Supplier Churn and Growth: A Micro-to-Macro Analysis

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Abstract

It is widely believed that access to new suppliers leads to consumer surplus and that this surplus drives long-run growth and international trade. Despite its importance, little direct empirical evidence exists on the size of this force. We investigate the importance of this effect for both micro- and macroeconomic outcomes using detailed Belgian data. Instrumenting for supplier entry and exit, we find that the elasticity of downstream firms' marginal costs to the cost share of entering and exiting suppliers is around 0.25%. That is, marginal costs rise when suppliers are exogenously lost and they fall when suppliers are exogenously added. We show that this elasticity measures the ratio of the area under the input demand curve to expenditures, and can be used to calibrate love-of-variety and quality-ladder models. We develop a macroeconomic growth-accounting framework that quantifies the importance of supplier addition and separation for aggregate growth. Using firm-level production network data and estimated microeconomic elasticities, we show that supplier churn plausibly accounts for as much as half of aggregate productivity growth.

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†Emmanuel Farhi tragically passed away in July, 2020.

1 Introduction

It is widely believed that suppliers create surplus for their consumers, and this surplus can drive economic growth and motivate international trade. Despite its importance, little direct empirical evidence exists on the size of this force. Our study consists of a microeconomic and a macroeconomic part. In the microeconomic part, we define a statistic, the "inframarginal surplus" ratio, which quantifies consumer surplus from additional suppliers per unit of expenditures. We show that the inframarginal surplus ratio is an important statistic in many models of growth and trade, including expanding-variety and quality-ladder models.[1] We propose a strategy to estimate it and implement this strategy using microeconomic data from Belgium. In the macroeconomic part, we develop a growth accounting framework to assess the contribution of supplier churn to economy-wide productivity growth. We apply our growth-accounting framework to Belgian firm-to-firm production network data from value-added tax (VAT) filings, using the estimates of inframarginal surplus ratio from the first part of the paper. We discuss the two parts of the paper in turn.

To estimate the inframarginal surplus ratio at the micro-level, we employ a unique approach that enables us to estimate the area under the input demand curve without specifying the demand system itself, thus reducing potential errors due to misspecification and extrapolation. We show that the inframarginal surplus ratio can be estimated as the elasticity of downstream firms' marginal costs with respect to upstream entry and exit. Bypassing a fully specified demand system is useful because it would be extremely high dimensional in our dataset, and could only be estimated under very strong functional form assumptions.

Our estimates use a detailed survey of manufacturing firms in Belgium called Prodcom. This survey contains sales and quantity information for manufacturing firms in Belgium. We merge this data with firm-to-firm input-output linkage information from VAT returns. Using this tax information, we observe at annual frequency almost all suppliers of the firms in Prodcom. We calculate a measure of marginal cost for Prodcom firms as the log change in average variable costs and regress it on supplier additions and separations. We show that, when this regression is consistently estimated, the coefficient should identify the inframarginal surplus ratio.

To achieve consistent estimation, we instrument the addition and subtraction of sup-

[1] Expanding varieties models of growth and trade include Dixit and Stiglitz (1977), Krugman (1979), Romer (1987), and Melitz (2003). Ricardian models of growth and trade include Dornbusch et al. (1977), Aghion and Howitt (1992), and Eaton and Kortum (2002). For a synthesis of these models see Grossman and Helpman (1993), Acemoglu (2009), and Costinot and Rodriguez-Clare (2014).

pliers using firm births and deaths. To ensure that births and deaths of upstream suppliers are not driven by idiosyncratic shocks to their downstream customers, we restrict attention to entry and exits of suppliers for whom the downstream firm is small as a share of their customer base (e.g., less than 5%). For both entry and exit, the identification requirement is that addition and separation of suppliers caused by our instrument is not correlated with idiosyncratic shocks to the downstream firms' marginal costs, like the downstream firm's productivity shocks. We also control for other input prices and include 6-digit by year and firm fixed effects to allow for industry-level shocks and differential trends among firms.

We find significant microeconomic effects of supply linkage destruction and creation on downstream marginal costs. According to our baseline estimates, if 1 percentage point of a firm's suppliers, in terms of its variable costs share, exit or enter, then this raises or lowers its marginal cost by around 0.25 percentage points. We also find a reduced-form pass-through from marginal costs into prices of around 60%. That is, a little over half the changes in marginal costs are passed onto downstream customers while the remaining 40% are absorbed by markups.

Our estimate of the area under the input demand curve implies that in a CES expanding varieties model, the "love-of-variety" effect corresponds to an elasticity of substitution of roughly 5. In a quality-ladder model with unitary elasticities between inputs, the surplus corresponds to an innovation step-size of around 25 log points. In other words, at the microeconomic level, the destruction and creation of supply linkages has sizeable effects on downstream marginal costs.

Our estimates of the integral of demand are related to the broader objective of measuring different derivatives of demand curves. Estimates of the first derivative of demand are common, since the first derivative of demand affects the price elasticity of demand (see, e.g., Berry and Haile, 2021). The second derivative of demand has also received considerable empirical attention, since it determines the pass-through of marginal cost into the price (see, e.g., Burstein and Gopinath, 2014 for a survey on exchange rate pass-through). Even the third derivative of demand is an important statistic, because it disciplines the rate at which pass-through changes along the demand curve (e.g. Amiti et al., 2019).

All these objects can be estimated by considering small changes: the price elasticity is disciplined by how quantity responds to small price changes, the superelasticity by how prices respond to small changes in marginal costs, and the change in the super elasticity by how pass-through responds to small changes in marginal costs. In contrast, the area under the demand curve is more "global" in the sense that it depends on the entire shape of the demand curve, not just its properties around an observed point. The stan-

dard approach in the literature then is to estimate a fully parametric demand system and explicitly integrate demand curves to measure consumer surplus. Our paper shows that, in a production context, this is not necessary and the area under the input demand curve can be estimated directly without specifying the global demand system.

In the macroeconomic part of the paper, we develop a growth-accounting framework to quantify the importance of supplier churn for measured aggregate growth, adding an extensive margin for supplier entry and exit to otherwise standard growth accounting formulas (i.e. Solow, 1957; Domar, 1961; Hulten, 1978; Basu and Fernald, 2002; Baqaee and Farhi, 2019b). We take into account how the formation and separation of supplier links affects the prices of downstream firms, and how these price changes are transmitted along existing supply chains from supplