous year account for around 92 percent of country-product pairs and 99 percent of the world import.

[13]The term $\tilde{H}_{kn,t-1}$ is defined as the k, n element of matrix $\tilde{H}_{t-1}$. The matrix $\tilde{H}_{t-1}$ is defined as $(I - R_{t-1})^{-1}$, which the k, n element of matrix R_{t-1} is the share of revenue of firm k that is sold to firm n, $r_{kn,t-1}$.

(linearly at the firm level and unrestricted at the industry level). The motivation for doing so is that the foreign demand shock to a firm might covary with underlying secular trends in or shocks to the firm's outcomes, such as in its use of factor inputs (e.g., because of changes to input prices facing the firm or from shifts in the workers' valuation of the firm's amenities). On top of this, the time-varying parameters β_{Et} capture changes in sales that reflect shifts in domestic household demand, as measured by $\sum_n \tilde{H}_{kn,t-1} r_{nH,t-1}$ where $r_{nH,t-1}$ is firm n's lagged revenue share to households.

Graphical evidence We now plot a set of estimates that allow us to visually inspect the pre-trends in that data and the timing of the responses to the foreign demand shocks.

To make these plots, we run a series of first-difference regressions. In these regressions, the dependent variable is the (percentage) change from year $t+\tau-1$ to year $t+\tau$ in the outcome of firm k (denoted generically by $\Delta_{t+\tau-1}^{t+\tau} \log W_k$). The regressor of interest is our instrument, the (percentage) change from year $t-1$ to t in the foreign demand the firm faces (as measured by the foreign demand shock, $\sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock}$). Our specification of the first difference regressions is given by

$$\Delta_{t+\tau-1}^{t+\tau} \log W_k = \alpha^\tau + \beta_{Et}^\tau \sum_n \tilde{H}_{kn,t-1} r_{nH,t-1} + \beta^\tau \sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock} + \varphi_{k,t}^\tau. \quad (21)$$

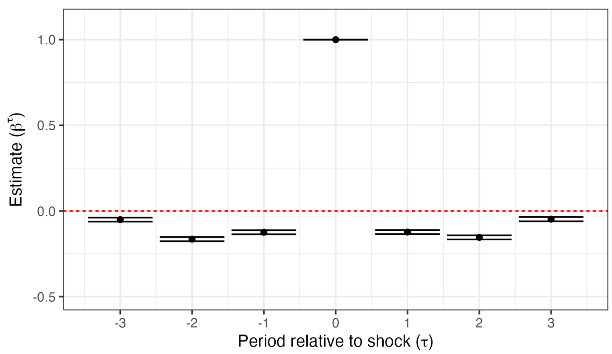
For each outcome variable we consider, we estimate this model separately for different choices of τ. The outcome is measured prior to the shock if $\tau \in \{-3, -2, -1\}$, at the same time as the shock if $\tau = 0$, and after the shock if $\tau \in \{1, 2, 3\}$. As explained above, all specifications control for industry-year fixed effects, firm fixed effects, and shifts in domestic household demand as measured by the share of firm k's sales that is (directly or indirectly) sold to domestic households in the previous year, $\sum_n \tilde{H}_{kn,t-1} r_{nH,t-1}$.

The first set of outcome variables we consider is the past and future values of the foreign demand shock. By doing so, we empirically examine the persistence of the foreign demand shocks (see, e.g., Campbell and Perron, 1991). In Figure 2, we report estimates (and 95 percent confidence intervals) of the coefficient β^τ for different choices of τ for this outcome.

By construction, the estimate for $\tau = 0$ is equal to one. The estimates for other values of τ can be small or large depending on the statistical dependence between the current foreign demand shock and past or future foreign demand shocks.[14] The results suggest that foreign demand shocks to a firm are weakly correlated over time. A firm that currently experiences a demand shock is not much more likely to have experienced a demand shock in the past or experience a demand shock in the future. In other words, the changes in the foreign demand

[14]The symmetry in the pre and post estimates is to be expected. The reason is that the covariance between the foreign demand shock in $t-1$ and t and the foreign demand shock in t and $t+1$ are necessarily the same (without other control variables) in a balanced panel.

Figure 2: Characterizing the foreign demand shock



Notes: This figure uses the main estimation sample of 995,739 firm-year observations in Belgium from 2002 to 2014 (see Section 2.3 for details). We run seven firm-level regressions based on equation (21) for τ from -3 to 3 with total foreign demand shock as the outcome variable. Total foreign demand shocks are defined in Section 4. This figure shows the point estimates as well as 95 percent confidence intervals. Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors are clustered at the NACE four-digit level. All specifications include industry-year fixed effects and firm fixed effects.

shocks over time are reasonably consistent with a unit root process. This suggests that we can infer lagged responses from regressions of future outcomes on current foreign demand shocks.

In Figure 3, we examine how the shocks to foreign demand affect a wide range of outcomes. For each outcome variable, this is done by plotting the estimate (and 95 percent confidence intervals) of the coefficient β^τ for different choices of τ. In panel (a), we focus on the outcome variable in the first stage regression of our IV model: total sales (which include sales to foreign markets as well as sales to domestic firms and households). This panel displays how past, current, and future total sales statistically depend on current foreign demand shocks.[15]

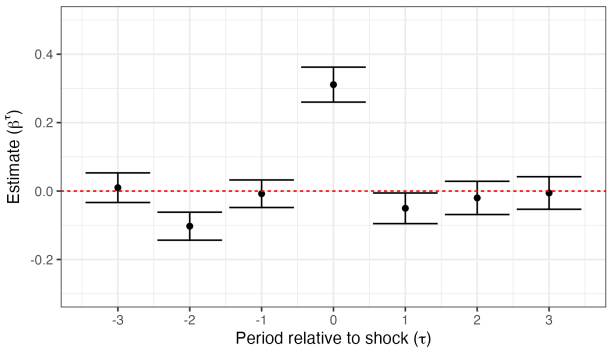
We find that an increase in the foreign demand facing a firm leads to an instantaneous, sharp and fairly persistent increase in its total annual sales. The point estimates suggest that if foreign demand increases by 10 percent, the firm's sales are expected to instantaneously (i.e., for $\tau = 0$) increase by 3.1 percent. Over time, the yearly increases in sales decline modestly. As of the fourth year after this shock (i.e., for $\tau = 3$), the cumulative increase in sales is approximately 2.4 percent. Thus, the cumulative or total impact on sales is about three-quarters of the immediate effect. If, for example, a foreign demand shock leads to a 10 percent instantaneous increase in sales, the firm's cumulative sales are expected to increase by 7.6 percent.

In panels (b)-(f) of Figure 3, we shift attention to outcomes other than total sales. For all outcomes, we find significant instantaneous impacts of the foreign demand shocks. The

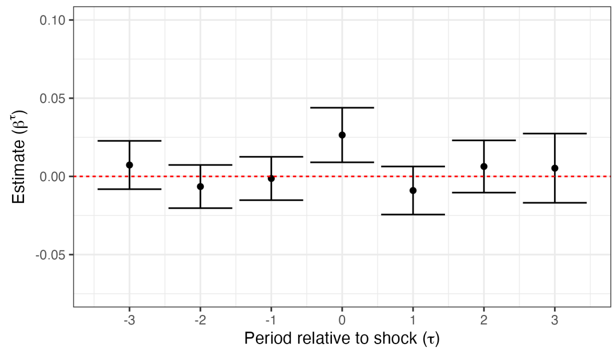
[15]In Appendix C.4, we examine directly how an increase in the world import demand changes the exports of direct exporters at the country-product level. The results suggest that idiosyncratic changes in the world import demand give rise to persistent and unanticipated increases in exports.

Figure 3: Examining the pre-trends in that data and the timing of the responses to the foreign demand shocks

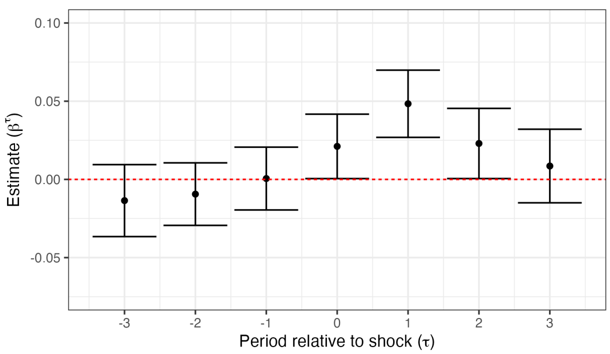
(a) LHS: total sales



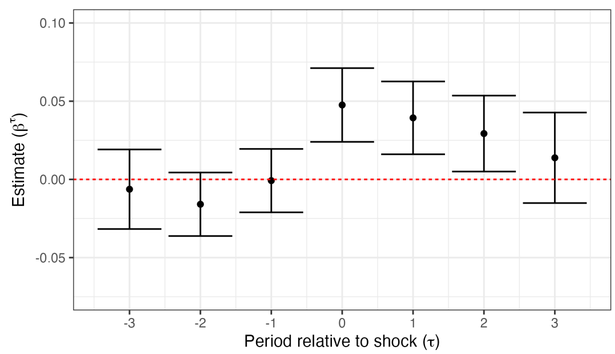
(b) LHS: average wage



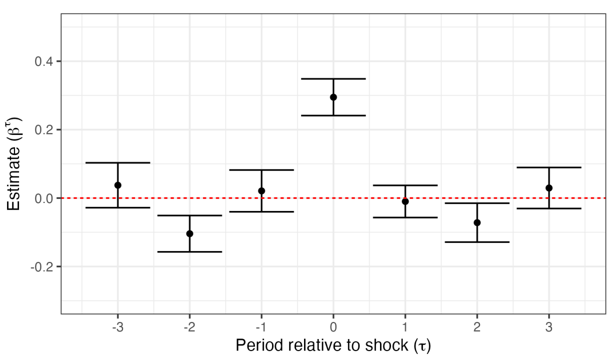
(c) LHS: FTE employment



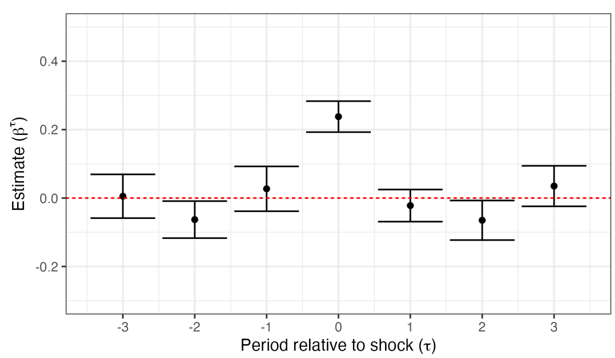
(d) LHS: labor cost



(e) LHS: input purchases



(f) LHS: domestic input purchases



Notes: The figures use the main estimation sample of 995,739 firm-year observations in Belgium from 2002 to 2014 (see Section 2.3 for details). For each panel, we run seven firm-level regressions based on equation (21) for τ from -3 to 3 and report the responses of the outcome variable to the total foreign demand shocks defined in Section 4. Each panel shows the point estimates as well as 95 percent confidence intervals. Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors are clustered at the NACE four-digit level. All specifications include industry-year fixed effects and firm fixed effects.

delayed or lagged responses, however, vary across outcomes. Our estimates suggest that both the wage a firm pays and its use of intermediate inputs (from either domestic sources or from abroad) increase instantaneously and persistently in response to a foreign demand shock. By comparison, employment and labor cost increase gradually over time, consistent with some form of adjustment costs. The yearly increases in these variables decline over time, and there is little if any additional growth as of the fourth year after the shock. Guided by these estimates, we will be measuring the total responses to the foreign demand shocks by cumulating the impacts over time for τ equal to 0 to 3.

5 Firm responses and worker impacts of changes in foreign demand

We begin our presentation of results with estimates of firm responses and worker impacts of changes in firm sales that are induced by changes in foreign demand. Next, we present estimates of the key parameters that govern these responses and impacts in the model described in Section 3.

5.1 Estimates of firm responses and worker impacts

We now present IV estimates of the impacts of the changes in firm sales that are induced by the foreign demand shocks. The first-stage regression of the IV model is given by equation (20), isolating the change in sales in the year after the foreign demand shock. The second stage estimates tell us how this exogenous change in sales impact workers and affect firm behavior along several dimensions, including subsequent sales as well as the use and cost of labor and intermediates inputs.

Using the same notation, we can express the second stage as a regression in first-differences of the outcome variable of interest, $\Delta_{t+\tau'}^{t+\tau} \log W_k$, on the total sales of the firm, $\Delta_{t-1}^{t} \log X_k$:

$$\Delta_{t+\tau'}^{t+\tau} \log W_k = \tilde{\alpha}^{\tau',\tau} + \gamma_{Et}^{\tau',\tau} \sum_n \tilde{H}_{kn,t-1} r_{nH,t-1} + \gamma^{\tau',\tau} \Delta_{t-1}^{t} \log X_k + \tilde{\varphi}_{k,t}^{\tau',\tau}. \tag{22}$$

As discussed in Section 4, we control for industry-year fixed effects, firm fixed effects, and shifts in domestic household demand as measured by the share of firm k's sales that is (directly or indirectly) sold to domestic households in the previous year, $\sum_i \tilde{H}_{ji,t-1} r_{iH,t-1}$. We estimate the IV model by two-stage least squares regressions separately for different combinations of (τ', τ), determining the choice of pre and post period in the first-difference specification. Standard errors are clustered at the NACE four-digit level.

The IV estimates are presented in Table 1. Guided by the graphical results in the previous section, we report both the instantaneous response ($\gamma^{-1,0}$) and the cumulative response, the sum of $\gamma^{-1,0}$, $\gamma^{0,1}$, $\gamma^{1,2}$, and $\gamma^{2,3}$. The cumulative responses are reported both for the full estimation sample of firms and for the balanced panel of firms that are observed in each consecutive year $t-1$ to $t+3$. The standard errors of the cumulative response are computed using the bootstrap method.[16]

The first column of Table 1 shows how the firm changes its sales over time in response to the instantaneous increase in sales that is induced by the foreign demand shocks. As we characterized in Section 4, the response of sales to the foreign demand shocks is fairly persistent. If sales increase by 10 percent instantaneously, the firm's cumulative sales over the course of four years increase by about 6.7 to 7.6 percent, depending on whether we consider the unbalanced panel (second row) or balanced panel (third row).

The second and third columns of Table 1 report the impacts on wages and employment of the instantaneous increase in sales that is induced by the foreign demand shocks. The point estimates in the first row suggest that if sales increase by 10 percent, the firm's average wage and employment are expected to instantaneously increase by 0.9 percent and 0.7 percent, respectively. Over time, the employment effects increase. As of the fourth year after the demand shock, cumulative impacts on employment are about 2.8 to 3.2 percent, depending on whether we consider the unbalanced panel or balanced panel.

The evidence that both wages and employment increase notably in response to the increase in sales that is induced by the foreign demand shock implies that labor costs also go up. The fourth column of Table 1 reports the estimated impacts on labor costs. These estimates suggest that if sales increase by 10 percent, the firm's labor costs are expected to instantaneously increase by 1.5 percent. Over time, labor costs continue to grow as the employment effects increase. Four years after the demand shock, the cumulative impact on labor costs are about 3.5 to 4.1 percent, depending on whether we consider the unbalanced or balanced panel.

The fifth column of Table 1 reports the impacts on total input purchases of the increase in sales that is induced by the foreign demand shocks. The estimates in the first row suggest that if, induced by a foreign demand shock, the initial increase in sales is 10 percent, the firm's total input purchases are expected to instantaneously increase by about 9.5 percent. Four years after the demand shock, the cumulative impacts on total input purchases are about 7.8 (7.0) percent in the full (balanced) sample of firms. Comparing these estimates with the last column of Table 1, we find that the cumulative impacts on domestic input

[16] The point estimates of the cumulative responses in the balanced sample are numerically equivalent to those of the long difference outcomes using $(\tau', \tau) = (-1, 3)$ (i.e., $\gamma^{-1,3}$). The bootstrapped standard errors of the cumulative responses are similar to the asymptotic standard errors of the long difference outcomes. We note that computing standard errors proposed by Adao et al. (2019) is infeasible because of the high-dimensionality of the exposure shares, $\tilde{H}$. See also footnote 44 of Adao et al. (2022).

Table 1: Worker impacts and firm responses to foreign-demand induced change in sales

	(1) Sales	(2) Average wage	(3) FTE Employment	(4) Labor cost	(5) Input purchases	(6) Domestic input purchases
Instantaneous response	1.000***	0.0850***	0.0679**	0.153***	0.946***	0.764***
($\gamma^{-1,0}$)		(0.0295)	(0.0322)	(0.0368)	(0.0770)	(0.0672)
Cumulative response	0.760***	0.0920**	0.320***	0.412***	0.781***	0.599***
($\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau}$, unbalanced)	(0.0755)	(0.0458)	(0.0544)	(0.0673)	(0.112)	(0.0986)
Cumulative response	0.668***	0.0725**	0.280***	0.353***	0.701***	0.534***
($\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau}$, balanced)	(0.0735)	(0.0365)	(0.0498)	(0.0547)	(0.105)	(0.0935)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table uses the main estimation sample of private-sector firms in Belgium from 2002 to 2014 (see Section 2.3 for details). For each outcome variable, we estimate its elasticity with respect to sales. We run four firm-level 2SLS regressions based on equation (22) for $\tau \in \{0, 1, 2, 3\}$ and $\tau' = \tau - 1$ and report the instantaneous response ($\gamma^{-1,0}$) as well as the cumulative response (the sum of four coefficients $\{\gamma^{\tau-1,\tau}\}_{\tau=0}^{3}$). In the third row, we use a balanced panel of firms that are observed for four consecutive years from $t-1$ to $t+3$. The first-stage F-statistics for excluded instruments is 142.3. Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors in parentheses are clustered at the NACE four-digit level, and standard errors of the cumulative responses are computed using the bootstrap method. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

purchases are relatively similar in magnitude: As of the fourth year after the demand shock, the cumulative impacts on domestic input purchases are about 6 (5.3) percent in the full (balanced) sample of firms. These findings suggest that firms pass on a large share of their foreign demand shocks to their domestic suppliers.[17]

5.2 Specification checks

We consider several specification checks to evaluate the sensitivity of the above estimates. These results from these specification checks are presented in Appendix C.5.

Our first robusness check investigates the sensitivity of our results to weighting each firm by the level of employment (as measured in year prior to the demand shock). By doing so, we assign more weights to larger firms. The IV estimates reported in Table 1 do not materially change when we use these weights.

Another possible concern with our baseline specification is that foreign demand shocks might be correlated with regional shocks that may directly affect both sales and input costs. To address this concern, we add location-year fixed effects. Location is measured using level 2 of the Eurostat NUTS classification. We find that the IV estimates reported in Table 1 barely change when we include these controls.

A related concern is that foreign demand shocks might be correlated with changes in import prices that may directly affect both sales and input costs. We test this empirically, finding that the correlation between firm-level import price changes and the firm-level foreign demand change, $\sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock}$, is close to zero.

Furthermore there is no significant correlation between firm-level foreign demand change and the firm-level input price changes computed for the sample of firms in Prodcom.

5.3 Elasticities and fixed overhead costs

The results in Table 1 empirically characterizes the worker impacts and firm responses to the foreign demand shock to sales. The model in Section 3 tells us how these estimates can be interpreted and connected through a set of elasticities and parameters governing labor supply and technology.

Labor supply curve facing the firm. The estimates in Table 1 suggest that a foreign-demand-driven increase in sales causes the firm to bid up wages to hire more workers. This finding is at odds with the textbook model in which the labor supply curve facing the firm

[17]The difference between the cumulative responses of manufacturing goods and service input purchases (see Section 5.3) can help explain the slight difference in the responses of total input purchases and domestic input purchases. Unlike imported inputs that are exclusively goods, domestic input purchases include service inputs, hence having a smaller response.

is perfectly elastic. Instead, it is consistent with the notion that firms face upward-sloping labor supply curves and, therefore, have wage-setting power in the labor market.

As shown in equation (17) of Section 3.2, it is possible to recover the magnitude of the labor supply elasticity from the results in Table 1. It is given by the ratio of IV estimates for wages to employment. This identification argument, however, requires that firms are shifted along their labor supply curve. A possible threat to identification is adjustment costs. Since our findings suggest that labor enters the firm slowly over time rather than immediately when the new wage is posted, the instantaneous impacts on wages and employment will understate the labor supply elasticity. Thus, we need to look at the cumulative responses to infer the labor supply elasticity. In the balanced sample of firms, we find a 0.7 percent cumulative increase in wages and a 2.8 percent cumulative increase in employment, which is consistent with firms facing a labor supply elasticity of about 3.9.[18]

To directly estimate the labor supply elasticity and perform statistical inference, it is useful to observe that (in a balanced sample) the ratio of IV estimates for wages to employment gives a numerically equivalent estimate of the labor supply elasticity as a standard labor supply regression of employment on wages with wages instrumented by the foreign demand shock. To be precise, consider the IV model with the reduced form equation

$$\Delta_{t-1}^{t+3} \log \ell_k = \hat{\alpha} + \hat{\beta}_{Et} \sum_n \tilde{H}_{kn,t-1} r_{nH,t-1} + \beta_L \sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock} + \hat{\varphi}_{k,t}, \quad (23)$$

and the first stage equation

$$\Delta_{t-1}^{t+3} \log w_k = \bar{\alpha} + \bar{\beta}_{Et} \sum_n \tilde{H}_{kn,t-1} r_{nH,t-1} + \beta_W \sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock} + \bar{\varphi}_{k,t}, \quad (24)$$

where $\Delta_{t-1}^{t+3} \log l_k$ and $\Delta_{t-1}^{t+3} \log w_k$ denote the log differences in firm k's employment and wage from $t-1$ to $t+3$, respectively, and $\sum_n \tilde{H}_{kn,t-1} r_{nF,t-1} \Delta_{t-1}^{t} \log X_{nF}^{shock}$ is our instrument, the foreign demand shock, as defined in Section 4. Both the first stage and the reduced form include the same set of controls as used in the analyses of worker impacts and firm responses in Table 1.

In Table 2, we present the estimates of the labor supply elasticity from the IV model of equations (23) and (24). This table also reports the estimates of wage markdown $(1/(1+\varepsilon))$ implied by the labor supply elasticity (ε). The wage markdown is the estimated by the same IV model as the labor supply elasticity, except the reduced form equation (23) is now a regression of wage on the foreign demand shock and the first stage equation (24) is now a regression of labor cost on foreign demand shock.

The first two columns Table 2 consider all the workers in our sample, while the last two

[18]The same calculations in the unbalanced sample gives a labor supply elasticity of 3.5.

Table 2: IV estimates of labor supply elasticity and markdown

	(1)	(2)	(3)	(4)
	Main estimation sample		Stayer subsample	
Panel A: IV estimates				
Labor supply elasticity (ε)	3.865		2.331***	
	(2.387)		(0.872)	
Markdown $\left(\frac{1}{1+\varepsilon}\right)$		0.206**		0.300***
		(0.101)		(0.0786)
Panel B: Reduced form				
Reduced form	0.0928***	0.0240*	0.108***	0.0462***
	(0.0176)	(0.0128)	(0.0264)	(0.0140)
Panel C: First stage				
First stage	0.0240*	0.117***	0.0462***	0.154***
	(0.0128)	(0.0184)	(0.0140)	(0.0308)
	[F=3.51]	[F=40.43]	[F=10.97]	[F=24.94]
Panel D: Test statistics				
p-value for perfect competition in the labor market	0.061	0.061	0.001	0.001
Number of observations	577,539	577,539	75,849	75,849
Industry-Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Notes: This table uses the main estimation sample as well as the subsample of firms for which we have additional information from the worker data (see Section 2.3 for details). We use a balanced panel of firms that are observed for four consecutive years from $t-1$ to $t+3$. In Columns (1) and (3), we run firm-level 2SLS regression based on equations (23) and (24) to estimate the labor supply elasticity. In Columns (2) and (4), we estimate the wage markdown by the same IV model as the labor supply elasticity, except the reduced form equation (23) is now a regression of wage on the foreign demand shock and the first stage equation (24) is now a regression of labor cost on foreign demand shock. The first-stage F-statistics for excluded instruments are reported in brackets in Panel C. In Panel D, we report the p-value for perfect competition in the labor market in each estimation sample, based on the closure method (see Appendix C.7 for details). Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors in parentheses are clustered at the NACE four-digit level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

columns restrict the sample to the incumbent workers who stay in the same firm before and after the foreign demand shock. An advantage of restricting the sample to incumbent workers is that it keeps the composition of the workforce fixed, and thus, we are not confounding increases in the wages paid to a given worker with changes in the quality of the workers.[19]

The point estimates from the full sample suggest a labor supply elasticity of about 3.9, and that wages in the Belgian economy are marked down around 21 percent relative to the marginal revenue product of labor. The point estimates from the stayer sample suggest even

[19]We report the IV estimates of the impact of changes in firm sales that are induced by the foreign demand shocks on the stayer subsample in Table 11 of Appendix C.6. We find that the wage increase of the incumbent workers in response to an increase in sales is similar to the impact for all workers. We also find that the estimated impact on hours of work is close to zero, suggesting that Belgian firms mostly adjust to demand shocks by hiring additional workers, not by increasing incumbent workers' hours of work.

stronger imperfect competition, with a labor supply elasticity of about 2.3 and a markdown of 30 percent. By comparison, perfect competition would imply a perfectly elastic labor supply elasticity and zero markdown of wages. Taken together, these results suggest that Belgian firms face upward-sloping labor supply curves, and, as a result, choose to substantially mark down wages.

Our estimate of the labor supply elasticity is broadly comparable to existing work from countries other than Belgium. Card et al. (2018) review this work and pick 4.0 as the preferred value in their calibration exercise. More recent evidence includes Lamadon et al. (2022), who estimate an average labor supply elasticity in the U.S. economy of 4.6, and Kroft et al. (2020), who estimate a labor supply elasticity in the U.S. construction sector of 4.2. By comparison, Huneeus et al. (2021) find labor supply elasticities that range from around 3 to 6 in Chile, and Chan et al. (2021) estimate the elasticity to be 5.7 in Denmark.

The reported standard errors in panel A of Table 2 suggest that both perfectly elastic labor supply and zero wage markdown are statistically unlikely. A possible caveat is that the first-stage F-statistic is relatively small in the first of the four columns. In this specification, one might therefore be concerned about a weak instrument problem. As shown by Angrist and Kolesár (2024), however, a weak instrument is unlikely to be too problematic in our case, because we have a single-variable just-identified 2SLS estimator and an estimated first-stage with the expected sign. Angrist and Kolesár (2024) show that in such cases the conventional 2SLS estimates and tests are compromised little by failures of the usual asymptotic theory due to weak instruments. The reported standard errors for the 2SLS estimates are therefore also likely to have good coverage.

In any case, our test for imperfect competition in Panel D of Table 2 is valid independently of whether the instrument is strong or weak. As explained in Appendix C.7, we here use the closure method to formally test whether we can reject perfect competition. Re-reassuringly, we can reject perfect competition in the full sample and the stayer sample at a significance level of 0.06 and 0.001 respectively.

Elasticity of labor costs and fixed overhead costs in labor inputs. Another key model parameter is the elasticity of labor costs with respect to a demand-driven change in sales. As shown in equation (15), the elasticity of labor costs is informative about the presence and importance of fixed overhead costs in labor inputs. In the absence of such costs, the elasticity would be equal to one in our model. If all labor is fixed, on the other hand, the elasticity would be zero.

As shown in equation (15) of Section 3.2, it is possible to recover the elasticity of labor cost from the results in Table 1. It is given by the ratio of the IV estimates for labor cost to sales. As for the labor supply elasticity, it is preferable to focus on the cumulative impacts to infer the elasticity of labor costs. The reason for doing so is that our comparative statics assume that firms are shifted along their labor demand curve. In the balanced sample of firms, we find a 3.5 percent cumulative increase in wages and a 6.7 percent cumulative increase in sales, which suggests a labor cost elasticity of 0.53.[20]

The labor supply elasticity can be directly estimated by the same IV model as the labor supply elasticity, except the reduced form equation (23) is now a regression of labor cost on the foreign demand shock and the first stage equation (24) is now a regression of sales on foreign demand shock. As shown in Table 3, this labor cost elasticity is fairly precisely estimated, with a point estimate of 0.53 and a standard error of 0.08. This finding suggests there is significant overhead costs in labor inputs.

Table 3: IV estimates of labor cost and input purchases elasticity

	(1) Labor cost	(2) Input purchases	(3) Domestic input purchases
Panel A: IV estimates			
Elasticity	0.528***	1.050***	0.799***
	(0.0848)	(0.150)	(0.147)
Panel B: Reduced form			
Reduced form	0.117***	0.232***	0.177***
	(0.0184)	(0.0359)	(0.0336)
Panel C: First stage			
First stage	0.221***	0.221***	0.221***
	(0.0283)	(0.0282)	(0.0282)
	[F=61.25]	[F=61.31]	[F=61.48]
Number of observations	577,539	575,282	575,259
Industry-Year FE	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes

Notes: This table uses the main estimation sample as well as the subsample of firms for which we have additional information from the worker data (see Section 2.3 for details). We use a balanced panel of firms that are observed for four consecutive years from $t-1$ to $t+3$. For each outcome variable, we run firm-level 2SLS regression to estimate its elasticity with respect to sales. The reduced form equation (23) is a regression of outcome variable on the foreign demand shock and the first stage equation (24) is a regression of sales on foreign demand shock. The first-stage F-statistics for excluded instruments are reported in brackets in Panel C. Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors in parentheses are clustered at the NACE four-digit level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Even if we know the average elasticity of labor costs, we do not necessarily know the share of labor costs that is fixed (on average or for any given firm). The reason is that our model allows for upward sloping labor supply curves, implying that the relationship between the labor cost elasticity and the fixed shares of labor inputs is nonlinear (see equation (15)). A special case in which one is easily able to recover the fixed share of labor cost is if the labor supply is perfectly elastic. In this case, the share of labor cost that, on average, is

[20] The same calculations in the unbalanced sample gives a labor cost elasticity of 0.54.

fixed would be pinned down directly by the estimated labor cost elasticity. If one imposes this restriction (which is admittedly at odds with the data) one would conclude that, on average, the fixed share of labor inputs is about 46 percent. This suggests the nonlinearities that arise because of the upward-sloping labor supply curves do not matter greatly for the estimates of the fixed shares of labor inputs.

The problem arising from the nonlinearities is resolved if one is willing to assume that the share of labor costs that is fixed homogeneous across firms. Under this restriction, we can plug our estimate of the labor cost elasticity into equation (15) and solve for the share of labor costs that is fixed. We then find that 53 percent of the firm's labor is fixed. As discussed later, this conclusion is robust to allowing for heterogeneity in the share of labor costs that is fixed between fixed across firms that trade internationally and those that do

Elasticity of input purchases and fixed overhead costs in labor inputs. The last key model parameter is the elasticity of input purchases with respect to a demand-driven change in sales. As shown in equation (16), the change in input purchases due to a demand-driven change in sales allows us to draw inferences about both the presence and importance of fixed overhead costs in intermediate inputs. In the absence of such costs, the elasticity would be equal to one in our model. If all intermediate inputs are fixed, on the other hand, the elasticity would be zero.

As shown in equation (16) of Section 3.2, it is possible to recover the elasticity of input purchases from the results in Table 1. It is given by the ratio of the IV estimates for total input purchases to sales. Since our comparative statics assume that firms are shifted along their input demand curve, it is preferable to focus on the cumulative impacts to infer the elasticity of input purchases. In the balanced sample of firms, we find a 7.0 percent cumulative increase in input purchases and a 6.7 percent cumulative increase in sales, which gives an implied elasticity of input purchases close to one.[21] In other words, the fixed share of intermediate inputs is roughly equal to zero.

The elasticity of input purchases can be directly estimated by the same IV model as the other elasticities, except the reduced form equation (23) is now a regression of total input purchases on the foreign demand shock and the first stage equation (24) is now a regression of sales on the foreign demand shock. As shown in Table 3, the elasticity of input purchases is then fairly precisely estimated, with a point estimate of 1.05 and a standard error of 0.15.

As shown in Figure 10 in Appendix C.8, the elasticities of input purchases, and thus, the fixed shares of intermediate inputs, vary systematically by the type of input. To reach this conclusion, we estimate the elasticities of (domestic and foreign) input purchases separately by the industry (as measured by the one-digit NACE code) of the firms' suppliers.

[21] The same calculations in the unbalanced sample also gives an elasticity of input purchases of approximately one.

Close to half of all input purchases in the Belgian economy come from the manufacturing industry (including imported manufactured goods). We find that purchases from this industry increase by nearly as much (6.1 percent) as the cumulative increase in total sales (6.7 percent). This suggests that the elasticity of input purchases from this industry is close to one. Thus, we conclude that inputs from the manufacturing industry are predominately variable and can be adjusted in response to demand shocks. In contrast, input purchases from the service industry (a combination of NACE G to N one-digit sectors) have a larger share of fixed inputs. We compute the size-weighted average of the cumulative responses of these service inputs and find that purchases from this industry increase by around 4.3 percent. This implies that these service inputs—which supply around 30 percent of total input purchases in Belgium—have a fixed input cost share of 36 percent.

Heterogeneity between exporters, importers, and domestic firms. If firms pay a fixed cost to export or import, total fixed costs are higher for firms that trade internationally, everything else equal. However, these firms are typically the more productive firms with larger output, so it is an empirical question whether the fixed *share* of costs are higher or lower.

To examine this, we estimate the elasticities of labor cost and input purchases separately for firms that internationally and those that do not. The results are presented in Appendix C.9. Empirically, we do not find support for systematic differences in these elasticities between exporters, importers, and domestic firms. This finding suggests that exporters and importers tend to have higher fixed costs — but comparable fixed share of costs – since these firms tend to be larger than domestic firms.

6 Aggregate effects of tariff shocks on wages

Our estimates of firm responses to foreign demand shocks suggest that Belgian firms both face upward-sloping firm-specific labor supply curves, and have sizable fixed overhead costs in labor. We now specify a general equilibrium model with these features to quantify the aggregate effects of simulated tariff shocks on wages.

Throughout this section, the foreign demand shock we consider is a five percent increase in foreign tariffs on all Belgian exports. We implement this shock by expressing it as a change in the foreign demand shifters, $\hat{D}_{kF} = 1.05^{-\sigma}$.[22]

[22] We denote the change in variable x, defined as the ratio of the post-shock value x' over the pre-shock value x, by $\hat{x}$.

6.1 Counterfactual economies

We consider several counterfactual economies, defined by alternative parameterizations of the model outlined in Section 3.

One of these economies is constructed to mirror the actual Belgian economy. We then use the estimates we obtained in Section 5, including the estimated value of the labor supply curve ($\varepsilon = 3.9$) and the estimated values of the fixed cost shares in labor inputs and input purchases. For the fixed cost shares of input purchases, we use the estimates for each NACE one-digit industry obtained in Appendix C.8. One of the alternative counterfactual economies is constructed by shutting down the fixed overhead costs. This is done by imposing the restriction $\bar{\ell}_k^f = \bar{q}_k^f = 0$, so all the inputs of firms are variable inputs, as is standard in previous work. In another counterfactual economy, we allow for fixed costs but shut down imperfect competition in the labor market. This economy is constructed by setting $\varepsilon = \infty$ so that the labor supply is perfectly elastic. The last counterfactual economy we consider has a perfectly competitive labor market and no fixed costs.

6.2 Parameterization and solution of the model

For each of the counterfactual economies, it is necessary to parameterize the model in order to calculate key variables and predict the impacts of the foreign demand shocks. Prior work on trade and production networks highlight the importance of holding key variables fixed to meaningfully compare results across counterfactual economies (see, e.g., Baqaee and Farhi, 2022). We therefore impose the restriction that certain firm-level observables (i.e., firms' total labor costs, imports, exports, and purchases from and sales to other domestic firms) are identical across the alternative parameterizations of the model and equal to what we observe in the data (in 2012, our reference year throughout this section).

To rationalize that different parameterizations of the model are producing identical firm-level observables, we let certain parameters vary across the counterfactual economies, including the firm-level productivity parameters, ϕ_k, the technology parameters, ω_{jk}^v, ω_{Fk}^v, ω_{jk}^f, and ω_{Fk}^f, and the workers' preference parameters, ν_{nk}. For each counterfactual economy, these parameters are assumed to be invariant to the foreign demand shock. With this assumption, we can solve for the counterfactual changes without recovering these underlying parameters by implementing the technique developed by Dekle et al. (2007). We solve for the counterfactual outcomes using the system of equations described in Appendix B.5.

We further parameterize the model as follows. We calculate the Belgian trade balance as the difference between exports and imports in our reference year, 2012. We hold the trade balance fixed throughout the counterfactual analyses. We set $\sigma = 4$, a common choice in the prior literature (see, e.g., Antras et al., 2017, Oberfield and Raval, 2021, and Dhyne et al., 2021). This choice implies that firms charge a common markup of $\frac{\sigma}{\sigma-1} = 1.33$ over marginal cost. Furthermore, the five percent increase in foreign tariffs is approximately equal to an 18 percent decline in the foreign demand shifters, $\hat{D}_{kF} = 1.05^{-\sigma}$.

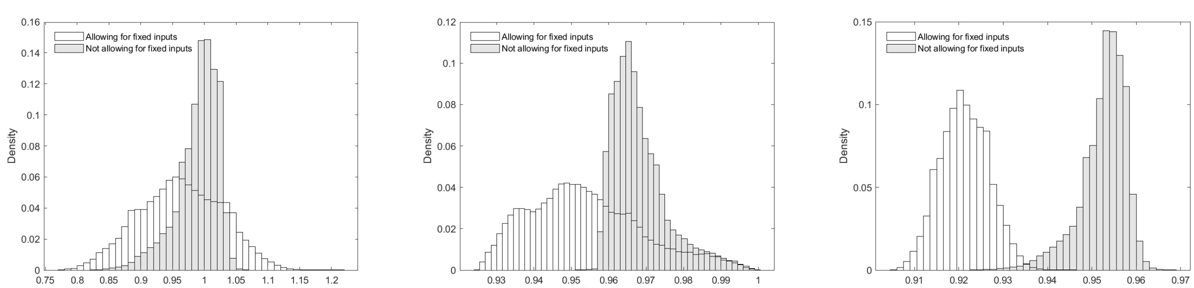
As shown in Appendix B.5, our parameterization of the model may create firm-level discrepancies between the variable input costs inferred from firms' sales and markups, $\left(\frac{\varepsilon}{\varepsilon+1}\alpha_{\ell k} + 1 - \alpha_{\ell k}\right)\frac{\sigma-1}{\sigma}p_k q_k$, and the variable input costs inferred from the estimated variable cost shares and observed input expenditures, $w_k \ell_k^v + \sum_j p_j q_{jk}^v + p_{Fk} q_{Fk}^v$. A possible reason for these discrepancies is the firms' usage of inventories, which we do not model. To deal with these discrepancies, we follow Dhyne et al. (2022) in imposing that the firm-level ratios of the two variable input costs are invariant to the foreign demand shock. A natural interpretation of this assumption is that the amount of inventory the firm uses (or accumulates) relative to its inputs and sales does not change in response to the foreign demand shocks.[23]

6.3 Impacts of foreign demand shocks in the actual economy

We begin by analyzing the impacts of the foreign demand shocks in our representation of the actual Belgian economy with firms that face fixed overhead costs and upward-sloping labor supply curves. The results are presented in the white bars in Figure 4. This figure shows the firm-level distributions of changes in output (panel (a)), marginal costs (panel (b)), and wages (panel (c)).

Figure 4: Firm-level distribution of changes in output, marginal costs, and wages in response to a 5 percent increase in foreign tariffs, with and without fixed inputs

(a) Output changes | (b) Marginal cost changes | (c) Nominal wage changes



Notes: The three panels in this figure show the distribution of the changes in firm-level variables due to a uniform 5 percent increase in foreign tariffs on Belgian exports. Panel (a) shows the distribution of firm-level output changes, $\hat{q}_k$, panel (b) shows the distribution of firm-level marginal cost changes, $\hat{c}_k$, and panel (c) shows the distribution of firm-level nominal wage changes, $\hat{w}_k$. In all panels, the white bars represent the distributions when one allows for fixed inputs, and the grey bars represent the distributions when one does not allow for fixed inputs. In this figure, we allow for imperfect competition in the labor market, $\varepsilon = 3.9$.

We find that most but not all firms decrease their output in response to the foreign

[23] In Appendix B.5.1, we show that this assumption is isomorphic to assuming that firm k charges a firm-specific markup of $\frac{p_k q_k}{w_k \ell_k^v + \sum_j p_j q_{jk}^v + p_{Fk} q_{Fk}^v}$.

demand shocks. The median firm reduces its output by 3.8 percent. The marginal costs of firms fall, with the median firm experiencing a cost reduction of 4.8 percent. Marginal costs fall primarily because the cost of labor decreases significantly for all firms. The median firm reduces its wage by 7.9 percent.

To interpret these results, it is important to observe that the foreign demand shocks have both direct and indirect effects. A reduction in foreign demand would directly reduce the output of the firms that sell directly or indirectly to foreign markets. This translates to a reduction in demand for both labor and intermediate inputs, thereby lowering the prices on these factors. Indirect equilibrium effects also influence how firms respond to and workers are affected by the foreign demand shock. Importantly, imports have to be reduced to ensure trade balance. The foreign price is exogenous and fixed, and the wage is the only price that can move to ensure trade balance. This decline in wages contributes to reducing marginal costs, increasing labor, and raising output, especially among firms that rely heavily on labor (instead of foreign inputs) in their production. Indeed, some of these firms experience an overall increase in output as a result of the foreign demand shock, as evident from the right tail of the distribution in panel (a) of Figure 4.

6.4 How fixed costs affect the impacts of foreign demand shocks

We now shift attention to how fixed overhead costs affect the propagation and implications of foreign demand shocks. To do so, Figure 4 compares the impacts of these shocks in our representation of the actual Belgian economy (white bars) to those we obtain in the counterfactual economy where firms face upward-sloping labor supply curves but no fixed costs in labor or intermediate goods (grey bars).

The results suggest that fixed overhead costs lead to foreign demand shocks having larger and more dispersed impacts on both output and marginal cost. In the economy without fixed overhead costs, the median firm reduces output by 0.3 percent and marginal costs by 3.4 percent. By comparison, output and marginal costs decline by 3.8 and 4.8 percent if one incorporates the fixed overhead costs. These differences are mirrored in the changes in nominal wages. Shutting down fixed costs attenuates the decline in the nominal wage of the median firms by over 3 percentage points (from 7.9 percent in the economy with fixed costs to 4.6 percent in the economy with no fixed costs).

Fixed overhead costs in labor amplify the consequences of foreign demand shocks because they make labor relatively less important for total variable costs.[24] Intuitively, when labor constitutes a smaller share of firms' variable costs, output prices become less sensitive to

[24]The flip side of this is that fixed overhead costs in labor would make foreign inputs relatively more important for firms' total variable costs. We show this empirically in Figure 11 of Appendix D.1, that (direct and indirect) imports make up a considerably larger share of the total variable costs when we take our estimates of fixed overhead costs into account.

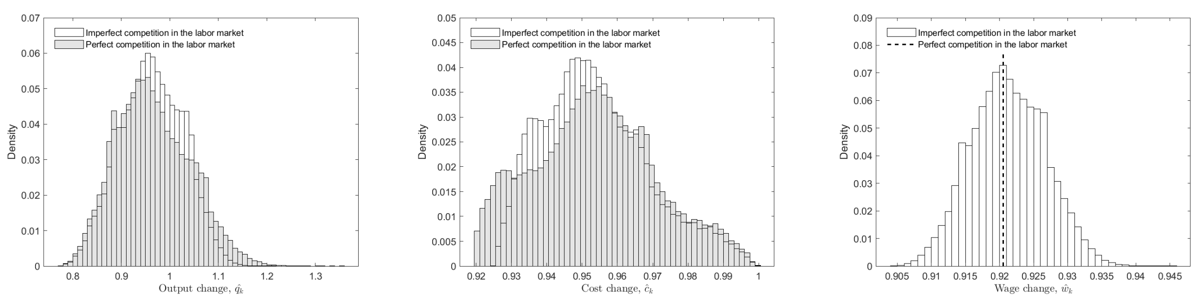
changes in wages. With the aggregate labor supply fixed, the economy responds to a negative demand shock by lowering prices through wage reductions, and to an increase in the foreign price by countering the price increase through lower wages. In both cases, wages have to decrease with larger magnitudes when fixed labor costs are taken into account.[25]

6.5 How imperfect competition in the labor market affects the impacts of foreign demand shocks

We now turn to an analysis of how imperfect competition in the labor market affects the propagation and implications of foreign demand shocks. To do so, Figure 5 compares the impacts of these shocks in our representation of the actual Belgian economy (white bars) to those we obtain in the counterfactual economy where firms face fixed costs in labor and intermediate goods and perfectly elastic labor supply curves (grey bars). This figure shows the firm-level distributions of changes in output (panel (a)), marginal costs (panel (b)), and nominal wages (panel (c)).

Figure 5: Firm-level distribution of changes in output, marginal costs, and wages in response to a 5 percent increase in foreign tariffs, with and without imperfect competition in the labor market

(a) Output changes (b) Marginal cost changes (c) Nominal wage changes



Notes: The three panels in this figure show the distribution of the changes in firm-level variables due to a uniform 5 percent increase in foreign tariffs on Belgian exports. Panel (a) shows the distribution of firm-level output changes, $\hat{q}_k$, panel (b) shows the distribution of firm-level marginal cost changes, $\hat{c}_k$, and panel (c) shows the distribution of firm-level wage changes, $\hat{w}_k$. In all panels, the white bars represent the distributions when one allows for imperfect competition in the labor market, and the grey bars represent the distributions when one assumes perfect competition in the labor market. Because all firms have common wages under perfect competition in the labor market, the corresponding wage change is depicted as a vertical line in panel (c). In the figure, we allow for fixed input costs in both labor inputs and input purchases.

In our model, introducing imperfect competition in the labor market can have impact on how firms organize production through creating distortions in firms' input composition between labor and input purchases. Distortions in firms' input composition attenuate firms'

[25]See Appendix B.6 for a stylized framework of aggregate labor supply and demand that illustrates this point.

responses to the foreign demand shock. This is because firms internalize the upward sloping labor supply curves and hence their quantity responses are attenuated given the same shift in demand. As can be seen in Panel (a) of Figure 5, firms expand and shrink with smaller magnitudes when they face upward sloping labor supply curves. The magnitude of this attenuation effect is an empirical question which depends on the estimates of the labor supply curve elasticity.

The results in Figure 5 suggest that imperfect competition in the labor market does not greatly change the impacts of the foreign demand shocks on output or marginal costs. These findings are mirrored in the changes in nominal wages. In the economy without imperfect competition in the labor market, the five percent increase in foreign tariffs on Belgian exports produces a 8.0 percent decline in the nominal wages of all firms. By comparison, nominal wages decline by 7.9 percent for the median firm if one incorporates that firms face upward-sloping labor supply curves. Taken together, these findings suggest that the essential feature to accurately predict the impacts of the foreign tariff is fixed overhead costs, not imperfect competition in the labor market.

A natural question is whether this quantitative implication is robust to other specifications of imperfect competition in the labor market. In Appendix D.2 we follow Lamadon et al. (2022) and consider a nested logit structure in worker preference. This extension is useful as Belgium is no longer a single labor market, it allows markdowns to vary across markets, and, importantly, we can still prove identification of the parameters. Empirically, we find that incorporating multiple labor markets and potentially heterogeneous markdowns on wages do not quantitatively alter the aggregate counterfactual predictions in response to foreign demand shocks.

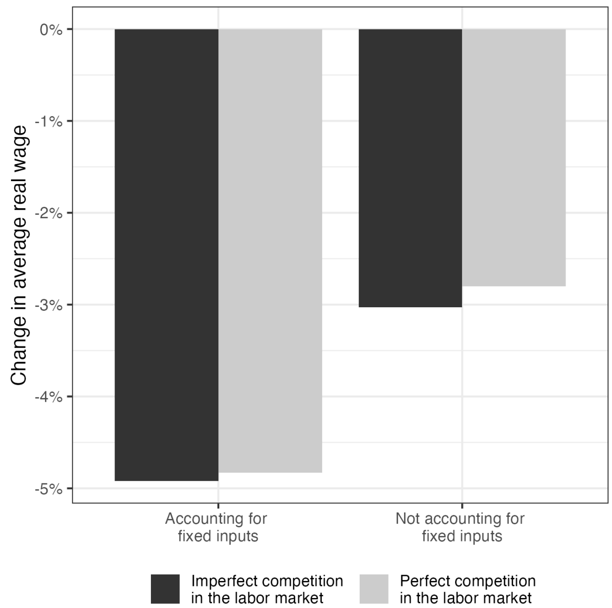
6.6 Implications for real wages

We conclude the analysis of foreign demand shocks by studying how the implications for *real* wages vary across the counterfactual economics. The results are reported in Figure 6. For each counterfactual economy, this figure presents our estimate of how the increase in foreign tariffs on Belgian exports would affect the average real wage, $\sum_k \frac{w_k \ell_k}{\sum_j w_j \ell_j} \hat{w}_k \hat{\ell}_k / \hat{P}$.[26]

The reduction in real wages is largest in our representation of the actual Belgian economy with firms that face fixed overhead costs and upward sloping labor supply curves. In this economy, the five percent increase in foreign tariffs on Belgian exports produces a 4.9 percent fall in the average real wage. In the counterfactual economy with fixed costs and

[26] In Appendix D.3, we report the same set of results for the changes in real income, $\hat{E}/\hat{P}$, which captures not only the impacts on wages and consumer prices but also the effects on profits. The results are qualitatively the same. However, the quantitative impacts are larger, reflecting the negative effects of foreign tariffs on firms' profits. Note that because of the lack of free entry and positive profits, the results on welfare are different from that of Arkolakis et al. (2012)

Figure 6: Changes in average real wage in response to a 5 percent increase in foreign tariffs



Notes: In this figure, we report the changes in average real wage, $\sum_k \frac{w_k \ell_k}{\sum_j w_j \ell_j} \hat{w}_k \hat{\ell}_k / \hat{P}$, due to a uniform 5 percent increase in foreign tariffs on Belgian exports. Each bar represents the responses under different parameterizations of the model presented in Section 3. We use our estimated labor supply elasticity $\varepsilon = 3.9$ in the counterfactual Belgian economies with upward-sloping labor supply curves. When accounting for fixed inputs, we use the fraction of fixed inputs for both labor and intermediate inputs (at NACE one-digit level) that we obtained in Section 5.

perfectly elastic labor supply, this increase in foreign tariffs results in a 4.8 percent fall in the average real wage. By comparison, the average real wage declines only by 3.0 percent in the counterfactual economy with no fixed costs and upward-sloping labor supply curves, and by 2.8 percent with perfectly elastic labor supply.

It is worth examining the magnitude of these substantial welfare effects. With a foreign demand shock equivalent to a 5 percent increase in import prices (per the Lerner Symmetry Theorem), one might expect the decline in real wages to be capped at 5 percent times the share of imports in Belgian GDP (close to 100 percent), assuming expenditure shifts toward domestic firms and Belgian wages rise. However, it should be noted that nominal wages may *decline* in response to an increase in import prices. Due to the nested Cobb-Douglas-CES structure in production, the demand exporters face is relatively elastic compared to the demand for imports. Additionally, as foreign inputs are extensively used in Belgian exports, domestic nominal wages decrease to maintain trade balance.

Taken together, these findings show that the essential feature to accurately predict the impacts of foreign tariffs on the real wages of Belgian workers is fixed overhead costs, not imperfect competition in the labor market. Furthermore, our results suggest that the way the labor market is typically modeled in existing research on foreign demand shocks—with no fixed costs and perfectly elastic labor supply—may grossly understate the decline in real wages due to an increase in foreign tariffs.

6.7 Shocks to variables other than foreign demand

While our paper is centered around foreign demand shocks, the presence of fixed costs and imperfect competition could also have important implications for the analyses of other types of shocks. In Appendix D.4, we explore this by considering the propagation and implications of domestic productivity shocks, $\left\{\hat{\phi}_k\right\}$.

The analyses in this appendix closely follow the analyses in Subsections 6.3-6.6, except that we now replace the foreign demand shocks with a uniform 5 percent reduction in the productivity of all manufacturing firms. The results echo the key insights from our analyses of the foreign demand shocks. Fixed overhead costs and, to a lesser extent, imperfect competition in the labor market matter considerably for the predicted impacts of domestic productivity shocks.

7 Conclusion

The goal of our paper was to quantify and explain the firm responses and worker impacts of foreign demand shocks to domestic production networks. To capture that firms can be indirectly exposed to such shocks by buying from or selling to domestic firms that import or export, we used Belgian data with information on both domestic firm-to-firm sales and foreign trade transactions. Our estimates of firm responses suggest that Belgian firms pass on a large share of a foreign demand shock to their domestic suppliers, face upward-sloping labor supply curves, and have sizable fixed overhead costs in labor.

Motivated and guided by these findings, we developed and estimated an equilibrium model that allows us study how idiosyncratic and aggregate changes in foreign demand propagate through a small open economy and affect firms and workers. Our results suggest that the way in which the labor market is typically modeled in existing research on foreign demand shocks—with no fixed costs and perfectly elastic labor supply—would grossly understate the decline in real wages due to an increase in foreign tariffs. When interpreting these results, it is useful to observe that our model is parsimonious and restrictive in several ways. For example, we take all buyer-supplier relationships as given, in terms of both the domestic firm-to-firm links and the firms' direct export and import participation. Furthermore, we do not model firm entry and exit. Such adjustments could be especially important if one studies larger foreign demand shocks.

References

Abowd, J. M., F. Kramarz, and D. N. Margolis (1999): "High Wage Workers and High Wage Firms," Econometrica, 67, 251–333.

Acemoglu, D. and A. Tahbaz-Salehi (2020): "Firms, Failures, and Fluctuations: The Macroeconomics of Supply Chain Disruptions," Working Paper 27565, National Bureau of Economic Research.

Adao, R., P. Carrillo, A. Costinot, D. Donaldson, and D. Pomeranz (2020): "International Trade and Earnings Inequality: A New Factor Content Approach," Working Paper 28263, National Bureau of Economic Research.

——— (2022): "Imports, exports, and earnings inequality: Measures of exposure and estimates of incidence," The Quarterly Journal of Economics, 137, 1553–1614.

Adao, R., M. Kolesár, and E. Morales (2019): "Shift-share designs: Theory and inference," The Quarterly Journal of Economics, 134, 1949–2010.

Alfaro-Urena, A., I. Manelici, and J. P. Vasquez (2019): "The Effects of Multinationals on Workers: Evidence from Costa Rica," Working paper.

Almunia, M., P. Antras, D. Lopez-Rodriguez, and E. Morales (2021): "Venting Out: Exporters during a Domestic Slump," American Economics Review, 111, 3611–3662.

Amiti, M., O. Itskhoki, and J. Konings (2019): "International Shocks, Variable Markups and Domestic Prices," Review of Economic Studies.

Angrist, J. and M. Kolesár (2024): "One instrument to rule them all: The bias and coverage of just-ID IV," Journal of Econometrics, 240, 105398.

Antras, P., T. C. Fort, and F. Tintelnot (2017): "The Margins of Global Sourcing: Theory and Evidence from U.S. Firms," American Economic Review, 107, 2514 – 64.

Arkolakis, C., A. Costinot, and A. Rodríguez-Clare (2012): "New Trade Models, Same Old Gains?" American Economic Review, 102, 94–130.

Arkolakis, C., F. Huneeus, and Y. Miyauchi (2023): "Spatial Production Networks," Working paper.

Atalay, E. (2017): "How Important Are Sectoral Shocks?" American Economic Journal: Macroeconomics, 9, 254–80.

Autor, D., D. Dorn, L. F. Katz, C. Patterson, and J. Van Reenen (2020): "The fall of the labor share and the rise of superstar firms," The Quarterly Journal of Economics, 135, 645–709.

Autor, D. H., D. Dorn, and G. H. Hanson (2013): "The China Syndrome: Local Labor Market Effects of Import Competition in the United States," American Economic Review, 103, 2121–2168.

Autor, D. H., D. Dorn, G. H. Hanson, and J. Song (2014): "Trade Adjustment: Worker-Level Evidence," The Quarterly Journal of Economics, 129, 1799–1860.

Balke, N. and T. Lamadon (2022): "Productivity Shocks, Long-Term Contracts, and Earnings Dynamics," American Economic Review, 112, 2139–77.

Baqaee, D., A. Burstein, C. Duprez, and E. Farhi (2023): "Supplier Churn and Growth: A Micro-to-Macro Analysis," Working Paper 31231, National Bureau of Economic Research.

Baqaee, D. and E. Farhi (2022): "Networks, Barriers, and Trade," Working Paper 26108, National Bureau of Economic Research.

Baqaee, D. R. and E. Farhi (2019a): "The Macroeconomic Impact of Microeconomic Shocks: Beyond Hulten's Theorem," Econometrica, 87, 1155–1203.

——— (2019b): "Productivity and Misallocation in General Equilibrium," The Quarterly Journal of Economics, 135, 105–163.

——— (2020): "Entry vs. Rents: Aggregation with Economies of Scale," Working Paper 27140, National Bureau of Economic Research.

Bartelsman, E., J. Haltiwanger, and S. Scarpetta (2013): "Cross-country differences in productivity: The role of allocation and selection," American Economic Review, 103, 305–334.

Berger, D., K. Herkenhoff, and S. Mongey (2022): "Labor Market Power," American Economic Review, 112, 1147–93.

Bigio, S. and J. La'O (2020): "Distortions in Production Networks," The Quarterly Journal of Economics, 135.

Calvo, G. A. (1983): "Staggered prices in a utility-maximizing framework," Journal of Monetary Economics, 12, 383–398.

Campbell, J. Y. and P. Perron (1991): Pitfalls and Opportunities: What Macroeconomists Should Know about Unit Roots, MIT Press, 141–220.

Card, D., A. R. Cardoso, J. Heining, and P. Kline (2018): "Firms and labor market inequality: Evidence and some theory," Journal of Labor Economics, 36, S13–S70.

Chan, M., S. Salgado, and M. Xu (2021): "Heterogeneous Passthrough from TFP to Wages," Working paper.

Chen, K.-M., C. Ding, J. A. List, and M. Mogstad (2020): "Reservation Wages and Workers' Valuation of Job Flexibility: Evidence from a Natural Field Experiment," Working Paper 27807, National Bureau of Economic Research.

Comin, D., D. Lashkari, and M. Mestieri (2021): "Structural Change With Long-Run Income and Price Effects," Econometrica, 89, 311–374.

Costinot, A., M. Sarvimaki, and J. Vogel (2022): "Exposure(s) to Trade and Earnings Dynamics: Evidence from the Collapse of Finnish-Soviet Trade," Working paper.

De Loecker, J., J. Eeckhout, and G. Unger (2020): "The Rise of Market Power and the Macroeconomic Implications," Quarterly Journal of Economics, 135, 561–644.

De Loecker, J., C. Fuss, and J. Van Biesebroeck (2014): "International competition and firm performance : Evidence from Belgium," NBB Working Paper Series, 269.

Dekle, R., J. Eaton, and S. Kortum (2007): "Unbalanced Trade," American Economic Review Papers & Proceedings, 97, 351–355.

Demir, B., A. C. Fieler, D. Y. Xu, and K. K. Yang (2024): "O-Ring Production Networks," Journal of Political Economy, 132, 200–247.

Dhyne, E., A. K. Kikkawa, X. Kong, M. Mogstad, and F. Tintelnot (2023a): "Endogenous production networks with fixed costs," Journal of International Economics, 145, 103841.

Dhyne, E., A. K. Kikkawa, and G. Magerman (2022): "Imperfect Competition in Firm-to-Firm Trade," Journal of the European Economic Association.

Dhyne, E., A. K. Kikkawa, M. Mogstad, and F. Tintelnot (2021): "Trade and Domestic Production Networks," The Review of Economic Studies, 88, 643–668.

——— (2023b): "Measuring the Share of Imports in Final Consumption," AEA Papers and Proceedings, 113, 81–86.

Dhyne, E., G. Magerman, and S. Rubinova (2015): "The Belgian production network 2002-2012," NBB Working Paper Series, 288.

Dix-Carneiro, R. (2014): "Trade Liberalization and Labor Market Dynamics," Econometrica, 82, 825–885.

Dix-Carneiro, R. and B. K. Kovak (2017): "Trade Liberalization and Regional Dynamics," American Economic Review, 107, 2908–46.

Duprez, C. and G. Magerman (2018): "Price updating in production networks," NBB Working Paper Series.

——— (2022): "Correspondences of EU product classifications," Tech. rep.

Ederhof, M., V. Nagar, and M. Rajan (2021): "How Economically Significant Are Unused Capacity Costs? A Large-Scale Empirical Analysis," Management Science, 67, 1956–1974.

Egger, H., P. Egger, U. Kreickemeier, and C. Moser (2020): "The exporter wage premium when firms and workers are heterogeneous," European Economic Review, 130, 103599.

Elliott, M., B. Golub, and M. Leduc (2021): "Supply Network Formation and Fragility," Working paper.

Felix, M. (2021): "Trade, Labor Market Concentration, and Wages," Working paper.

Frías, J. A., D. S. Kaplan, E. Verhoogen, and D. Alfaro-Serrano (2024): "Exports and Wage Premiums: Evidence from Mexican Employer-Employee Data," Review of Economics and Statistics, 1–17.

Friedrich, B., L. Laun, C. Meghir, and L. Pistaferri (2019): "Earnings Dynamics and Firm-Level Shocks," Working Paper 25786, National Bureau of Economic Research.

Gagliardone, L., M. Gertler, S. Lenzu, and J. Tielens (2023): "Anatomy of the Phillips Curve: Micro Evidence and Macro Implications," Working Paper 31382, National Bureau of Economic Research.

Galle, S., A. Rodríguez-Clare, and M. Yi (2022): "Slicing the Pie: Quantifying the Aggregate and Distributional Effects of Trade," The Review of Economic Studies, rdac020.

Garin, A. and F. Silvério (2023): "How Responsive Are Wages to Firm-Specific Changes in Labour Demand? Evidence from Idiosyncratic Export Demand Shocks," Review of Economic Studies, rdad069.

Gibbons, R., L. F. Katz, T. Lemieux, and D. Parent (2005): "Comparative Advantage, Learning, and Sectoral Wage Determination," Journal of Labor Economics, 23, 681–724.

Guiso, L., L. Pistaferri, and F. Schivardi (2005): "Insurance within the Firm," Journal of Political Economy, 113, 1054–1087.

Gutiérrez, A. (2022): "Labor market power and the pro-competitive gains from trade," Working Paper.

Hamermesh, D. S. (1999): "Changing Inequality in Markets for Workplace Amenities," The Quarterly Journal of Economics, 114, 1085–1123.

Hanoch, G. (1975): "Production and Demand Models with Direct or Indirect Implicit Additivity," Econometrica, 43, 395–419.

Helpman, E., O. Itskhoki, M.-A. Muendler, and S. J. Redding (2016): "Trade and inequality: From theory to estimation," The Review of Economic Studies, 84, 357–405.

Howell, S. T. and J. D. Brown (2020): "Do Cash Windfalls Affect Wages? Evidence from R&D Grants to Small Firms," Working Paper 26717, National Bureau of Economic Research.

Hummels, D., R. Jørgensen, J. Munch, and C. Xiang (2014): "The Wage Effects of Offshoring : Evidence from Danish Matched Worker-Firm Data," American Economic Review, 104, 1597–1629.

Huneeus, F. (2018): "Production network dynamics and the propagation of shocks," Working paper.

Huneeus, F., K. Kroft, and K. Lim (2021): "Earnings Inequality in Production Networks," Working Paper 28424, National Bureau of Economic Research.

Irarrazabal, A., A. Moxnes, and K. H. Ulltveit-Moe (2013): "Heterogeneous Firms or Heterogeneous Workers? Implications for Exporter Premiums and the Gains from Trade," The Review of Economics and Statistics, 95, 839–849.

Juhn, C., K. McCue, H. Monti, and B. Pierce (2018): "Firm Performance and the Volatility of Worker Earnings," Journal of Labor Economics, 36, S99–S131.

Kim, R. and J. Vogel (2020): "Trade and Welfare (Across Local Labor Markets)," Working Paper 27133, National Bureau of Economic Research.

——— (2021): "Trade Shocks and Labor Market Adjustment," American Economic Review: Insights, 3, 115–30.

Klenow, P. J. and H. Li (2024): "Entry Costs Rise with Growth," Working Paper 32974, National Bureau of Economic Research.

Kline, P., N. Petkova, H. Williams, and O. Zidar (2019): "Who Profits from Patents? Rent-Sharing at Innovative Firms," The Quarterly Journal of Economics, 134, 1343–1404.

Kovak, B. K. (2013): "Regional Effects of Trade Reform: What Is the Correct Measure of Liberalization?" American Economic Review, 103, 1960–76.

Kroft, K., Y. Luo, M. Mogstad, and B. Setzler (2020): "Imperfect Competition and Rents in Labor and Product Markets: The Case of the Construction Industry," Working Paper 27325, National Bureau of Economic Research.

Lamadon, T., M. Mogstad, and B. Setzler (2022): "Imperfect Competition, Compensating Differentials, and Rent Sharing in the US Labor Market," American Economic Review, 112, 169–212.

Lim, K. (2018): "Endogenous Production Networks and the Business Cycle," Working paper.

MacKenzie, G. (2021): "Trade and market power in product and labor markets," Tech. rep., Bank of Canada Staff Working Paper.

Maestas, N., K. J. Mullen, D. Powell, T. von Wachter, and J. B. Wenger (2018): "The Value of Working Conditions in the United States and Implications for the Structure of Wages," Working Paper 25204, National Bureau of Economic Research.

Marcus, R., E. Peritz, and K. R. Gabriel (1976): "On Closed Testing Procedures with Special Reference to Ordered Analysis of Variance," Biometrika, 63, 655.

Mas, A. and A. Pallais (2017): "Valuing Alternative Work Arrangements," American Economic Review, 107, 3722–3759.

Matsuyama, K. (2023): "Non-CES Aggregators: A Guided Tour," Annual Review of Economics, 15, 235–265.

Oberfield, E. (2018): "A Theory of Input-Output Architecture," Econometrica, 86, 559–589.

Oberfield, E. and D. Raval (2021): "Micro Data and Macro Technology," Econometrica, 89, 703–732.

Pierce, B. (2001): "Compensation Inequality," The Quarterly Journal of Economics, 116, 1493–1525.

Pierce, J. R. and P. K. Schott (2016): "The Surprisingly Swift Decline of US Manufacturing Employment," American Economic Review, 106, 1632–62.

Romano, J. P., A. Shaikh, and M. Wolf (2011): "Consonance and the Closure Method in Multiple Testing," The International Journal of Biostatistics, 7, 1–25.

Rosen, S. (1986): "Chapter 12 The theory of equalizing differences," Elsevier, vol. 1 of Handbook of Labor Economics, 641–692.

Roussille, N. and B. Scuderi (2024): "Bidding for Talent: A Test of Conduct in a High-Wage Labor Market," Working paper.

Sharma, G. (2024): "Collusion Among Employers in India," Working paper.

Taschereau-Dumouchel, M. (2018): "Cascades and Fluctuations in an Economy with an Endogenous Production Network," Working paper.

Traiberman, S. (2019): "Occupations and import competition: Evidence from Denmark," American Economic Review, 109, 4260–4301.

Traina, J. (2018): "Is Aggregate Market Power Increasing? Production Trends Using Financial Statements," Working paper.

Van Reenen, J. (1996): "The Creation and Capture of Rents: Wages and Innovation in a Panel of U.K. Companies," The Quarterly Journal of Economics, 111, 195–226.

vom Lehn, C. and T. Winberry (2021): "The Investment Network, Sectoral Comovement, and the Changing U.S. Business Cycle," The Quarterly Journal of Economics, 137, 387–433.

Wiswall, M. and B. Zafar (2018): "Preference for the Workplace, Investment in Human Capital, and Gender," The Quarterly Journal of Economics, 133, 457–507.

Wooldridge, J. M. (2009): "On estimating firm-level production functions using proxy variables to control for unobservables," Economics Letters, 104, 112–114.

A Data appendix

A.1 Aggregating VAT identifiers into firms

As discussed in the main text, the NBB datasets are available at the level of VAT identifiers. In order to conduct our analyses at the firm level, we aggregate multiple VAT identifiers into the firm identifiers, using the same procedure as in Dhyne et al. (2021). We leverage the information from ownership filings in the annual accounts as well as the Balance of Payments survey to determine if a pair of VAT identifiers belongs to the same firm. We aggregate multiple VAT identifiers to the same firm if they are linked with at least 50 percent of ownership or if they share the same foreign parent firm that holds at least 50 percent of their shares. In order to determine the foreign parent firm of a given VAT identifier, we apply a "fuzzy string matching" method, comparing all possible pairs of foreign firms' names. Lastly, we correct for potential misreporting by linking the pair of VAT identifiers that are linked one year before and one year after.

After collecting multiple VAT identifiers that belong to the same firm, we then assign their firm identifier using the "most representative" VAT identifiers among them. The criteria for selecting such "head VAT" identifiers are explained in detail in Appendix C.4 of Dhyne et al. (2021). Once we determine the head VAT identifiers for all firms that have multiple VAT identifiers, we then sum up all the variables across VAT identifiers to the firm level. In order to avoid the double counting of transactions within the firm, we further adjust total sales and inputs by the amount of B2B sales between the pair of VAT identifiers that belong to the same head VAT identifier. For other variables such as firms' age, their primary industry, and location of their main economic activities, we take those of head VAT identifiers.

A.2 Merging NBB datasets with BCSS datasets

The BCSS datasets are available at the level of Banque Carrefour des Entreprises (Crossroads Bank for Enterprises, BCE) identifiers. All businesses in Belgium are required to register with the BCE, which assigns them the unique identifiers upon registration. Registration with the BCE is required for firms to pay VAT, so the BCE identifiers can be easily converted to VAT identifiers. In order to match the BCSS datasets with the NBB datasets, we first convert all BCE identifiers to VAT identifiers and then aggregate multiple VAT identifiers into firms, as explained in Appendix A.1.

A.3 Coverage and summary statistics on the merged sample

Table 4 reports the coverage of our main estimation sample (NBB sample) in 2012 and compares it to the official aggregate statistics obtained from Eurostat. Our sample covers a large majority of the aggregate value added, gross output, labor costs, exports, and imports in the Belgian economy. We also report the coverage of the subsample of firms for which we have additional information from the worker data (merged NBB-BCSS sample for the firms with 10 or more FTE employees at least once from 2002 to 2014), which still makes up most of the total sales, inputs, and trade in the Belgian economy.

Table 4: Coverage of NBB and NBB-BCSS datasets in 2012

	Eurostat
GDP (excl. Gov.&Fin.)	248
Output (excl. Gov.&Fin.)	672
Import	310
Export	311

	NBB sample	NBB-BCSS sample
Count:		
Total	98,745	26,470
Direct exporters	11,892	7,024
Indirect exporters	74,529	18,043
Value added	164	145
Total sales	796	704
Network sales	225	190
Import	292	279
Export	292	281
Labor cost	100	90
Employment (FTE)	1,824,066	1,578,505

Notes: All numbers except for count and employment are denominated in billion euro in current prices. Belgian GDP and output are for all sectors excluding the public and financial sectors. Data for Belgian GDP, output, imports, and exports are from Eurostat. Firms' value added is from the reported values from the annual accounts. Firms' sales consist of their sales to other firms in the NBB sample (network sales), sales to households at home, and direct exports to foreign markets.

Using our main estimation sample, we also present the (direct and total) export participation and shares of firms that directly export to those that only export indirectly, building on the work of Dhyne et al. (2021). This finding motivates why our model and analysis will include indirect export through the production network to measure the firms' exposure to foreign demand.

To arrive at this conclusion, we first construct measures of the firms' total export. As in Dhyne et al. (2021), we assume the firm's composition of inputs in production does not vary across its buyers, so that we can measure the total export of a firm by the total share of output that it sells directly or indirectly to foreign markets (i.e., the total export share). Formally, the total export share of firm k, r_{kF}^{Total}, is defined as the share of revenue from direct export, r_{kF}, and the share of revenue coming from sales to other domestic firms, multiplied by the total export shares of those firms:

$$r_{kF}^{Total} = r_{kF} + \sum_{i \in W_k} r_{ki} r_{iF}^{Total}, \tag{25}$$

where W_k denotes the set of buyers of firm k, and r_{kF} and r_{ki} are the share of k's revenue that comes from direct export and from sales to domestic firm i, respectively. The denominator of the export shares is the total revenue of the firm, which consists of sales to other domestic firms, sales to households, and direct exports.

It is important to observe that the definition of the total export share is recursive. A firm's total export share is the sum of its direct export share and the share of its sales to other domestic firms multiplied by the total export shares of those firms. Thus, the total export share is high if a lot of the firm's output is exported directly to foreign markets or indirectly via sales to domestic buyers with high export shares.

Table 5: Descriptive statistics in 2012

(a) Direct and total export participation

	Exporters and non-exporters	Exporters only	Non-exporters only
Number of observations	98,745	11,892	86,853
Fraction of firms with total export participation	0.875	1.000	0.858
Average export shares:			
Total export	0.138	0.445	0.096
Direct export	0.039	0.322	0.000
Indirect export	0.100	0.122	0.096

(b) Firm characteristics

	Exporters and non-exporters	Exporters only	Non-exporters only
Log sales	13.6	15.5	13.3
Log TFP	10.7	11.3	10.6
Log value added	12.5	13.9	12.3
Log FTE employment	1.5	2.5	1.3
Log average wage	10.5	10.8	10.5

Notes: This table uses the main estimation sample of private-sector firms in Belgium in 2012 (see Section 2.3 for details). Panel (a): The total export share of firm k, r_{kF}^{Total}, is recursively defined as $r_{kF}^{Total} = r_{kF} + \sum_{i \in W_k} r_{ki} r_{iF}^{Total}$, which can be decomposed into direct export share, r_{kF}, and indirect export share, $\sum_{i \in W_k} r_{ki} r_{iF}^{Total}$. Panel (b): For each column, we report the averages of variables listed on the left for a set of firms noted at the top of the column. Firms' sales consist of their sales to other firms in the NBB sample (network sales), sales to households at home, and direct exports to foreign markets. Firms' TFPs are calculated using the estimation procedure of Wooldridge (2009). Firms' value added and FTE employment are from the reported values from the annual accounts. Firms' average wages are the reported labor costs divided by their FTE employment.

In panel (a) of Table 5, we compare the (direct and total) export participation and shares of firms that directly export to those that only export indirectly. While few Belgian firms are directly exporting, a majority of the firms are indirectly exporting through sales to domestic buyers that subsequently trade internationally. In fact, even the firms that do not directly export are, on average, selling nearly 10 percent of their output indirectly to foreign markets.

B Model appendix

B.1 General equilibrium of the model in Section 3.1

We characterize the firm-level outcomes implied by the firms' profit maximization and cost minimization problem. First, the sum of the variable and fixed costs of firm k can be written as

$$\begin{aligned} TC_k =& \phi_k^{-1} \frac{\frac{1+\varepsilon}{\varepsilon}\left(1-\alpha_{\ell k}\right)+\alpha_{\ell k}}{\left(\frac{1+\varepsilon}{\varepsilon}\left(1-\alpha_{\ell k}\right)\right)^{1-\alpha_{\ell k}} \alpha_{\ell k}^{\alpha_{\ell k}}} \left(\sum_{j \in Z_k} \left(\omega_{jk}^v\right)^\sigma p_j^{1-\sigma} + \left(\omega_{Fk}^v\right)^\sigma p_{Fk}^{1-\sigma}\right)^{\frac{1-\alpha_{\ell k}}{1-\sigma}} w_k^{\alpha_{\ell k}} q_k \\ &+ \left(\sum_{j \in Z_k} \left(\omega_{jk}^f\right)^\sigma p_j^{1-\sigma} + \left(\omega_{Fk}^f\right)^\sigma p_{Fk}^{1-\sigma}\right)^{\frac{1}{1-\sigma}} \bar{q}_k^f \\ &+ w_k \bar{\ell}_k^f, \end{aligned} \tag{26}$$

where the first term represents the variable costs, the second term represents the fixed input purchases, and the last term represents the fixed labor costs. Note that firms face a common demand elasticity of σ regardless of whom they sell to; hence,

$$p_k = \mu_k c_k = \frac{\sigma}{\sigma - 1} c_k. \tag{27}$$

Taking the total derivative of the total cost with respect to output quantity, one can derive the firm's marginal cost,

$$c_k = \frac{1}{\phi_k \alpha_{\ell k}^{\alpha_{\ell k}} \left(1-\alpha_{\ell k}\right)^{1-\alpha_{\ell k}}} \left(\sum_{j \in Z_k} \left(\omega_{jk}^v\right)^\sigma p_j^{1-\sigma} + \left(\omega_{Fk}^v\right)^\sigma p_{Fk}^{1-\sigma}\right)^{\frac{1-\alpha_{\ell k}}{1-\sigma}} \left(\frac{1+\varepsilon}{\varepsilon} w_k\right)^{\alpha_{\ell k}}. \tag{28}$$

The marginal cost follows the standard structure except that the firm's wage enters the cost with a wedge of $\frac{1+\varepsilon}{\varepsilon}$. One can then derive the total variable input cost of the firm—the first term in equation (26)—in terms of its sales $p_k q_k$, by substituting in equations (27) and (28):

$$w_k \ell_k^v + \sum_j p_j q_{jk}^v + p_{Fk} q_{Fk}^v = \left(\frac{\varepsilon_m}{\varepsilon_m + 1} \alpha_{\ell k} + 1 - \alpha_{\ell k}\right) \frac{\sigma - 1}{\sigma} p_k q_k. \tag{29}$$

The firm's variable labor input share out of its variable cost, $s_{\ell k}^v$, is a constant but lower than the Cobb-Douglas parameter $\alpha_{\ell k}$ as a result of the upward sloping labor supply curve:

$$s_{\ell k}^v = \frac{\frac{\varepsilon}{1+\varepsilon} \alpha_{\ell k}}{1 - \alpha_{\ell k} + \frac{\varepsilon}{1+\varepsilon} \alpha_{\ell k}}. \tag{30}$$

The share of variable inputs from firm j out of firm k's variable cost, s_{jk}^v, can be expressed as the share of variable input purchases times the share of firm j's goods out of the variable input purchases:

$$s_{jk}^{v}=\frac{1-\alpha_{\ell k}}{1-\alpha_{\ell k}+\frac{\varepsilon}{1+\varepsilon}\alpha_{\ell k}}\frac{\left(\omega_{jk}^{v}\right)^{\sigma}p_{j}^{1-\sigma}}{\sum_{j\in Z_{k}}\left(\omega_{jk}^{v}\right)^{\sigma}p_{j}^{1-\sigma}+\left(\omega_{Fk}^{v}\right)^{\sigma}p_{Fk}^{1-\sigma}}. \tag{31}$$

Analogously, the share of variable imports in variable cost is expressed as

$$s_{Fk}^{v}=\frac{1-\alpha_{\ell k}}{1-\alpha_{\ell k}+\frac{\varepsilon}{1+\varepsilon}\alpha_{\ell k}}\frac{\left(\omega_{Fk}^{v}\right)^{\sigma}p_{Fk}^{1-\sigma}}{\sum_{j\in Z_{k}}\left(\omega_{jk}^{v}\right)^{\sigma}p_{j}^{1-\sigma}+\left(\omega_{Fk}^{v}\right)^{\sigma}p_{Fk}^{1-\sigma}}. \tag{32}$$

Similar to the variable input purchases, one can write firm j's share and import share in firm k's total purchases of fixed intermediate inputs as follows:

$$s_{jk}^{f}=\frac{\left(\omega_{jk}^{f}\right)^{\sigma}p_{j}^{1-\sigma}}{\sum_{j\in Z_{k}}\left(\omega_{jk}^{f}\right)^{\sigma}p_{j}^{1-\sigma}+\left(\omega_{Fk}^{f}\right)^{\sigma}p_{Fk}^{1-\sigma}} \tag{33}$$

$$s_{Fk}^{f}=\frac{\left(\omega_{Fk}^{f}\right)^{\sigma}p_{Fk}^{1-\sigma}}{\sum_{j\in Z_{k}}\left(\omega_{jk}^{f}\right)^{\sigma}p_{j}^{1-\sigma}+\left(\omega_{Fk}^{f}\right)^{\sigma}p_{Fk}^{1-\sigma}}. \tag{34}$$

Firm-level sales consist of the sum of domestic sales to other firms as either variable or fixed inputs, domestic sales to domestic final demand, and exports. Therefore, we have the following equation for firm k's sales:

$$p_{k}q_{k}=\sum_{i\in W_{k}}s_{ki}^{v}\frac{p_{i}q_{i}}{\mu_{i}}+\sum_{i\in W_{k}}s_{ki}^{f}c_{i}^{f}\bar{q}_{i}^{f}+s_{kH}E_{H}+p_{k}^{1-\sigma}D_{kF}, \tag{35}$$

where W_k is the set of firm k's domestic buyers and

$$s_{kH}=\frac{\beta_{kH}^{\sigma-1}p_{k}^{1-\sigma}}{\sum_{j}\beta_{jH}^{\sigma-1}p_{j}^{1-\sigma}} \tag{36}$$

is firm k's share in household expenditure.

We close the model by assuming that all variable profits generated by firms are transferred back to households. We obtain the following expression for aggregate household income:

$$E_{H}=\sum_{k}w_{k}\ell_{k}^{v}+\sum_{k}\frac{\mu_{k}-1}{\mu_{k}}p_{k}q_{k}-\sum_{j}\sum_{k}p_{j}q_{jk}^{f}-\sum_{k}p_{Fk}q_{Fk}^{f}-TB, \tag{37}$$

where TB is the aggregate trade balance. Labor market clearing implies that firms' labor demand equals the total labor supply in each labor market:

$$L_m = \sum_k \frac{1}{w_k} s^v_{\ell k} \frac{p_k q_k}{\mu_k} + \sum_k \bar{\ell}^f_k. \tag{38}$$

Definition 1 (Equilibrium) *Given the set of price of imports p_{Fk}, foreign demand shifters D_{kF}, aggregate trade balance TB, aggregate labor supply L, firms' domestic supplier sets Z_k and their importing and exporting decisions, and firms' fixed overhead input requirements $\bar{q}^f_k$ and $\bar{\ell}^f_k$, an equilibrium is the firms' wages, $\{w_k\}$, and the aggregate expenditure, E_H, such that equations* (5)–(7), (11)–(13), *and* (27)–(38) *hold.*

B.2 Derivations of equations (15) and (16)

To obtain equation (15), we take the total derivative of equation (10) while holding supply-side technology parameters fixed. From equation (10), the right-hand side of which is constant, we have

$$d \log \ell^v_k w_k(\ell_k) = d \log p_k q_k \left(\ell^v_k, \left\{q^v_{jk}\right\}, q^v_{Fk}\right).$$

Further rearranging the above using equation (8), we obtain

$$\begin{aligned} d \log \ell_k w_k(\ell_k) + d \log \left(1 - \frac{\bar{\ell}^f_k}{\ell_k}\right) &= d \log p_k q_k \left(\ell^v_k, \left\{q^v_{jk}\right\}, q^v_{Fk}\right) \\ d \log \ell_k w_k(\ell_k) + \frac{\bar{\ell}^f_k}{\ell^v_k} d \log \ell_k &= d \log p_k q_k \left(\ell^v_k, \left\{q^v_{jk}\right\}, q^v_{Fk}\right). \end{aligned}$$

We know from the labor supply curve of equation (5) that

$$\begin{aligned} d \log \ell_k &= \varepsilon d \log w_k \\ &= \frac{\varepsilon}{1+\varepsilon} d \log w_k \ell_k. \end{aligned}$$

Plugging this in, we have

$$\left(1 + \frac{\bar{\ell}^f_k}{\ell^v_k} \frac{\varepsilon}{1+\varepsilon}\right) d \log w_k \ell_k = d \log p_k q_k \left(\ell^v_k, \left\{q^v_{jk}\right\}, q^v_{Fk}\right),$$

and hence

$$\frac{d \log w_k \ell_k}{d \log p_k q_k \left(\ell^v_k, \left\{q^v_{jk}\right\}, q^v_{Fk}\right)} = \frac{\ell^v_k}{\ell_k} \frac{1+\varepsilon}{\frac{\ell^v_k}{\ell_k} + \varepsilon}.$$

We take a similar approach in deriving equation (16). The output elasticity in equation (14) can be written as

$$\frac{\partial \log q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)}{\partial \log q_{jk}^v} = \left(1 - \alpha_{\ell k}\right) \omega_{jk}^v \left(\frac{q_{jk}^v}{q_k^v}\right)^{\frac{\sigma-1}{\sigma}},$$

where q_k^v is the CES bundle of variable intermediate inputs. The term $\frac{q_{jk}^v}{q_k^v}$ depends only on the relative prices of firm k's suppliers, which we assume to be constant. Then one can write the total derivative of equation (14) as

$$d \log p_j q_{jk}^v = d \log p_k q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right).$$

Further rearranging using equation (8), we obtain

$$d \log p_j q_{jk} + d \log \left(1 - \frac{q_{jk}^f}{q_{jk}}\right) = d \log p_k q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right).$$

The fixed input purchases from firm j are given by equation (12) and only depend on the prices of firm j and the prices of other suppliers of firm k, which are all taken as fixed. Hence, one can further rearrange and obtain the following:

$$\begin{aligned} d \log p_j q_{jk} + \frac{q_{jk}^f}{q_{jk}^v} d \log q_{jk} &= d \log p_k q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right) \\ \frac{d \log p_j q_{jk}}{d \log p_k q_k \left(\ell_k^v, \left\{q_{jk}^v\right\}, q_{Fk}^v\right)} &= \frac{q_{jk}^v}{q_{jk}}. \end{aligned}$$

B.3 Non-homothetic production function

We explore how labor cost and input purchases move with sales, when one assumes non-homotheticity in production functions but with no fixed costs in production. We consider a common class of non-homothetic production function—isoelastic nonhomothetic CES production function—following Hanoch (1975), Comin et al. (2021), Matsuyama (2023), and others. With this non-homothetic production function, we illustrate how labor cost and input purchases respond to sales changes. We investigate whether the model can rationalize the empirical pattern observed in the data: the labor cost elasticity to sales is below one and the input purchase elasticity to sales is close to one. We find that under this setup, whenever the labor cost elasticity to sales is less than one, the input purchase elasticity to sales should be larger than one. This leads to our conclusion that a non-homothetic production function is not sufficient to explain our main empirical findings.

To ease exposition and to build basic intuition, we first characterize the elasticities by assuming that firms take as given the prices of labor and input purchases. We then illustrate how the results change once one incorporates upward sloping labor supply curve. As in the main text, firm k uses labor ℓ_k^v and input purchases q_k^v for production. We assume that the production function takes the following implicit form:

$$1 = \left(\beta_\ell^{\frac{1}{\sigma}} q_k^{\frac{\epsilon_\ell-\sigma}{\sigma}} \left(\ell_k^v\right)^{\frac{\sigma-1}{\sigma}} + \beta_n^{\frac{1}{\sigma}} q_k^{\frac{\epsilon_n-\sigma}{\sigma}} \left(q_k^v\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}},$$

where the two non-homotheticity parameters ϵ_ℓ and ϵ_n are related to the elasticity of input usage with respect to output, as we will show below. The input with a larger value of this non-homotheticity parameter requires less amount of input to achieve an increase in output. And as the firm grows, the firm shifts its input usage towards the input with a larger non-homotheticity parameter. Because we consider a case in which the labor cost elasticity to sales is less than one, we assume throughout that $\epsilon_\ell < \epsilon_n$. On the output side, we assume that firms face a demand elasticity of $\sigma > 1$ and charge a constant markup of $\frac{\sigma}{\sigma-1}$. Moreover, we assume $\frac{\epsilon_\ell-\sigma}{1-\sigma} > 0$ and $\frac{\epsilon_n-\sigma}{1-\sigma} > 0$ to ensure global monotonicity where the input expenditure is increasing in the output quantity (as we show below), which effectively creates an upper bound on the two parameters, $0 < \epsilon_\ell < \epsilon_n < \sigma$.

B.3.1 Price taking firms

We first assume that firms take as given input prices, w_k and p_k^I. The cost minimization problem of the firm gives the firm's average cost index, c_k, of

$$c_k = \left(\beta_\ell q_k^{\epsilon_\ell-1} w_k^{1-\sigma} + \beta_n q_k^{\epsilon_n-1} \left(p_k^I\right)^{1-\sigma}\right)^{\frac{1}{1-\sigma}},$$

with expenditure shares of

$$\begin{aligned} s_{\ell k} =& \frac{\beta_\ell w_k^{1-\sigma} \left(E_k/c_k\right)^{\epsilon_\ell-1}}{c_k^{1-\sigma}} \\ s_{Ik} =& \frac{\beta_n \left(p_k^I\right)^{1-\sigma} \left(E_k/c_k\right)^{\epsilon_n-1}}{c_k^{1-\sigma}}. \end{aligned}$$

The firm's expenditure on inputs can be written as $E_k = q_k c_k$ and demand for inputs can be expressed as

$$\begin{aligned} \ell_k^v =& \beta_\ell \frac{w_k^{-\sigma}}{c_k^{1-\sigma}} q_k^{\epsilon_\ell-1} E_k = \beta_\ell \frac{w_k^{-\sigma}}{c_k^{-\sigma} q_k^{-\sigma}} q_k^{\epsilon_\ell-\sigma} \\ q_k^v =& \beta_n \frac{\left(p_k^I\right)^{-\sigma}}{c_k^{1-\sigma}} q_k^{\epsilon_n-1} E_k = \beta_n \frac{\left(p_k^I\right)^{-\sigma}}{c_k^{-\sigma} q_k^{-\sigma}} q_k^{\epsilon_n-\sigma}. \end{aligned}$$

From the average cost index, we have the following relationship between output quantity and average cost,

$$\frac{d\ln c_k}{d\ln q_k} = \frac{\bar{\epsilon}_k - 1}{1-\sigma},$$

where $\bar{\epsilon}_k$ is the weighted average of the two non-homotheticity parameters, $\bar{\epsilon}_k = \epsilon_\ell s_{\ell k} + \epsilon_n s_{Ik}$. The firm's marginal cost can be expressed as

$$\begin{aligned} MC_k =& \frac{dE_k}{dq_k} = \left(1 + \frac{d\ln c_k}{d\ln q_k}\right)\frac{E_k}{q_k} \\ =& \frac{\bar{\epsilon}_k - \sigma}{1-\sigma} c_k, \end{aligned}$$

with

$$\frac{d\ln E_k}{d\ln q_k} = \frac{\bar{\epsilon}_k - \sigma}{1-\sigma}.$$

The output price is the markup times the marginal cost,

$$p_k = \frac{\sigma}{\sigma-1} MC_k.$$

Putting these together, the relationship between expenditure and sales can be written as

$$E_k = c_k q_k = \frac{\sigma-1}{\sigma}\frac{1-\sigma}{\bar{\epsilon}_k - \sigma} p_k q_k.$$

Using the above, we derive the following elasticities of input usage with respect to a sales change:

$$\begin{aligned} \frac{d\ln w_k \ell_k^v}{d\ln p_k q_k} &= \underbrace{\left(\sigma - (\sigma-1)\frac{\sigma-\epsilon_\ell}{\sigma-\bar{\epsilon}_k}\right)}_{\frac{d\ln w_k \ell_k^v}{d\ln E_k}} \frac{d\ln E_k}{d\ln p_k q_k} \\ \frac{d\ln p_k^I q_k^v}{d\ln p_k q_k} &= \underbrace{\left(\sigma - (\sigma-1)\frac{\sigma-\epsilon_n}{\sigma-\bar{\epsilon}_k}\right)}_{\frac{d\ln p_k^I q_k^v}{d\ln E_k}} \frac{d\ln E_k}{d\ln p_k q_k}. \end{aligned} \tag{39}$$

Equation (39) implies that when $\epsilon_\ell < \epsilon_n$, the elasticity of labor cost to expenditure, $\frac{d\ln w_k \ell_k^v}{d\ln E_k}$, is less than one while the elasticity of purchases to expenditure, $\frac{d\ln p_k^I q_k^v}{d\ln E_k}$, is larger than one. To reconcile with our main empirical results where the labor cost elasticity to sales is less than one and the input purchase elasticity to sales is close to one, one would need the expenditure elasticity to sales, $\frac{d\ln E_k}{d\ln p_k q_k}$, to be less than one.

We first write this expenditure elasticity to sales as

$$\begin{aligned}\frac{d\ln E_k}{d\ln p_k q_k} &= \frac{d\ln \frac{\sigma-1}{\sigma}\frac{1-\sigma}{\bar{\epsilon}_k-\sigma}p_k q_k}{d\ln p_k q_k} \\ &= 1+\frac{\bar{\epsilon}_k}{\sigma-\bar{\epsilon}_k}\frac{d\ln \bar{\epsilon}_k}{d\ln p_k q_k}.\end{aligned}$$

As seen from above, how the expenditure changes in response to a change in sales can be summarized by how the average non-homotheticity parameter, $\bar{\epsilon}_k$, changes with sales. Recall that the non-homotheticity parameters govern how input expenditures respond to scale. And if $\bar{\epsilon}_k$ increases with scale, then the firm's overall expenditure will be less responsive when it scales up. One can show that

$$\frac{d\ln \bar{\epsilon}_k}{d\ln q_k} = \frac{\epsilon_\ell}{\bar{\epsilon}_k}\epsilon_\ell s_{\ell k} + \frac{\epsilon_n}{\bar{\epsilon}_k}\epsilon_n s_{Ik} - \bar{\epsilon}_k > 0,$$

meaning that as the firm scales up, it uses more inputs with higher non-homotheticity parameter, and hence $\bar{\epsilon}_k$ increases. Using this we derive the elasticity $\frac{d\ln \bar{\epsilon}_k}{d\ln p_k q_k}$ to find:

$$\frac{d\ln \bar{\epsilon}_k}{d\ln p_k q_k} = \underbrace{\left(\frac{\epsilon_\ell}{\bar{\epsilon}_k}\epsilon_\ell s_{\ell k} + \frac{\epsilon_n}{\bar{\epsilon}_k}\epsilon_n s_{Ik} - \bar{\epsilon}_k\right)}_{\frac{d\ln \bar{\epsilon}_k}{d\ln q_k}} \underbrace{\frac{\sigma-1}{\sigma-\bar{\epsilon}_k}}_{\frac{d\ln q_k}{d\ln E_k}>0} \frac{d\ln E_k}{d\ln p_k q_k},$$

and therefore $\frac{d\ln E_k}{d\ln p_k q_k}$ to be larger than one:

$$\frac{d\ln E_k}{d\ln p_k q_k} = \frac{1}{1-\frac{\bar{\epsilon}_k}{\sigma-\bar{\epsilon}_k}\left(\frac{\epsilon_\ell}{\bar{\epsilon}_k}\epsilon_\ell s_{\ell k} + \frac{\epsilon_n}{\bar{\epsilon}_k}\epsilon_n s_{Ik} - \bar{\epsilon}_k\right)\frac{\sigma-1}{\sigma-\bar{\epsilon}_k}} > 1. \tag{40}$$

The intuition is as follows. As the firms scales up, it shifts its input usage towards the input that require less for a given increase in output, implying that its returns to scale increases as it scales up. This leads to marginal cost falling faster than the average cost, making its sales, $p_k q_k$, less responsive than its expenditure, $E_k = c_k q_k$, to a given increase in output. Therefore, the total input expenditure grows at a faster rate than its sales.

Taken together, equations (39) and (40) imply that this nonhomothetic production function is not able to reconcile the empirical finding where the input purchase elasticity to sales is one while the labor cost elasticity to sales is less than one.

B.3.2 Upward sloping labor supply curve

We now incorporate upward sloping labor supply curve, represented by the following:

$$\ell_k = A_k w_k^{\varepsilon}.$$

The firm's cost minimization problem now yields the following average cost index and the expenditure shares.

$$\begin{aligned} c_k &= \left(\beta_\ell q_k^{\epsilon_\ell - 1} \left(\frac{\varepsilon}{\varepsilon + 1} \right)^{\sigma} w_k^{1-\sigma} + \beta_n \left(p_k^I \right)^{1-\sigma} q_k^{\epsilon_n - 1} \right)^{\frac{1}{1-\sigma}} \\ s_{\ell k} &= \frac{\beta_\ell q_k^{\epsilon_\ell - 1} \left(\frac{\varepsilon}{\varepsilon+1} \right)^{\sigma} w_k^{1-\sigma}}{c_k^{1-\sigma}} \\ s_{Ik} &= \frac{\beta_n \left(p_k^I \right)^{1-\sigma} q_k^{\epsilon_n - 1}}{c_k^{1-\sigma}}. \end{aligned}$$

The average cost index and the labor supply equation yield the following relationships:

$$\begin{aligned} (1-\sigma)\, d\ln c_k &= (\bar{\epsilon}_k - 1)\, d\ln q_k + s_{\ell k} (1-\sigma)\, d\ln w_k \\ d\ln \ell_k^v &= -\sigma d\ln w_k + \sigma d\ln c_k + \epsilon_\ell d\ln q_k. \end{aligned}$$

Combining these two together, we have the elasticity of average cost to scale written as:

$$\frac{d\ln c_k}{d\ln q_k} = \frac{\bar{\epsilon}_k - 1}{1-\sigma} + s_{\ell k} \frac{d\ln w_k}{d\ln q_k}.$$

We assume that wage increases with scale, $\frac{d\ln w_k}{d\ln q_k} > 0$.[27]

These relationships yield the following elasticities

$$\begin{aligned} \frac{d\ln E_k}{d\ln q_k} &= \frac{\sigma - \bar{\epsilon}_k}{\sigma - 1} + s_{\ell k} \frac{d\ln w_k}{d\ln q_k} \\ \frac{d\ln E_k}{d\ln c_k} &= \frac{\frac{\sigma - \bar{\epsilon}_k}{\sigma - 1} + s_{\ell k} \frac{d\ln w_k}{d\ln q_k}}{\frac{1 - \bar{\epsilon}_k}{\sigma - 1} + s_{\ell k} \frac{d\ln w_k}{d\ln q_k}}, \end{aligned}$$

[27] Combining with the labor supply curve equation, we obtain $\frac{d\ln w_k}{d\ln q_k} = \frac{\frac{\sigma}{\varepsilon+\sigma}\frac{\sigma-\bar{\epsilon}_k}{\sigma-1} - \frac{\sigma-\epsilon_\ell}{\varepsilon+\sigma}}{1 - s_{\ell k}\frac{\sigma}{\varepsilon+\sigma}}$. We assume $\frac{\sigma}{\sigma-1} > \frac{\sigma-\epsilon_\ell}{\sigma-\bar{\epsilon}_k}$ to ensure that wage increases with scale.

which we use to derive the following input elasticities to sales:

$$
\begin{aligned}
\frac{d\ln w_k \ell_k^v}{d\ln p_k q_k} &= \left(\sigma - (\sigma-1)\frac{\sigma-\epsilon_\ell}{\sigma-\bar{\epsilon}_k}\frac{1}{1+\frac{\sigma-1}{\sigma-\bar{\epsilon}_k}s_{\ell k}\frac{d\ln w_k}{d\ln q_k}} - (\sigma-1)\frac{d\ln w_k}{d\ln E_k}\right)\frac{d\ln E_k}{d\ln p_k q_k} \\
\frac{d\ln p_k^I q_k^v}{d\ln p_k q_k} &= \left(\sigma - (\sigma-1)\frac{\sigma-\epsilon_n}{\sigma-\bar{\epsilon}_k}\frac{1}{1+\frac{\sigma-1}{\sigma-\bar{\epsilon}_k}s_{\ell k}\frac{d\ln w_k}{d\ln q_k}}\right)\frac{d\ln E_k}{d\ln p_k q_k}
\end{aligned}
\tag{41}
$$

Comparing equation (41) with equation (39), one can observe that as the firm scales up, the firm faces a higher wage. This results in a lower labor cost elasticity to sales, as captured by the term $(\sigma-1)\frac{d\ln w_k}{d\ln E_k}$. To ensure that the weighted sum of the input share elasticities sum up to one, $1 = s_{\ell k}\frac{d\ln w_k \ell_k^v}{d\ln E_k} + s_{Ik}\frac{d\ln p_k^I q_k^v}{d\ln E_k}$, the two input elasticities to scale are adjusted upwards with the term $1/\left(1+\frac{\sigma-1}{\sigma-\bar{\epsilon}_k}s_{\ell k}\frac{d\ln w_k}{d\ln q_k}\right)$. Ignoring so far how the expenditure elasticity $\frac{d\ln E_k}{d\ln p_k q_k}$ is affected, we see that the input purchase elasticity to sales increases further by incorporating upward sloping labor supply curve.

As the last step, we focus on how the expenditure responds to sales change, $\frac{d\ln E_k}{d\ln p_k q_k}$. We have

$$
\begin{aligned}
\frac{d\ln E_k}{d\ln p_k q_k} = 1 + &\left(\frac{\frac{\sigma-\bar{\epsilon}_k}{\sigma-1}}{\frac{\sigma-\bar{\epsilon}_k}{\sigma-1} + s_{\ell k}\frac{d\ln w_k}{d\ln q_k}}\frac{\bar{\epsilon}_k}{\sigma-\bar{\epsilon}_k}\frac{d\ln \bar{\epsilon}_k}{d\ln q_k}\right. \\
&\left. - \frac{s_{\ell k}\frac{d\ln w_k}{d\ln q_k}}{\frac{\sigma-\bar{\epsilon}_k}{\sigma-1} + s_{\ell k}\frac{d\ln w_k}{d\ln q_k}}\left(\frac{d\ln s_{\ell k}}{d\ln q_k} + \frac{d\ln\left(\frac{d\ln w_k}{d\ln q_k}\right)}{d\ln q_k}\right)\right)\frac{d\ln q_k}{d\ln E_k}\frac{d\ln E_k}{d\ln p_k q_k}.
\end{aligned}
$$

This equation shows that the expenditure elasticity to sales depends on how the average non-homotheticity parameter, labor cost share, and the wage elasticity to scale, responds to scale ($\frac{d\ln \bar{\epsilon}_k}{d\ln q_k}$, $\frac{d\ln s_{\ell k}}{d\ln q_k}$, and $\frac{d\ln\left(\frac{d\ln w_k}{d\ln q_k}\right)}{d\ln q_k}$). We show that the average non-homotheticity parameter increases with scale at a faster rate when wage is increasing,

$$
\frac{d\ln \bar{\epsilon}_k}{d\ln q_k} = \frac{\epsilon_\ell}{\bar{\epsilon}_k}\epsilon_\ell s_{\ell k} + \frac{\epsilon_n}{\bar{\epsilon}_k}\epsilon_n s_{Ik} - \bar{\epsilon}_k + s_{\ell k}\left(1-\frac{\epsilon_\ell}{\bar{\epsilon}_k}\right)(\sigma-1)\frac{d\ln w_k}{d\ln q_k} > 0.
$$

We also show that the labor share is decreasing with scale at a faster rate when wage is increasing,

$$
\frac{d\ln s_{\ell k}}{d\ln q_k} = \epsilon_\ell - \bar{\epsilon}_k - (\sigma-1)(1-s_{\ell k})\frac{d\ln w_k}{d\ln q_k} < 0.
$$

Moreover, we can show that the elasticity of wage to scale is decreasing with scale, $\frac{d\ln\left(\frac{d\ln w_k}{d\ln q_k}\right)}{d\ln q_k} < 0$, under the parametric space that ensures $\frac{d\ln w_k}{d\ln q_k} > 0$. Taken together, these results lead to the expenditure elasticity to sales being greater than one, $\frac{d\ln E_k}{d\ln p_k q_k} > 1$.

In conclusion, accounting for upward sloping labor supply curve would further increase the input purchase elasticity to sales, pushing it further away from one. Therefore, we maintain the result that this nonhomothetic production function is not able to reconcile the empirical finding where the input purchase elasticity to sales is one while the labor cost elasticity to sales is less than one.

B.4 Adjustment frictions in labor costs

In this appendix we illustrate how adjustment costs in variable labor inputs affect the labor cost elasticity with respect to sales. In particular, we consider a simplified version of the model outlined in Section 3.1, where the production function is defined as in equation (7). We consider two alternative types of labor adjustment frictions: a quadratic adjustment cost, and labor adjustment à la Calvo (1983). With these setups, we investigate the long run effect of a permanent demand shock. We show that the ratio of variable labor cost to sales remains a constant, even when adjustment frictions are accounted for. As a result, fixed costs in labor can be identified by examining the long run response of total labor costs to changes in sales induced by a permanent demand shock.

B.4.1 Quadratic adjustment cost in labor inputs

We first consider quadratic adjustment costs in variable labor inputs. To focus solely on the role of the adjustment cost in variable labor inputs, we assume that the firm's productivity and the price of input purchases $\left(p_k^I\right)$ are fixed. The firm chooses its variable labor cost one period in advance, and its output price and variable input purchases contemporaneously. The firm's profit maximizing problem is written as follows:

$$\begin{aligned}
\max_{p_{kt},\ell^v_{kt+1},q^v_{kt}} & \sum_{t=0}^{\infty} \beta^t \left(p_{kt}q_{kt} - w_{kt}\ell^v_{kt} - p^I_k q^v_{kt} - w_{kt}\bar{\ell}^f_k - p^I_{kt}\bar{q}^f_k - \frac{\psi}{2}\left(\frac{\ell^v_{kt+1}-\ell^v_{kt}}{\ell^v_{kt}}\right)^2 \ell^v_{kt} \right) \\
s.t.\ q_{kt} &= p_{kt}^{-\sigma} D_{kt} \\
q_{kt} &= \phi_k \left(q^v_{kt}\right)^{1-\alpha_{\ell k}} \left(\ell^v_{kt}\right)^{\alpha_{\ell k}} \\
w_{kt} &= A_{kt}^{-\frac{1}{\varepsilon}} \left(\ell^v_{kt} + \bar{\ell}^f_k\right)^{\frac{1}{\varepsilon}},
\end{aligned}$$

where the first constraint is the demand curve the firm faces, the second is the firm's production function, and the last constraint is the labor supply curve.[28] We illustrate the solution to this dynamic problem where there are i.i.d. shocks on the firm-level demand shifter, D_{kt}, such that $E\left[D_{k,t+1}|D_{k,t}\right] = E\left[D_k\right]$. Consistent with the assumption made in the main text, we assume that firms are infinitesimal in the labor market. Therefore the only state variables are the demand shifter and the labor input.

[28]Note that when there are no adjustment costs, $\psi = 0$, then the problem becomes identical to the static problem.

The Bellman equation can be written as:

$$
\begin{aligned}
V\left(\ell_k^v, D_k\right) = & \max_{\ell_k^{v'}, q_k^v} \phi_k^{\frac{\sigma-1}{\sigma}} \left(q_k^v\right)^{\frac{\sigma-1}{\sigma}(1-\alpha_{\ell k})} \left(\ell_k^v\right)^{\frac{\sigma-1}{\sigma}\alpha_{\ell k}} D_k^{\frac{1}{\sigma}} - A_k^{-\frac{1}{\varepsilon}} \left(\ell_k^v + \bar{\ell}_k^f\right)^{\frac{\varepsilon+1}{\varepsilon}} - p_k^I q_k^v - p_k^I \bar{q}_k^f \\
& - \frac{\psi}{2} \left(\frac{\ell_k^{v'} - \ell_k^v}{\ell_k^v}\right)^2 \ell_k^v + \beta E\left[V\left(\ell_k^{v'}, D_k^{'} \mid D_k\right)\right].
\end{aligned}
$$

The first order condition with respect to the input purchases gives the same relationship between contemporaneous variable input purchases and sales,

$$
\frac{p_k^I q_k^v}{p_k q_k} = \frac{\sigma-1}{\sigma}\left(1-\alpha_{\ell k}\right).
$$

The first order condition with respect to the variable labor inputs using the above solution for input purchases can be written as follows:

$$
\begin{aligned}
\psi\left(\frac{\ell_k^{v'} - \ell_k^v}{\ell_k^v}\right) = & \beta \frac{d}{d\ell_k^{v'}} E\left[V\left(\ell_k^{v'}, D_k^{'}\right)\right] \\
\psi \frac{\ell_k^{v'}}{\ell_k^v} - \psi = & \beta \frac{\sigma-1}{\sigma} \phi_k^{\frac{\sigma-1}{\sigma}} \left(q_k^{v'}\right)^{\frac{\sigma-1}{\sigma}(1-\alpha_{\ell k})} \left(\ell_k^{v'}\right)^{\frac{\sigma-1}{\sigma}\alpha_{\ell k}} E\left[D_k^{\frac{1}{\sigma}}\right] \left(\ell_k^{v'}\right)^{-1} \alpha_{\ell k} \\
& - \beta \frac{\varepsilon+1}{\varepsilon} A_k^{-\frac{1}{\varepsilon}} \left(\ell_k^{v'} + \bar{\ell}_k^f\right)^{\frac{1}{\varepsilon}} + \beta \frac{\psi}{2} \left(\left(\frac{\ell_k^{v''}}{\ell_k^{v'}}\right)^2 - 1\right).
\end{aligned}
$$

We focus on the labor inputs under steady state, namely where $\ell_k^{v'} = \ell_k^v$. Hence, we have

$$
E\left[\frac{w_k^{'} \ell_k^{v'}}{p_k^{'} q_k^{'}}\right] = \alpha_{\ell k} \frac{\varepsilon}{1+\varepsilon} \left(\frac{\sigma}{\sigma-1}\right)^{-1},
$$

implying a constant relationship between variable labor cost and sales, as in equation (10) of the static model.

In the long run steady state, we find that the ratios of both variable labor cost and variable input purchases to sales are constant even under the presence of quadratic adjustment costs in variable labor inputs. These imply that the long run elasticities of labor cost and input purchases to sales change that is driven by an idiosyncratic shock on the firm's demand shifter would be the same as in equations (15) and (16). Furthermore, if one assumes away fixed overhead costs in labor inputs, then the ratio of total labor cost to sales becomes a constant. In this case, the long run elasticity of labor cost to sales becomes one.

B.4.2 Labor adjustment à la Calvo (1983)

We now consider the firm facing labor adjustment frictions à la Calvo (1983). Suppose in each period, the firm cannot adjust labor inputs with probability θ, while intermediate inputs can be adjusted freely every period. The value function then becomes:

$$\begin{aligned} V\left(\ell_k^v, D_k\right) = & \max_{q_k^v} \phi_k^{\frac{\sigma-1}{\sigma}} \left(q_k^v\right)^{\frac{\sigma-1}{\sigma}(1-\alpha_{\ell k})} \left(\ell_k^v\right)^{\frac{\sigma-1}{\sigma}\alpha_{\ell k}} D_k^{\frac{1}{\sigma}} - A_k^{-\frac{1}{\varepsilon}} \left(\ell_k^v + \bar{\ell}_k^f\right)^{\frac{\varepsilon+1}{\varepsilon}} - p_k^I q_k^v - p_k^I \bar{q}_k^f \\ & + \beta\theta E\left[V\left(\ell_k^v, D_k^{'} \mid D_k\right)\right] + \beta\left(1-\theta\right) E\left[\max_{\ell_k^{v'}} V\left(\ell_k^{v'}, D_k^{'} \mid D_k\right)\right]. \end{aligned}$$

Note that if firms could adjust their labor inputs freely, i.e., $\theta = 0$, then the problem becomes identical to the static problem.

Given ℓ_k^v and D_k, the optimal amount of variable input purchases in any period can be derived from the first order condition and is the same as the static problem:

$$\frac{p_k^I q_k^v}{p_k q_k} = \frac{\sigma-1}{\sigma}\left(1-\alpha_{\ell k}\right). \tag{42}$$

The first order condition with respect to labor inputs can be written as:

$$\begin{aligned} \frac{\partial V\left(\ell_k^v, D_k\right)}{\partial \ell_k^v} = 0 = & \frac{\sigma-1}{\sigma}\alpha_{\ell k}\phi_k^{\frac{\sigma-1}{\sigma}} \left(q_k^v\right)^{\frac{\sigma-1}{\sigma}(1-\alpha_{\ell k})} \left(\ell_k^v\right)^{\frac{\sigma-1}{\sigma}\alpha_{\ell k}} D_k^{\frac{1}{\sigma}} \left(\ell_k^v\right)^{-1} - \frac{\varepsilon+1}{\varepsilon} w_k \\ & + \beta\theta E\left[\frac{\partial}{\partial \ell_k^v}\left(\phi_k^{\frac{\sigma-1}{\sigma}} \left(q_k^{v'}\right)^{\frac{\sigma-1}{\sigma}(1-\alpha_{\ell k})} \left(\ell_k^v\right)^{\frac{\sigma-1}{\sigma}\alpha_{\ell k}} \left(D_k^{'}\right)^{\frac{1}{\sigma}}\right)\right] - \beta\theta\frac{\varepsilon+1}{\varepsilon} w_k \\ & + \cdots. \end{aligned} \tag{43}$$

In the second line of equation (43), the firm takes into account that the amount of intermediate input purchases is an endogenous object that satisfy equation (42). Arranging further, we obtain the following ratio of variable labor cost to sales:

$$\frac{w_k \ell_k^v}{p_k q_k} = \alpha_{\ell k}\frac{\varepsilon}{1+\varepsilon}\left(\frac{\sigma}{\sigma-1}\right)^{-1} \frac{1 + \sum_{s=1}^{\infty}\left(\frac{\beta\theta}{1-\frac{\sigma-1}{\sigma}(1-\alpha_{\ell k})}\right)^s E\left[\left(\frac{D_{k,t+s}}{D_{k,t}}\right)^{\frac{1}{\sigma}\frac{1}{1-\frac{\sigma-1}{\sigma}(1-\alpha_{\ell k})}}\right]}{1+\sum_{s=1}^{\infty}\left(\beta\theta\right)^s}. \tag{44}$$

Equation (44) reveals that the share of variable labor cost to sales can be different from the optimal share in the static problem, $\alpha_{\ell k}\frac{\varepsilon}{1+\varepsilon}\left(\frac{\sigma}{\sigma-1}\right)^{-1}$. When the firm expects a larger demand in the future (larger expectation of $\frac{D_{k,t+s}}{D_{k,t}}$), then the firm hires more labor today because with some probability, it would not be able to adjust the amount of labor when larger demand is realized. However, as long as the series of expected future demand are fixed, the variable labor cost to sales ratio is constant. Moreover, the equation implies that in response to a permanent demand shock where current and future demand is shifted by a constant multiplier, the variable labor cost to sales share before and after the shock is unaffected, as the ratio of $\frac{D_{k,t+s}}{D_{k,t}}$ remains the same. This is true for one firm conditional on being able to change its labor, and also for the aggregate once all firms have the opportunity to change their labor. Therefore, we find that when firms face frictions in labor cost adjustment à la Calvo (1983), the long run elasticity of labor cost to a sales change that is driven by a permanent demand shock is the same as that in equation (15).

B.5 System of counterfactual changes in variables

B.5.1 Setup of the counterfactual exercise

In our main counterfactual exercise in Section 6, we assume that firms charge a common markup of $\frac{\sigma}{\sigma-1}$ and that firms face upward sloping labor supply curve with elasticity ε. By having firms set a common markup of $\frac{\sigma}{\sigma-1}$, we have a discrepancy between a firm's variable input cost inferred from its sales and markup, $\left(\frac{\varepsilon}{\varepsilon+1}\alpha_{\ell k}+1-\alpha_{\ell k}\right)\frac{\sigma-1}{\sigma}p_k q_k$, and its variable input cost inferred from the estimated variable cost shares and observed input expenditure, $varinput_k = w_k \ell_k^v + \sum_j p_j q_{jk}^v + p_{Fk} q_{Fk}^v$. We denote these firm-level discrepancies by adj_k:

$$adj_k = \underbrace{\left(\frac{\varepsilon}{\varepsilon+1}\alpha_{\ell k}+1-\alpha_{\ell k}\right)\frac{\sigma-1}{\sigma}p_k q_k}_{\text{theory-implied input}} - \underbrace{varinput_k}_{\text{observed input}} .$$

One interpretation of this term adj_k is the usage of firm k's inventories. If $adj_k > 0$, then the firm is purchasing fewer variable inputs than what is implied from its sales and markup and hence is using the past inventory of inputs to produce. If $adj_k < 0$, then the firm is purchasing more variable inputs than what is implied from its sales and markup and hence is accumulating inventory for future use.

In the counterfactual exercise, we follow Dhyne et al. (2022) and assume that the ratios of adj_k relative to the firm's two different variable inputs are fixed. This is consistent with an interpretation in which the fraction of how much inventory the firm uses (or accumulates) relative to its inputs and sales does not change in response to foreign shocks. With this assumption, we have the following relationship:

$$\widehat{varinput}_k = \frac{\frac{\sigma-1}{\sigma}p_k q_k}{varinput_k}\widehat{p_k q_k} - \frac{adj_k}{varinput_k}\widehat{adj}_k,$$

where we have $\widehat{varinput}_k = \widehat{p_k q_k} = \widehat{adj}_k$.

This treatment of the differences in variable input costs is isomorphic to assuming that firms charge firm-specific markups of $\mu_k = \frac{p_k q_k}{w_k \ell_k^v + \sum_j p_j q_{jk}^v + p_{Fk} q_{Fk}^v}$, which can be read from the data. To see this, we refer to equation (45) in Appendix B.5.2, which illustrates how the change in aggregate income is affected by changes in firms' variable profits $\left(\frac{\pi_k^v p_k q_k}{E_H}\widehat{p_k q_k}\right)$ and the changes in the discrepancy terms $\left(\frac{adj_k}{E_H}\widehat{adj}_k\right)$. If one assumes that firms charge markups of μ_k, then the effect of the changes in their variable profits on aggregate income can be summarized by $\frac{\frac{\mu_k - 1}{\mu_k} p_k q_k}{E_H}\widehat{p_k q_k}$. With the assumption that firm sales and the discrepancy terms move in tandem $\left(\widehat{adj}_k = \widehat{p_k q_k}\right)$, the effects on aggregate income are isomorphic to each other.

B.5.2 Counterfactual changes in response to import price and foreign demand shocks

The steps to solve for the counterfactual outcomes are as follows:

1. Guess the changes in firm-level wages $\hat{w}_k$. If $\varepsilon = \infty$, then the guess is common across all firms.

2. Compute the firm-level changes in total and variable labor inputs, $\hat{\ell}_k$ and $\hat{\ell}_k^v$, using equations (5) and (8):

$$\hat{\ell}_k = \frac{\hat{w}_k^\varepsilon}{\sum_j \ell_j \hat{w}_j^\varepsilon} L$$
$$\hat{\ell}_k^v = \frac{\ell_k}{\ell_k^v}\hat{\ell}_k - \frac{\bar{\ell}_k^f}{\ell_k^v}.$$

   Skip this step if $\varepsilon = \infty$.

3. Solve for $\hat{c}_k$ using equation (28):

$$\hat{c}_k = \left(\sum_{j \in Z_k} \frac{s_{jk}^v}{1 - s_{\ell k}^v}\hat{c}_j^{1-\sigma} + \frac{s_{Fk}^v}{1 - s_{\ell k}^v}\hat{p}_{Fk}^{1-\sigma}\right)^{\frac{1-\alpha_{\ell k}}{1-\sigma}} \hat{w}_k^{\alpha_{\ell k}}.$$

4. Compute the change in shares and prices using equations (31), (32), (33), (34), and

(36):

$$
\begin{aligned}
\hat{s}^v_{jk} &= \frac{\hat{c}_j^{1-\sigma}}{\sum_{j\in Z_k}\frac{s^v_{jk}}{1-s^v_{\ell k}}\hat{c}_j^{1-\sigma}+\frac{s^v_{Fk}}{1-s^v_{\ell k}}\hat{p}_{Fk}^{1-\sigma}}\\
\hat{s}^v_{Fk} &= \frac{\hat{p}_{Fk}^{1-\sigma}}{\sum_{j\in Z_k}\frac{s^v_{jk}}{1-s^v_{\ell k}}\hat{c}_j^{1-\sigma}+\frac{s^v_{Fk}}{1-s^v_{\ell k}}\hat{p}_{Fk}^{1-\sigma}}\\
\hat{s}^f_{jk} &= \frac{\hat{c}_j^{1-\sigma}}{\left(\hat{c}^f_k\right)^{1-\sigma}}\\
\hat{s}^f_{Fk} &= \frac{\hat{p}_{Fk}^{1-\sigma}}{\left(\hat{c}^f_k\right)^{1-\sigma}}\\
\left(\hat{c}^f_k\right)^{1-\sigma} &= \sum_{j\in Z_k} s^f_{jk}\hat{c}_j^{1-\sigma}+s^f_{Fk}\hat{p}_{Fk}^{1-\sigma}\\
\hat{s}_{kH} &= \frac{\hat{c}_k^{1-\sigma}}{\sum_j s_{jH}\hat{c}_j^{1-\sigma}}.
\end{aligned}
$$

5. Solve for $\widehat{p_k q_k}$ using equation (35):

$$
\widehat{p_k q_k} = \sum_{i\in W_k} r^v_{ki}\hat{s}^v_{ki}\widehat{p_i q_i} + \sum_{i\in W_k} r^f_{ki}\hat{s}^f_{ki}\hat{c}^f_i + r_{kH}\hat{s}_{kH}\hat{E}_H + r_{kF}\hat{c}_k^{1-\sigma}\hat{D}_{kF},
$$

where we have the following revenue shares of firm k:

$$
r^v_{ki} = \frac{s^v_{ki}p_i q_i}{p_k q_k \mu_i},\ r^f_{ki} = \frac{p_k q^f_{ki}}{p_k q_k},\ r_{kH} = \frac{s_{kH}E_H}{p_k q_k},\ r_{kF} = \frac{p_k^{1-\sigma}D_{kF}}{p_k q_k}.
$$

The change in aggregate household expenditure is written as

$$
\begin{aligned}
\hat{E}_H =& \sum_k \frac{w_k \ell_k}{E_H}\hat{w}_k + \sum_k \frac{\pi^v_k}{E_H}\widehat{p_k q_k} - \sum_j\sum_k \frac{p_j q^f_{jk}}{E_H}\hat{s}^f_{jk}\hat{c}^f_k - \sum_k \frac{p^f_{Fk}q^f_{Fk}}{E_H}\hat{s}^f_{Fk}\hat{c}^f_k\\
&- \sum_k \frac{w_k \bar{\ell}^f_k}{E_H}\hat{w}_k - \frac{TB}{E_H} + \sum_k \frac{adj_k}{E_H}\widehat{adj}_k, \qquad (45)
\end{aligned}
$$

where $\widehat{adj}_k = \widehat{p_k q_k}$ and $\pi^v_k = \left(1 - \left(\frac{\varepsilon_m}{\varepsilon_m+1}\alpha_{\ell k} + 1 - \alpha_{\ell k}\right)\frac{\sigma-1}{\sigma}\right)p_k q_k$.

6. Update $\hat{w}_k$ with the following and iterate from Step 2 until $\hat{w}_k$ converges:

$$\hat{w}_k^{new} = \frac{\widehat{p_k q_k}}{\hat{\ell}_k^v}$$
$$\hat{w}_k = d\hat{w}_k^{new} + (1-d)\,\hat{w}_k.$$

If $\varepsilon = \infty$, then use the following to update the common guess of wage change:

$$\hat{w}_k^{new} = \frac{\sum_k w_k \ell_k^v \widehat{p_k q_k} + \sum_k w_k \bar{\ell}_k^f \hat{w}_k}{\sum_k w_k \ell_k}.$$

7. Finally, check that the trade balance holds (i.e., the exogenous TB is unchanged).

B.5.3 Counterfactual changes in response to firm productivity shocks

The system of counterfactual changes in variables when one considers changes in firms' productivities is similar to that presented in Appendix B.5.2. Instead of the changes in import price $\hat{p}_{Fk}$, we consider changes in productivities, $\hat{\phi}_k$. Hence, we replace Step 3 in Appendix B.5.2 with the following equation that solves for $\hat{c}_k$ given the shocks $\hat{\phi}_k$ and guess of $\hat{w}_k$:

$$\hat{c}_k = \hat{\phi}_k^{-1} \left(\sum_{j \in Z_k} \frac{s_{jk}^v}{1 - s_{\ell k}^v} \hat{c}_j^{1-\sigma} \right)^{\frac{1-\alpha_{\ell k}}{1-\sigma}} \hat{w}_k^{\alpha_{\ell k}}.$$

B.6 Fixed costs and aggregate labor demand

To gain intuition about how accounting for fixed labor inputs alter wage responses to foreign trade shocks, we work with a simple framework of aggregate labor supply and demand. In this stylized framework we consider one representative firm with no input-output linkages. We also abstract away from upward sloping labor supply curve, as in the aggregate, labor supply is fixed. To obtain the aggregate labor demand curve, we start with the output demand curve,

$$q = p^{-\sigma} D,$$

where p is the output price with price being the product of markup and marginal cost, $p = \mu c$. The demand shifter D contains demand from domestic final demand and export demand, $D = \frac{E}{p^{1-\sigma}} + D_F$, where E is the domestic household income. We consider a net production function that combines the two primary factors, labor and imports, with a Cobb-Douglas aggregater. Denoting variable labor inputs and imports by ℓ^v and I respectively, and prices of labor and imports by w and p^I respectively, we have

$$
\begin{aligned}
q &= \phi \left(\ell^v\right)^\alpha I^{1-\alpha} \\
c &= A\phi^{-1} w^\alpha \left(p^I\right)^{1-\alpha},
\end{aligned}
$$

where $A = \alpha^{-\alpha}\left(1-\alpha\right)^{-(1-\alpha)}$ is a constant, ϕ is the aggregate productivity term, and α is the share of labor inputs in variable costs. Finally, we have the following relationships for the aggregate income and trade balance,

$$
\begin{aligned}
E &= w\ell^v + \frac{\mu-1}{\mu}E + \frac{\mu-1}{\mu}p^{1-\sigma}D_F \\
p^{1-\sigma}D_F &= p^I I.
\end{aligned}
$$

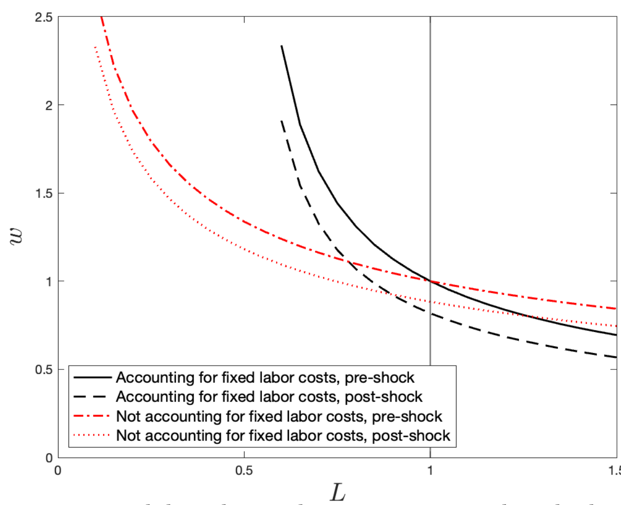
The above relationships implicitly yield a downwards sloping aggregate labor demand curve, where wage w is written as a function of total labor input (the sum of variable and fixed labor inputs, $L = \ell^v + \ell^f$) and foreign price and demand shifters, p^I and D_F.

Accounting for fixed labor inputs alter the aggregate labor demand curve in two ways. First, it rotates the aggregate labor demand curve clockwise around the initial equilibrium, as variable labor input is now less than L at $L - \ell^f$. Intuitively, when fixed labor inputs are accounted for, the amount of labor inputs that contribute to production decreases as the total labor supply is fixed. This effectively moves the economy to the more inelastic part of the aggregate labor demand curve. Second, accounting for fixed labor inputs alters the measurement of the labor cost share in variable costs, α, which governs the elasticities of wage with respect to foreign price p^I and demand D_F. Because there are labor inputs that are used as fixed overhead costs, the share of labor cost in variable costs, α, is lower than when one reads it off from the total cost shares. Therefore, for a given increase in foreign price (an increase in p^I) or for a given reduction in foreign demand (a reduction in D_F), wage is predicted to decrease more by accounting for fixed labor costs. Intuitively, when labor cost account for a smaller share in variable cost, output price is less responsive to wage. With aggregate labor supply fixed, the economy responds to a negative demand by lowering the price through lower wage, and to an increase in the foreign price by countering the price increase through a lower wage. In both cases, wage has to decrease with a larger magnitude when fixed labor costs are accounted for.

To visually convey how the aggregate labor demand curve changes when fixed labor inputs are accounted for, we numerically solve for the aggregate labor demand curves under different parametrizations, and plot them in Figure 7. We consider an economy where the aggregate labor supply is fixed at $L = 1$ (the vertical line). The two black lines use the labor cost share parameter of $\alpha = 0.3$ and account for fixed labor costs with $\ell^f = 0.5$.

The solid black line computes the labor demand when $p^I = 1$ and the dashed black line computes the labor demand when the import price increases by 20 percent, at $p^I = 1.2$. Their values are normalized with the level of wage when the import price is $p^I = 1$ and the labor supply is $L = 1$. The two lines show that when the import price increases by 20 percent, the aggregate labor demand curve shifts down, implying that the wage decreases given a fixed aggregate labor supply. In contrast, the two red lines, also normalized with the level of wage when the import price is $p^I = 1$ and the labor supply is $L = 1$, do not account for fixed labor inputs. The dash-dotted red line uses $p^I = 1$ as the import price, and the dotted red line uses $p^I = 1.2$. The economy in the dash-dotted red line has the same share of total labor expenditure in total costs as in the solid black line when $L = 1$. As discussed above, not accounting for fixed labor inputs should increase the measurement of α. We compute the share of labor costs in total inputs for the solid black line with labor supply of $L = 1$, and use $\alpha = 0.46$ for the two red lines. These two sets of lines confirm our arguments above: Accounting for fixed labor inputs makes the aggregate labor demand less elastic, and increases the magnitudes of the downward shifts in the labor demand upon negative foreign trade shocks.

Figure 7: Aggregate labor demand



Notes: This figure plots the aggregate labor demand curves computed with the following parameter values: $\sigma = 4$, $\phi = 1$, $D_F = 1$. We consider two economies that have the same share of labor expenditure in total costs. The two black lines use the variable labor cost share of $\alpha = 0.3$ and depict the labor demand when fixed labor inputs are accounted for with $\ell^f = 0.5$. The solid black line uses $p^I = 1$ as the import price, and the dashed black line uses $p^I = 1.2$. The values of the two black lines are normalized to the wage under $p^I = 1$ and $L = 1$. The two red lines use the variable labor cost share of $\alpha = 0.46$ and depict the labor demand when fixed labor inputs are not accounted for, $\ell^f = 0$. 0.46 is the share of total labor cost out of total inputs when $\ell^f = 0.5$, $p^I = 1$, and $L = 1$. The dash-dotted red line uses $p^I = 1$ as the import price, and the dotted red line uses $p^I = 1.2$. The values of the two red lines are normalized to the wage under $p^I = 1$ and $L = 1$.

C Additional empirical results

C.1 Additional results on labor costs and sales

In Figure 1 of Section 2.4, we explore the relationship between firms' changes in labor costs and sales, that are indicative of how much labor are used as fixed overhead inputs. In this section, we examine different cuts of the data to explore whether any group of firms have significantly lower correlation between changes in labor cost and sales than other firms. Table 6 reports the regression coefficients on changes in labor costs on changes in sales for different sets of firms. We find that groups of firms that are often associated with having larger fixed costs, such as exporters and importers, have significantly lower correlation between changes in labor cost and sales, suggesting that fixed labor cost shares are higher for those firms.

However, as we discussed in Section 2.4, one needs to be cautious in drawing conclusions from Table 6 because input costs and sales are simultaneously determined and may be affected by both measurement error and many omitted variables. The IV estimates reported in Appendix C.9 show a broadly comparable relationship between changes in labor costs and sales for firms that trade internationally and those that do not. This suggests that firms that trade internationally have higher fixed costs (as they are larger), but comparable fixed share of costs.

Table 6: Relationship between firm-level sales and labor costs

	Sales and labor costs (four-year change)	
	Slope of labor costs	Difference between groups
Exporters	0.471***	
	(0.00941)	-0.119***
Non-exporters	0.590***	(0.0189)
	(0.0201)	
Importers	0.503***	
	(0.00926)	-0.0846***
Non-importers	0.587***	(0.0208)
	(0.0217)	
Exporters or importers	0.499***	
	(0.00981)	-0.0951***
Domestic firms	0.594***	(0.0209)
	(0.0224)	

Notes: This table uses the main estimation sample of private-sector firms in Belgium (see Section 2.3 for details). In each panel, we report the regression coefficients of four-year changes in firms' labor costs on changes in their sales, for different groups of firms. Industry-fixed effects are included at the NACE four-digit level. Standard errors in parentheses are clustered at the NACE four-digit level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C.2 Wage differentials and firm effects

In Figure 1 of Section 2.4, we show that changes in average wage are correlated with the changes in sales, suggesting that firms face upward sloping labor supply curve. Using the firm and worker data, in this section we show that i) firms that are more exposed to foreign markets are larger, more productive, and pay higher wages, and that ii) these wage differentials cannot be entirely explained by observed or unobserved differences across workers. These findings further motivate why we will depart from the canonical model of a competitive labor market where wages depend only on the marginal product of workers and not the firm that employs them.

A large body of previous work has documented that firms that export look very different from non-exporters along a number of important dimensions. This is also true in the Belgian data: the descriptive statistics reported in Table 2 of Dhyne et al. (2021) show that the direct exporters not only are more productive and have higher sales but also have more employees and pay higher wages than other firms. This pattern in the data is consistent with an imperfectly competitive labor market where each individual firm faces an upward-sloping labor supply curve, implying that wages are an increasing function of firm size and productivity. However, several alternative explanations exist.

One alternative explanation is that workers could be paid differentially because of unobserved skill differences, not imperfect competition (see, e.g., Abowd et al., 1999, Gibbons et al., 2005). To investigate this possibility, we run a set of wage regressions on a sample of workers who switch firms (and have at least four years of tenure at both the origin and destination firms, to ensure that we can accurately measure their wages both before and after the move). This sample is based on the subset of firms for which we have additional information from the worker data (see Section 2.3 for details). The results are presented in Table 7. In the first column, we regress the log wages of workers on a dummy variable for being employed in a firm that directly exports, controlling only for calendar year effects. In the second and third columns, we add controls for observable worker characteristics and sector fixed effects, respectively. In the final column, we use the panel dimension of the data to add controls for worker fixed effects. By including these fixed effects, we control for any time-invariant (observed or unobserved) worker heterogeneity. Since aggregate shocks are absorbed by the time fixed effects, identification is achieved from a common trend assumption in the workers' wages in the absence of moving to firms that directly export.

To empirically assess the common trend assumption in the workers' wages in the absence of moving to direct exporters, we also perform the following movers analysis. We consider a sample of workers who switch their main jobs between $t-1$ and t and have tenures of no fewer than four years at both origin and destination firms. We then use the balanced panel of movers from $t-4$ to $t+3$ and estimate the effects of moving from non-exporters to

Table 7: Wage regressions on the sample of movers

	(1)	(2)	(3)	(4)
Exporter dummy	0.229***	0.131***	0.0639***	0.0258***
	(0.00375)	(0.00307)	(0.00361)	(0.00288)
Number of workers	10,179	10,179	10,179	10,179
Number of firms	7,101	7,101	7,101	7,101
Calendar year FE	Yes	Yes	Yes	Yes
Worker characteristics		Yes	Yes	Yes
Industry FE			Yes	Yes
Worker FE				Yes

Notes: This table uses the subsample of firms for which we have additional information from the worker data (see Section 2.3 for details). For each column, we run a worker-level regression of log FTE wage on the sample of movers between any firms. Movers in year t are defined as workers who are employed by the origin firms at no later than $t-4$, switch their jobs between $t-1$ and t, and stay at their destination firms at least until $t+3$. The sample is balanced from $t-4$ to $t+3$. Observations in years $t-1$ and t are dropped from the regressions, to ensure we only use full-year employment spells in a given firm. Worker characteristics include worker class (blue collar or white collar)—which can vary across employers for the same worker—gender, and age bin-year effects. Industry fixed effects are included at the NACE four-digit level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

exporters by running the following regression:

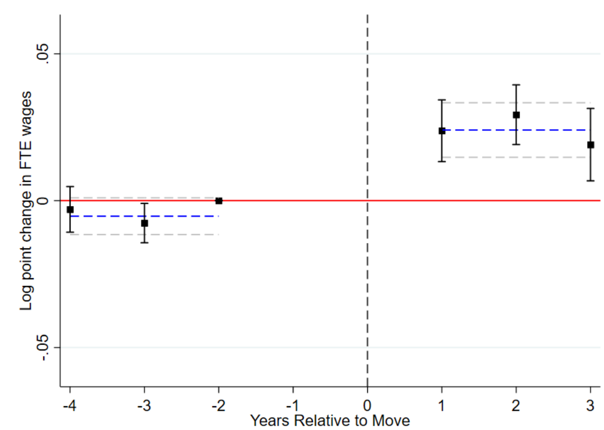
$$\log w_{n,s} = \sum_{\kappa=-4}^{3} \eta_\kappa \mathbf{1}[s=\kappa] + \sum_{k=-4}^{3} \chi_\kappa \mathbf{1}[s=\kappa, T(n)=1] + \zeta_n + \xi_{n,s}, \tag{46}$$

where $\log w_{n,s}$ denotes mover n's log wage in year s (relative to the year of move), $T(n)$ is an indicator for the move from non-exporters to exporters, and ζ_n is a worker fixed effect. In order to ensure that we only use full-year employment spells in a given firm, we drop the observations in years $t-1$ and t. We also pool all movers in the regression and assume that the effects of moving from exporters to non-exporters are symmetric.

Figure 8 presents a graphical representation of the exporter wage premium. In this figure, we report the estimated coefficients χ_κ in equation (46) for κ from -4 to 3 and normalize the estimates by setting $\chi_{-2} = 0$. As in Table 7, we additionally control for calendar year effects, observable time-varying worker characteristics, and sector fixed effects. Our findings support common trends prior to the move, suggesting that the wage growth of workers moving to a firm that does not directly export can be a valid counterfactual for those moving to a firm that directly exports.

Taken together, the results in Table 7 show that controlling for (observed and unobserved) worker characteristics significantly reduces the differences in wages between workers in firms that do and do not directly export, highlighting the benefits of using panel data in our setting. Nevertheless, even after controlling for worker characteristics, workers in firms that directly export still earn about 2.6 percent more than workers in firms that do not directly

Figure 8: Graphical representation of exporter wage premium from movers analysis



Notes: This figure uses the subsample of firms for which we have additional information from the worker data (see Section 2.3 for details). We run a worker-level regression based on equation (46) and report the estimated coefficients $\{\chi_\kappa\}_{\kappa=-4}^{3}$. We define movers in year t as workers who are employed by the origin firms at no later than $t-4$, switch their jobs between $t-1$ and t, and stay at their destination firms at least until $t+3$. The sample of movers is balanced from $t-4$ to $t+3$. Observations in years $t-1$ and t are dropped from the regression to ensure that we only use full-year employment spells in a given firm. The estimates are normalized by setting $\chi_{-2} = 0$. The assignment to the exporter or non-exporter category is made based on firms' export participation status at $t-2$ for both origin and destination firms. Industry fixed effects are included at the NACE four-digit level.

export, consistent with imperfect competition in the labor market.

An alternative explanation to imperfect competition for why (even the same) workers are paid differently across firms is that observed wages may not necessarily reflect the full compensation that individuals receive from working in a given firm. Indeed, both survey data (e.g., Hamermesh, 1999, Pierce, 2001, Maestas et al., 2018) and experimental studies (e.g., Mas and Pallais, 2017, Wiswall and Zafar, 2018, Chen et al., 2020) suggest that workers may be willing to sacrifice higher wages for better non-wage job characteristics or amenities when choosing an employer. Thus, the wage premia in firms that directly export could reflect compensating differentials for unfavorable amenities, not imperfect competition. To distinguish between compensating differentials and imperfect competition as sources of wage differentials, we will, in Section 5, exploit changes in employment and wages within firms in response to plausibly exogenous foreign demand shocks.

C.3 Firm-level output prices, wages, and input prices

In Section 2.4, we discuss a set of empirical facts on the relationships in our data between firm-level sales, labor costs, and intermediate input purchases. In this section, we present another set of facts describing the differential pass-through rates of changes in wages and input prices on firm-level output prices. In a simple model where output markups are fixed and input markets are competitive, the pass-through rates of changes in input prices to the output price are informative of the shares of those inputs in total variable costs. We regress firm-level output price changes on changes in average wage and the price of input purchases, and find that changes in output prices are more correlated with the changes in input prices than with the changes in average wage. This fact is suggestive of labor cost having a smaller share than input purchases in firms' variable costs. We also run the same regression but where we weigh the wage change and the input price change with their observed share in total costs in the previous period. Again, we find that the coefficient on average wage change is smaller than that on input price change, consistent with labor being used more intensively in fixed costs than in variable costs.

In this exercise, we use information on unit values provided by Duprez and Magerman (2018), which is based on Prodcom data that contains output values and quantities at the 8-digit level for large firms in the mining and quarrying, and manufacturing sectors.[29] For the set of firms that we have additional information on unit values, we first compute firm-level output price changes by taking the log differences of unit values for each firm. For multiple product firms, we compute the weighted average price change by using the products' output value at the initial period as weights. Firm-level input price changes are computed by aggregating these output price changes of each firm's suppliers. Since Prodcom only covers a small subset of firms in the Belgian economy (less than 1 percent of firms in 2012), for many firms, not all suppliers are in this subsample.[30] Therefore, we compute the input price change by taking the weighted average of the output price changes among Prodcom suppliers. We use these suppliers' initial period sales share in the firm's input purchases from all Prodcom suppliers as weights.[31] For the set of importers, we use the customs records and incorporate import price changes. We do so by taking the changes in the import prices for each firm-product pair, and then aggregate up to the firm-level using the initial period

[29] To be in the Prodcom sample, firms need to meet certain criteria that includes having 20 or more employees or sales above 4 million Euro. For details see Appendix A of Duprez and Magerman (2018). For mapping product codes across multiple years, we build on the year-to-year concordance of product codes provided by Duprez and Magerman (2022).

[30] However, since the sample of analysis is also the sample covered in Prodcom, we find that there is at least one supplier that is in Prodcom for more than 90 percent of the firms in Prodcom.

[31] This implicitly assumes that the input price changes from suppliers that are not in Prodcom are the same as those from suppliers that are in Prodcom. We discuss the implications of this potential measurement error below.

import values as weights.

To explore how changes in wages and input prices translate to changes in output prices, we regress firm-level four-year output price changes on both firm-level four-year wage changes and average input price changes. To account for differences across industries, in some specifications we control for industry-year fixed effects. We report the results in Columns (1) and (2) in Table 8. We first note that across these columns, the values of the coefficients on both inputs are far below one and do not add up to one. It is worth mentioning that one needs to be cautious in directly interpreting these coefficients as shares of these inputs in variable costs for several reasons. First, input price changes are likely subject to measurement error as not all suppliers are in the Prodcom sample. Second, firms may respond to input price changes by changing their markups, which makes our coefficients biased (Amiti et al., 2019). Similarly, changes in firms' productivities or technologies may drive both the changes in input and output prices, generating omitted variable biases. Moreover, nominal rigidity in output prices may dampen the pass-through of input prices on output prices, as in Gagliardone et al. (2023). Nevertheless, the magnitudes of these coefficients are consistent with those from Baqaee et al. (2023).

Having mentioned these limitations, these results may still be useful for inferring suggestive evidence on labor cost shares in variable inputs. For example, if we assume that the biases mentioned above are the same across the two coefficients, the relative magnitudes of the coefficients are informative.[32] The changes in the prices of input purchases are more associated with the changes in output prices, than the changes in average wages. This pattern is suggestive of labor cost having a smaller share in firms' variable costs than inputs.

In Column (3), we weigh the average wage change and the input price change with their observed share in total costs in the previous period. To aid the interpretation, suppose that the biases affect both coefficients equally. Then, these coefficients reject the null hypothesis that fixed costs and variable costs have the same labor and input composition. If the composition of labor and inputs in fixed costs is the same as that in variable costs, the two coefficients should equal each other. Furthermore, as with the previous specification, the relative magnitude of the coefficients here is also informative about the labor cost share in firms' fixed costs. When the labor cost share in fixed costs is higher than the labor cost share in variable costs, then the true labor share in variable costs is lower than the observed labor share in total costs. Then, one would expect a lower coefficient for wage change than for input price changes. Therefore, these results are consistent with labor being used more intensively in fixed costs than in variable costs.

Taken together, the results in Table 8 suggest the importance of labor cost in firms'

[32] If the biases affect the estimates multiplicatively, the ratio of the estimated coefficients is informative about the ratio of the true coefficients, and if the biases enter the estimates additively, the difference between the estimated coefficients is informative about the difference in the true coefficients.

fixed costs. However, it is difficult to draw definitive conclusions under the biases that are discussed above. Therefore, as argued in Section 2.4, to fully understand the cost structure of firms we make use of an explicit model together with an exogenous firm-level shifter in demand.

Table 8: Relationship between firm-level output prices, wages, and input prices

	(1)	(2)	(3)
	Four-year output price change		
Four-year difference			
Wage change	0.0189	0.0171	0.0572
	(0.0124)	(0.0149)	(0.0512)
Average input price change	0.159***	0.112***	0.174***
	(0.0240)	(0.0192)	(0.0267)
Ind.Year FE		Yes	Yes
Weighted by $t-1$ cost shares			Yes

Notes: This table uses the subsample of 35,772 firm-year observations in Belgium from 2002 to 2014 for which we have additional information on price from Prodcom data. For each column, we run a firm-level regression of the output price change on the wage change and the average input price change. Firm-level output price changes are computed by taking the weighted average of the log differences of unit values for each firm. Log differences of unit values are trimmed at top and bottom 1 percent. We then compute the input price changes by taking the weighted average of the output price changes among Prodcom suppliers. For the set of importers, we additionally incorporate import price changes using the initial period import values as weights. Industry fixed effects are included at the NACE four-digit level. In Columns (3), wage changes and average input price changes are weighted by the cost shares of labor costs and input purchases at $t-1$, respectively. Standard errors in parentheses are clustered at the NACE four-digit level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C.4 Export growth at the firm-country-product level

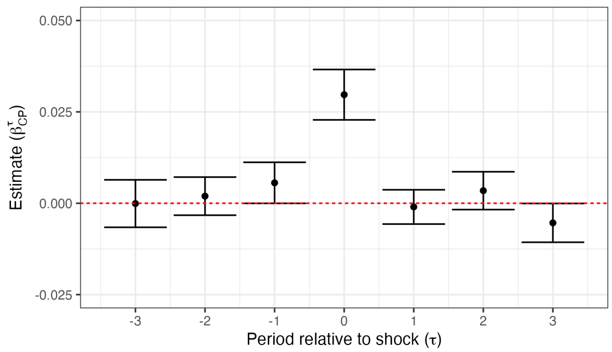
In this section, we examine how changes in $\Delta_{t-1}^{t} \log WID_{c,p}$ changes the exports of product p by firm k to country c. In doing so, we run a regression analogous to the one in equation (21) at the firm-country-product level:

$$\Delta_{t+\tau-1}^{t+\tau} \log X_{kF,c,p} = \ddot{\alpha}^{\tau} + \beta_{CP}^{\tau} \Delta_{t-1}^{t} \log WID_{c,p} + \ddot{\varphi}_{k,c,p,t}^{\tau}, \tag{47}$$

where $\Delta_{t+\tau-1}^{t+\tau} \log X_{kF,c,p}$ denotes the log change in firm k's export of product p to country c from year $t+\tau-1$ to year $t+\tau$. The estimates $\{\beta_{CP}^{\tau}\}_{\tau=-3}^{3}$ reported in Figure 9 suggest that idiosyncratic changes in the world import demand give rise to persistent and unanticipated increases in export demand.[33]

[33]We note that the sample of firms used in Figure 9 only includes direct exporters. On the other hand, the analyses in Section 4 also capture indirect trade.

Figure 9: Export growth at the firm-country-product level



Notes: This figure uses 4,443,426 firm-country-product-year observations in Belgium based on the main estimation sample from 2002 to 2014 (see Section 2.3 for details). We run seven firm-country-product-level regressions based on equation (47) for τ from -3 to 3 with exports as the outcome variable. This figure shows the point estimates as well as 95 percent confidence intervals. Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors are clustered at the NACE four-digit level. All specifications include country-year fixed effects, product-year fixed effects, industry-year fixed effects, and firm fixed effects

C.5 Specification checks

In this section, we consider several alternative specifications to our main results presented in Table 1. For each alternative specification, we also report the cumulative increase in sales ($\sum_{\tau=0}^{3} \beta^{\tau}$ in equation (21)) relative to its instantaneous response to the foreign demand shock (β^0). In Table 9, we report the results in which we weight each firm by its lagged employment. Table 10 shows the sensitivity of our results to additionally controlling for location-year fixed effects. We use level 2 of the Eurostat NUTS classification as a measure of location. In these specifications, our IV estimates relative to the cumulative increase in sales are not substantially affected.

C.6 Wages and work rate of stayers

In our main IV estimates reported in Table 1 of Section 5.1, we consider all the workers in our sample. However, we could also look at the incumbent workers who stay in the same firm. An advantage of doing so is that it keeps the composition of the workforce fixed, and thus, we are not confounding increases in the wages paid to a given worker with changes in the quality of the workers. In the first column of Table 11, we report the IV estimate on wages for the sample of stayers (who stay in the same firm before and after the demand shock, from $\tau = -1$ to $\tau = 3$). This sample is based on the subset of firms for which we have additional information from the worker data (see Section 2.3 for details).[34] We find that their wages increase by 1.3 percent in response to a 10 percent increase in sales, which is similar to the impact for all workers.

[34]We note that part of the wage growth of stayer workers may be from promotions to higher ranked occupations. Occupation information is not available in the social security data.

Table 9: Worker impacts and firm responses to foreign-demand induced change in sales: weighted by employment at $t-1$

	(1) Sales	(2) Average wage	(3) FTE Employment	(4) Labor cost	(5) Input purchases	(6) Domestic input purchases
Instantaneous response	1.000***	0.108**	0.0869	0.195***	1.081***	0.764***
($\gamma^{-1,0}$)		(0.0449)	(0.0582)	(0.0715)	(0.144)	(0.115)
Cumulative response	0.494***	0.0604	0.208*	0.268**	0.511***	0.383***
($\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau}$, unbalanced)	(0.164)	(0.0788)	(0.119)	(0.125)	(0.117)	(0.121)
Cumulative response	0.513***	0.0650	0.147*	0.212**	0.388**	0.181
($\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau}$, balanced)	(0.165)	(0.0554)	(0.0811)	(0.104)	(0.197)	(0.173)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table uses the main estimation sample of private-sector firms in Belgium from 2002 to 2014 (see Section 2.3 for details). For each outcome variable, we estimate its elasticity with respect to sales. We run four firm-level 2SLS regressions based on equation (22) for $\tau \in \{0, 1, 2, 3\}$ and $\tau' = \tau - 1$ and report the instantaneous response ($\gamma^{-1,0}$) as well as the cumulative response (the sum of four coefficients $\{\gamma^{\tau-1,\tau}\}_{\tau=0}^{3}$). In the third row, we use a balanced panel of firms that are observed for four consecutive years from $t-1$ to $t+3$. The first-stage F-statistics for excluded instruments is 142.3. Variables are winsorized at the top and bottom 0.5 percentiles. In all regressions, we weight each firm by its employment at $t-1$. Standard errors in parentheses are clustered at the NACE four-digit level, and standard errors of the cumulative responses are computed using the bootstrap method. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 10: Worker impacts and firm responses to foreign-demand induced change in sales: including location-year fixed effects

	(1) Sales	(2) Average wage	(3) FTE Employment	(4) Labor cost	(5) Input purchases	(6) Domestic input purchases
Instantaneous response	1.000***	0.0881***	0.0667**	0.155***	0.942***	0.760***
($\gamma^{-1,0}$)		(0.0298)	(0.0321)	(0.0369)	(0.0765)	(0.0670)
Cumulative response	0.757***	0.109**	0.323***	0.432***	0.779***	0.597***
($\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau}$, unbalanced)	(0.0771)	(0.0472)	(0.0592)	(0.0705)	(0.120)	(0.104)
Cumulative response	0.663***	0.0842**	0.283***	0.367***	0.700***	0.532***
($\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau}$, balanced)	(0.0773)	(0.0413)	(0.0520)	(0.0603)	(0.117)	(0.101)
Industry-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Location-Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes

Notes: This table uses the main estimation sample of private-sector firms in Belgium from 2002 to 2014 (see Section 2.3 for details). For each outcome variable, we estimate its elasticity with respect to sales. We run four firm-level 2SLS regressions based on equation (22) for $\tau \in \{0, 1, 2, 3\}$ and $\tau' = \tau - 1$ and report the instantaneous response ($\gamma^{-1,0}$) as well as the cumulative response (the sum of four coefficients $\{\gamma^{\tau-1,\tau}\}_{\tau=0}^{3}$). In the third row, we use a balanced panel of firms that are observed for four consecutive years from $t-1$ to $t+3$. The first-stage F-statistics for excluded instruments is 138.8. Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors in parentheses are clustered at the NACE four-digit level, and standard errors of the cumulative responses are computed using the bootstrap method. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Another advantage of the stayers sample is that it allows us to examine if the increase in our measure of FTE employment reflects the hiring of new workers or an increase in the working hours of incumbent workers. To do so, we report, in Table 11, the IV estimates on hours of work (as measured as the share of full-time employment) and on hourly wages for the sample of stayers. The estimated impact on hours of work is close to zero, whereas the effect on hourly wages is close to what we find for all workers. Taken together, these findings suggest that Belgian firms mostly adjust to demand shocks by hiring additional workers, not by increasing incumbent workers' hours of work.

Table 11: IV estimates on the wages and work rate of stayers

	(1) FTE Employment	(2) Stayer wage	(3) Stayer hourly wage	(4) Stayer work rate
Panel A: IV estimates				
Cumulative response	0.296***	0.126***	0.127***	0.0005
($\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau}$, balanced)	(0.0675)	(0.0438)	(0.0376)	(0.0166)
Panel B: Reduced form				
Reduced form	0.108***	0.0458***	0.0462***	0.0002
	(0.0264)	(0.0152)	(0.0140)	(0.0061)
Number of observations	75,849	75,849	75,849	75,849
Industry-Year FE	Yes	Yes	Yes	Yes
Firm FE	Yes	Yes	Yes	Yes

Notes: This table uses the subsample of firms for which we have additional information from the worker data (see Section 2.3 for details). For each outcome variable, we estimate its elasticity with respect to sales. We run four firm-level 2SLS regressions based on equation (22) for $\tau \in \{0, 1, 2, 3\}$ and $\tau' = \tau - 1$ and report the cumulative response (the sum of four coefficients $\{\gamma^{\tau-1,\tau}\}_{\tau=0}^{3}$). The first-stage F-statistics for excluded instruments is 57.5. Variables are winsorized at the top and bottom 0.5 percentiles. Standard errors in parentheses are clustered at the NACE four-digit level and computed using the bootstrap method. We compute firm-level average stayer wage, stayer hourly wage, and stayer work rate based on the balanced panel of stayers from $t-1$ to $t+3$. The analysis is based on 452,025 worker-year observations of stayers, which yield 75,849 firm-year observations of private-sector firms in Belgium from 2003 to 2014. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C.7 Testing for imperfect competition in the labor market

In Table 2, we present the IV estimates of the labor supply elasticity (ε) and the wage markdown ($1/(1+\varepsilon)$). In this section, we provide a formal testing procedure for the imperfect competition in the labor market. Perfect competition means that the firm can hire more workers in response to a foreign demand shock without bidding up wages. In the notation of equations (23) and (24), perfect competition corresponds to the null hypothesis that the instrument impacts employment but has no effect on wages ($\beta_L \neq 0$ and $\beta_W = 0$). The alternative hypothesis of imperfect competition is that the instrument impacts both employment and wages (both $\beta_L \neq 0$ and $\beta_W \neq 0$).

This is a non-standard testing problem because both the null and the alternative hypotheses includes the condition that foreign demand shock affects employment, $\beta_L \neq 0$. If employment was not affected, both perfect and imperfect competition would predict no impact on wages. To test the hypotheses, we therefore use the closure method of Marcus et al. (1976). It reduces the problem of constructing multiple test procedures which control the family wise error rates to the construction of single tests which control the usual probability of a Type 1 error (see Romano et al., 2011). Applied to our problem, the closure method considers three hypotheses:

$H_{1,2}$: The instrument has no effect on both wages and employment, i.e. $\beta_L = \beta_W = 0$
H_1: The instrument has no effect on wages, i.e. $\beta_W = 0$
H_2: The instrument has no effect on employment, i.e. $\beta_L = 0$

If we reject these three hypotheses, we can reject perfect competition and conclude there is imperfect competition, since the instrument impacts both employment and wages.

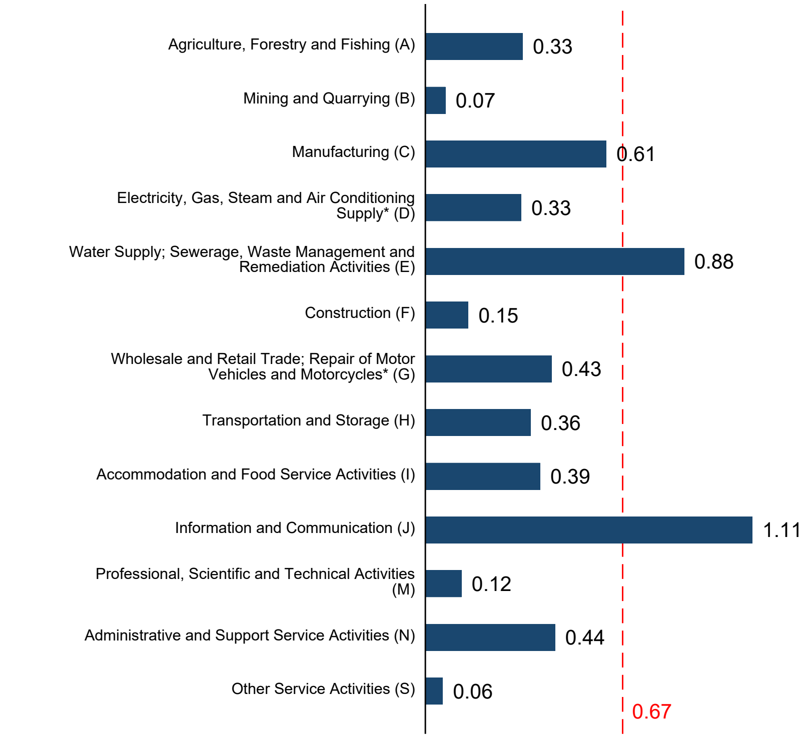
The closure method is straightforward to implement using standard statistical tests: H_1 and H_2 can be tested by considering the usual t-statistic on the instrument in the first-stage in equation (24) and the reduced form in equation (23), whereas $H_{1,2}$ can be tested by computing the F-statistic for the joint hypothesis that the instrument has no effect on wages and employment in these equations. The closure method tells us that both $H_{1,2}$, H_1, and H_2 can be rejected if the p-value for each test is less than or equal to a predefined level of significance α. When applied to our data, this means that we can reject the three hypotheses $H_{1,2}$, H_1, and H_2 at the same level of significance that we can reject H_1, since it is the test that gives us the highest p-value. We present the results in Panel D of Table 2

C.8 Elasticities of input purchases by suppliers' industries

In this section, we allow the elasticity of input purchases, and, thus, the fraction of an input that is used as a fixed factor, to vary across the types of inputs. In order to estimate the cumulative elasticities of input purchases by different types of inputs, we first categorize the purchases of inputs by the industry of supplier for domestic purchases and by the HS product code for import transactions. We then use an HS to NACE concordance to map the product-level import transactions to the industry level, so that we classify both domestic and foreign input purchases by supplying industries.

Figure 10 shows the cumulative elasticities of (domestic and foreign) input purchases at the NACE one-digit level. We report those elasticities relative to the cumulative increase in total sales of 0.67, as referenced by the dotted red line. For instance, we find that purchases from the manufacturing industry, which account for around half of all input purchases in the Belgian economy, increase by 6.7 percent when firms receive foreign demand shocks to increase their sales by 6.1 percent. On the other hand, input purchases from most of the service industry (NACE G to N one-digit sectors) do not increase as much, implying that service inputs have higher fixed input cost shares.

Figure 10: Elasticities of input purchases by suppliers' NACE one-digit industries



Notes: This figure uses the main estimation sample of private-sector firms in Belgium from 2002 to 2014 (see Section 2.3 for details). For each bar, we report the cumulative elasticities of input purchases from suppliers' respective industries. To compute the cumulative elasticities, we run four firm-level 2SLS regressions based on equation (22) for $\tau \in \{0, 1, 2, 3\}$ and $\tau' = \tau - 1$ and compute the sum of four coefficients $\{\gamma^{\tau-1,\tau}\}_{\tau=0}^{3}$. Variables are winsorized at the top and bottom 0.5 percentiles. The dotted red line corresponds to the cumulative response of sales. We report the cumulative elasticities at NACE one-digit sections. We exclude the public and financial sectors from our sample, and we drop NACE L (Real Estate Activities) because of the small sample size. (*) We include the input purchases from NACE 46.71 (Wholesale of solid, liquid and gaseous fuels and related products) and NACE 47.3 (Retail sale of automotive fuel in specialised stores) in NACE D (Electricity, Gas, Steam and Air Conditioning Supply) instead of NACE G (Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles).

C.9 Fixed labor input shares by firm categories

In Section 5.1, we assume that the fixed share of labor inputs is homogeneous across all firms in the Belgian economy. In this section, we allow the fixed shares of labor inputs to vary across firm categories. Table 12 reports our estimates when we distinguish between firms that trade internationally and those that do not. In doing so, we first estimate the cumulative elasticities of labor cost for each firm category by interacting our IV model in equation (22) with firm categories. We then use equation (15) to solve for the fixed share of labor inputs $(1 - \ell_k^v/\ell_k)$. Our IV estimates suggest that firms that trade internationally and those that do not have comparable fixed share of costs.

In the third column, we also report the weighted averages of fixed labor input shares, weighted by the shares of aggregate sales by firm categories. We find that these weighted averages are not substantially different from our main estimate in the first row, in which the fixed shares of labor inputs are assumed to be homogeneous across all firms.

Table 12: Fixed shares of labor inputs by firm categories

	Labor cost elasticity	Fixed share of labor inputs	
		by category	weighted average
All firms	0.528	0.529	
Exporters	0.552	0.505	0.516
Non-exporters	0.503	0.554	
Importers	0.493	0.564	0.549
Non-importers	0.588	0.469	
Exporters or importers	0.535	0.522	0.523
Domestic firms	0.532	0.525	

Notes: This table uses the main estimation sample of 995,739 firm-year observations in Belgium from 2002 to 2014 (see Section 2.3 for details). For each row, we report the cumulative elasticities of labor cost and fixed share of labor inputs $(1 - \ell_k^v/\ell_k)$ by firm category. To obtain the elasticities of labor cost, we estimate the cumulative responses $(\sum_{\tau=0}^{3} \gamma^{\tau-1,\tau})$ of labor cost for each firm category by interacting our IV model in equation (22) with firm categories. We then use equation (15) to solve for the fixed share of labor inputs $(1 - \ell_k^v/\ell_k)$. The reported elasticities of labor cost are relative to the cumulative responses of sales (see Section 5.1 for details). We use the shares of aggregate sales by firm categories as weights when computing the weighted average of fixed labor input shares.

D Additional counterfactual results

D.1 Total import shares

To gain intuition on how accounting for firms' fixed inputs affects firms' and aggregate responses to foreign demand shocks, we focus on the firm-level measure of total import share, defined in Dhyne et al. (2021). Because we impose the trade balance condition, the uniform foreign demand shock that we consider in the exercises can also be seen as a shock where the prices of imports uniformly increase.[35] A firm's total import share, which measures how much of the firm's variable inputs originate directly or indirectly from abroad, is a useful statistic that captures the degree of the firm's exposure to the foreign shock.

Firm k's total import share, $s_{Fk}^{v,Total}$, is defined in a recursive manner as follows:

$$s_{Fk}^{v,Total} = s_{Fk}^{v} + \sum_{j \in Z_k} s_{jk}^{v} s_{Fj}^{v,Total}, \tag{48}$$

where s_{Fk}^{v} and s_{jk}^{v} are the shares of foreign imports and inputs from firm j in the firm's variable costs. Dhyne et al. (2021) show that firms' total import shares become relevant statistics in predicting firm-level outcomes at a first-order approximation: when the labor market is competitive, the costs of firms with higher total import shares increase more than those of firms with lower total import shares in response to a uniform increase in the price of imports. Moreover, Dhyne et al. (2023b) show that the share of import content in final consumption, which is a weighted average of firm-level total import shares, $s_F^{Total} = \sum_k s_{kH} s_{Fk}^{v,Total}$, is a relevant statistics for calculating the welfare effects of trade.

Through the measure of firms' total import shares, one can see the two main effects of fixed inputs. On the one hand, if for example a large fraction of labor costs is a fixed input, the variable cost shares of s_{Fk}^{v} and s_{jk}^{v} become larger. This will magnify any direct cost shock from an import price change and indirect cost shocks from domestic suppliers. On the other hand, some of the foreign inputs are fixed as well, which, all else equal, lowers the direct cost shock through lower values of s_{Fk}^{v}. Quantitatively, however, more than 70 percent of imports are calculated as variable inputs (based on the estimated elasticities for the NACE one-digit level classification), and since around 50 percent of labor costs are fixed, the direct foreign input share tends to be larger under fixed inputs as well.

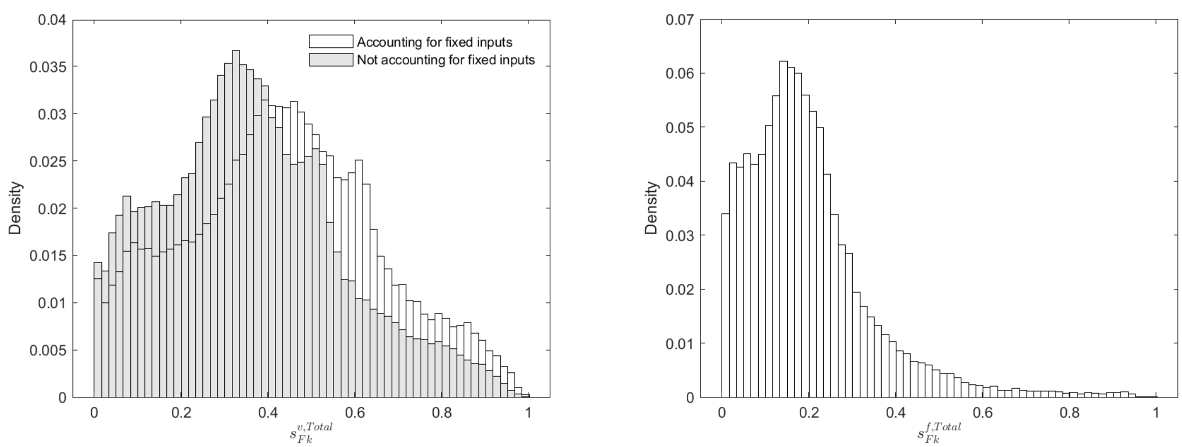
Panel (a) of Figure 11 plots the distributions of the total import shares, $s_{Fk}^{v,Total}$, one accounting for and another not accounting for fixed inputs. When one accounts for fixed inputs, the total import shares of firms in variable costs are larger (with the median firm

[35] This symmetry is called Lerner's symmetry. It implies that the outcomes from this uniform change in foreign demand can be mapped into an equivalent set of outcomes from a uniform change in import prices. In this case, the 5 percent increase in foreign tariffs on Belgian exports is equivalent to a 5 percent uniform increase in the price of Belgian imports.

having a share of 43 percent) than the total import shares of firms when not accounting for fixed inputs (with the median firm having a share of 35 percent). This difference also aggregates up when computing the share of import content in final consumption: when accounting for fixed inputs the import content share is 61 percent while it is 55 percent when not accounting for fixed inputs. Relatedly, we compute and plot the share of how much of a firm's fixed inputs originate directly or indirectly from abroad in panel (b) of the figure. We find that these shares are generally much lower than the total import share of variable inputs: 17 percent of the median firm's fixed inputs originates from abroad.

Figure 11: Total import shares

(a) Total import share in variable input costs (b) Total import share in fixed input costs



Notes: The left panel shows the distribution of the firm-level total import shares in variable input costs, $s_{Fk}^{v,Total}$, defined in equation (48). The white bars show the distribution of the shares when one accounts for fixed inputs, and the grey bars show the distribution of the shares when one does not account for fixed inputs. The right panel shows the distribution of the firm-level total import shares in fixed input costs, $s_{Fk}^{f,Total}$. Firms' total import shares in fixed input costs are defined recursively as in $s_{Fk}^{f,Total} = s_{Fk}^{f} + \sum_{j \in Z_k} s_{jk}^{f} s_{Fj}^{f,Total}$.

D.2 Incorporating nested logit structure in worker preference

In this appendix we consider an extension of the model where Belgium is no longer a single labor market. In our baseline model presented in the main text, Belgium was set to be a single labor market in which each firm is faced with a homogeneous iso-elastic labor supply curve, resulting in a constant markdown of wages. We consider a richer alternative, where Belgium is divided in multiple labor markets and workers have a nested structure in their preferences as in Lamadon et al. (2022). With this richer setup, we explore the sensitivity of how aggregate variables, such as the average real wage and real income, respond to foreign demand shocks.

D.2.1 Setup

We maintain the same preference structure for worker n as in equation (4). However, instead of assuming that ν_{nk} is distributed according to a Type-1 Extreme Value distribution with parameter ε, we assume a nested structure of

$$F\left(\overrightarrow{\nu}_n\right) = \exp\left[-\sum_m \left(\sum_{k\in J_m} \exp\left(-\beta\frac{\nu_{nk}}{\rho_m}\right)\right)^{\rho_m}\right].$$

As with ε, the parameter β governs the dispersion of taste shocks (smaller parameter value corresponds to larger dispersion). The parameter $\rho_m \in [0,1]$ governs the degree of independence in the taste shocks across firms within the labor market m (smaller ρ_m corresponds to more correlate taste shocks for firms in labor market m). In the special case where there are no correlation $\rho_m = 1$ and $\beta = \varepsilon$, then we converge back to the baseline case.

From the nested structure in workers' preference, we define a wage index for each labor market,

$$I_m = \left(\sum_{k\in J_m} \delta_k^{\frac{\beta}{\rho_m}} w_k^{\frac{\beta}{\rho_m}}\right)^{\frac{\rho_m}{\beta}}.$$

Each firm views itself as infinitesimal in the labor market and takes the wage indices I_m as given when choosing wages. The labor supply curve that each firm k faces hence becomes

$$\ell_k = L \times \underbrace{\frac{I_m^\beta}{\sum_{m'} I_{m'}^\beta}}_{\text{emp share of } m} \times \underbrace{\frac{\delta_k^{\frac{\beta}{\rho_m}} w_k^{\frac{\beta}{\rho_m}}}{I_m^{\frac{\beta}{\rho_m}}}}_{\text{firm } k\text{'s emp share in } m}. \tag{49}$$

Given this structure, the counterfactual exercise illustrated in Appendix B.5.2 can be operationalized through the following steps. First, define firm-level labor supply elasticity as $\varepsilon_k = \frac{\beta}{\rho_{m(k)}}$, and replace ε with ε_k. Second, the first equation in Step 2 will be replaced with

$$\hat{\ell}_k = L\frac{\left(\frac{\sum_{j\in J_{m(k)}}\ell_j}{\sum_{j\in J_{m(k)}}\ell_j\hat{w}_j^{\varepsilon_j}}\right)^{1-\rho_{m(k)}}}{\sum_{m'}\left(\frac{\sum_{j\in J_{m'}}\ell_j}{\sum_{j\in J_{m'}}\ell_j\hat{w}_j^{\varepsilon_j}}\right)^{1-\rho_{m'}}\left(\sum_{j\in J_{m'}}\ell_j\hat{w}_j^{\varepsilon_j}\right)}\hat{w}_k^{\varepsilon_k}.$$

D.2.2 Estimation

In estimating β and ρ_m, we follow Lamadon et al. (2022) and consider idiosyncratic firm-level shocks and market-level shocks. From the idiosyncratic firm-level foreign demand shocks that exogenously shift firms' sales, we obtain the following relationship that is derived from the new labor supply curve of equation (49).

$$\frac{d\log w_k\ell_k}{d\log p_kq_k} \Big/ \frac{d\log \ell_k}{d\log p_kq_k} = \frac{1+\frac{\beta}{\rho_{m(k)}}}{\frac{\beta}{\rho_{m(k)}}}.$$

The above equation is analogous to equation (17), and it allows us to estimate $\frac{\beta}{\rho_m}$ by running the second stage regressions (22) for each market, where firm-level labor costs and employment are the outcome variables. The estimated labor supply elasticity, $\varepsilon_k = \frac{\beta}{\rho_{m(k)}}$, can now vary at the labor market-level. We use these estimated values to back out the variable cost shares in labor costs using equation (15), which will now also potentially vary at the market-level.

From the same labor supply curve of equation (49), we obtain the following relationship between labor market-level employment changes and the weighted average wage changes in each market (with weights being the firm's employment share in the market).

$$d\log\left(\sum_{k\in J_m}\ell_k\right) = d\log\left(\frac{L}{\sum_{m'} I_{m'}^{\beta}}\right) + \beta\left(\sum_{k\in J_m} \underbrace{\frac{\delta_k^{\frac{\beta}{\rho_m}} w_k^{\frac{\beta}{\rho_m}}}{I_m^{\frac{\beta}{\rho_m}}}}_{\text{firm } k\text{'s emp share in } m} d\log w_k\right). \tag{50}$$

We operationalize these estimating equations by defining labor markets as the interaction of NACE three-digit industries (230 industries) and NUTS level 3 regions (43 regions). We consider two alternative assumptions on how ρ_m vary across labor markets. First, we assume that ρ_m are common across all labor markets. This implies $\varepsilon = \frac{\beta}{\rho_m}$ $\forall m$ and β is identified off equation (50). For each labor market, we aggregate employment changes, wage changes, and also aggregate the export demand shocks (using the same employment shares as weights), and obtain the estimate for β. We include in the regression year fixed effects and control for the weighted aggregate of firms' total household revenue shares. As reported in Table 13, we find that the estimate for β is 3.2, and because $\varepsilon = 3.9$, the common parameter of ρ is calculated to be 0.82.

The second assumption we consider is that ρ_m are heterogeneous but common at a higher level of labor market aggregation. In particular, we assume that ρ_m vary across six broad markets, which are defined as the interaction of NUTS level 1 regions (Brussels, Flanders, and Wallonia) and manufacturing versus non-manufacturing sectors. We estimate the labor supply elasticity $\frac{\beta}{\rho_m}$ for each broad market, and using $\beta = 3.2$ we back out the estimates for

Table 13: Market-level IV estimates of labor supply elasticity

	(1) Four-year difference of log employment
Panel A: IV estimates	
Labor supply elasticity (β)	3.171**
	(1.521)
Panel B: First stage	
First stage	0.0652**
	(0.0254)
Panel C: Reduced form	
Reduced form	0.207***
	(0.0503)
First-stage F-statistics	6.62
Implied ρ	0.82
Year FE	Yes

Notes: This table reports the second stage, first stage, and reduced form results of specification (50), where we regress employment changes on weighted average wage changes instrumented by the export demand shocks, all aggregated at the labor market level. For wage changes and export demand shocks, we use firms' employment shares as weights. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

ρ_m. The estimated values for ρ_m range from 0.64 to 1.[36]

D.2.3 Counterfactual results

Using the two alternative sets of estimates, we conduct counterfactual exercises that are analogous to those in Section 6. In particular, we consider a five percent increase in foreign tariffs on all Belgian exports and compute how the average real wage and real income respond to this shock.

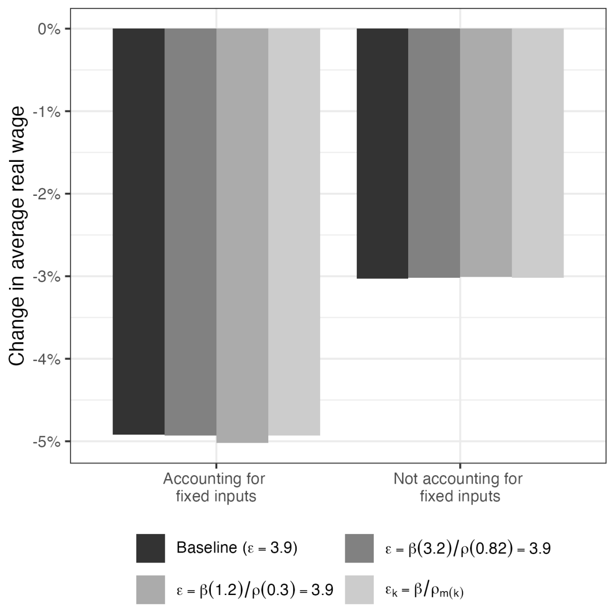
Figures 12 and 13 report the counterfactual results for the average real wage and real income, respectively. The leftmost black bars in the table reports the results in our baseline case where Belgium is treated as one labor market, and are identical to the black bars in Figures 6 and 14. The second bars from the left allow for multiple labor markets but assume a common ρ, with the estimated values of $\beta = 3.2$ and $\rho = 0.82$. Because the estimated value of ρ is close to 1 in which case the model collapses to the baseline model, the quantitative impact of allow for multiple labor markets are small. The third bars from the left still assume a common value of ρ, but use alternative values of β and ρ to explore sensitivity of the results. We consider a lower value of ρ with $\rho = 0.3$, and maintain that firms face a labor supply curve with elasticity of $\varepsilon = \frac{\beta}{\rho} = 3.9$, hence $\beta = 1.2$. We find that higher correlation of taste shocks within labor markets magnifies the responses of real wage, but

[36]Estimation results available upon request. When the point estimate for $\frac{\beta}{\rho_m}$ is smaller than 3.2, we set ρ_m to be 1 as ρ_m is bounded from above by 1. This correcting procedure was done for the two estimates involving Wallonia.

the magnitudes of the differences are quantitatively small. The rightmost bars allow for heterogeneous ρ_m that are estimated for each broad labor market. Again, we see a small impact of labor market heterogeneity as the estimated values of ρ_m are generally close to 1.

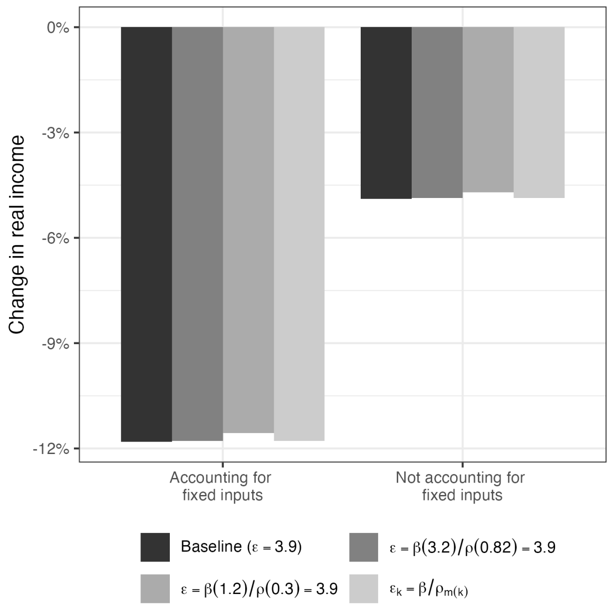
Taken together, the figures imply that allowing for a more general structure in worker preference by incorporating multiple labor markets and potentially heterogeneous markdowns on wages do not quantitatively alter the predictions of aggregate responses to foreign demand shocks.

Figure 12: Changes in average real wage in response to a 5 percent reduction in foreign tariffs (alternative worker preference)



Notes: In this figure, we report the changes in average real wage, $\sum_k \frac{w_k \ell_k}{\sum_j w_j \ell_j} \hat{w}_k \hat{\ell}_k / \hat{P}$, due to a 5 percent reduction in foreign tariffs. Each bar represents the response under different structures of worker preference. The baseline results in the leftmost bars are identical to the black bars in Figure 6. The middle two bars use ρ that is common across labor markets, with one using the estimated values of $\beta = 3.2$ and $\rho = 0.82$, and another using $\beta = 1.2$ and $\rho = 0.3$. The rightmost bars under $\varepsilon = \frac{\beta}{\rho_m}$ assume a preference structure where ρ_m varies across six broad labor markets.

Figure 13: Changes in real income in response to a 5 percent reduction in foreign tariffs (alternative worker preference)

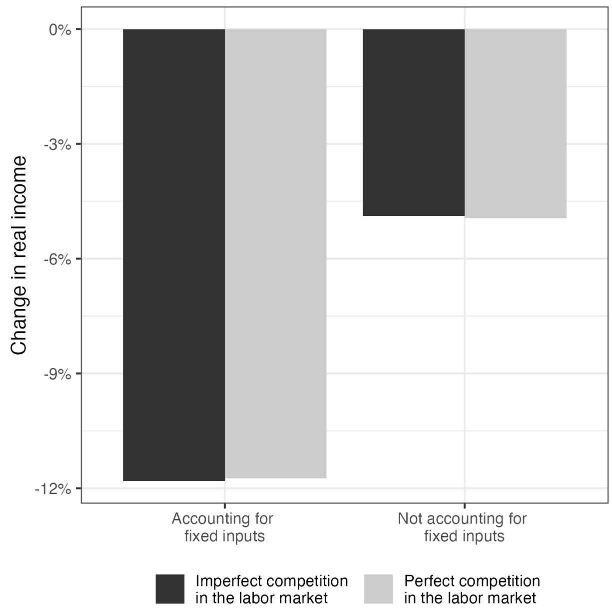


Notes: In this figure, we report the changes in real income, $\hat{E}/\hat{P}$, due to a 5 percent reduction in foreign tariffs. Each bar represents the response under different structures of worker preference. The baseline results in the leftmost bars are identical to the black bars in Figure 6. The middle two bars use ρ that is common across labor markets, with one using the estimated values of $\beta = 3.2$ and $\rho = 0.82$, and another using $\beta = 1.2$ and $\rho = 0.3$. The rightmost bars under $\varepsilon = \frac{\beta}{\rho_m}$ assume a preference structure where ρ_m varies across six broad labor markets.

D.3 Changes in real income

Figure 14 reports the changes in real income, $\hat{E}/\hat{P}$, in response to a 5 percent increase in foreign tariffs.

Figure 14: Changes in real income in response to a 5 percent increase in foreign tariffs

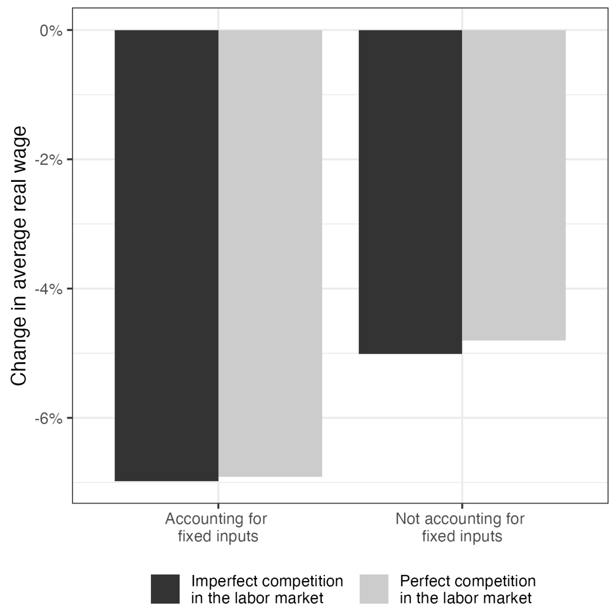


Notes: In this figure, we report the changes in real income, $\hat{E}/\hat{P}$, due to a uniform 5 percent increase in foreign tariffs on Belgian exports. Each bar represents the response under different parameterizations of the model presented in Section 3. We use our estimated labor supply elasticity $\varepsilon = 3.9$ in the counterfactual Belgian economies with upward-sloping labor supply curves. When accounting for fixed inputs, we use the fraction of fixed inputs for both labor and intermediate inputs (at NACE one-digit level) that we obtained in Section 5.

D.4 Domestic productivity shocks

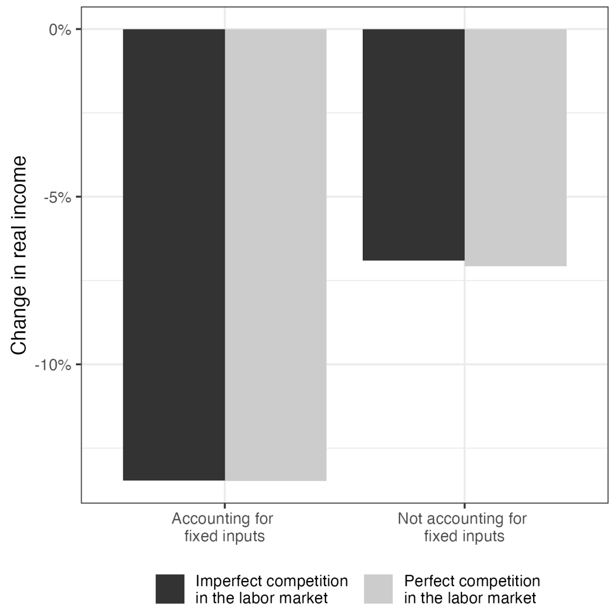
Figures 15 and 16 report the changes in average real wage and real income in response to a 5 percent reduction in productivity ϕ_k for all manufacturing firms. We outline the steps to solve for the counterfactual outcomes in Appendix B.5.3.

Figure 15: Changes in average real wage in response to a 5 percent reduction in manufacturing firms' productivity



Notes: In this figure, we report the changes in average real wage, $\sum_k \frac{w_k \ell_k}{\sum_j w_j \ell_j} \hat{w}_k \hat{\ell}_k / \hat{P}$, due to a 5 percent reduction in manufacturing firms' productivity. Each bar represents the response under different parameterizations of the model presented in Section 3. We use our estimated labor supply elasticity $\varepsilon = 3.9$ in the counterfactual Belgian economies with upward-sloping labor supply curves. When accounting for fixed inputs, we use the fraction of fixed inputs for both labor and intermediate inputs (at NACE one-digit level) that we obtained in Section 5.

Figure 16: Changes in average real income in response to a 5 percent reduction in manufacturing firms' productivity



Notes: In this figure, we report the changes in real income, $\hat{E}/\hat{P}$, due to a 5 percent reduction in manufacturing firms' productivity. Each bar represents the response under different parameterization of the model presented in Section 3. We use our estimated labor supply elasticity $\varepsilon = 3.9$ in the counterfactual Belgian economies with upward-sloping labor supply curves. When accounting for fixed inputs, we use the fraction of fixed inputs for both labor and intermediate inputs (at NACE one-digit level) that we obtained in Section 5.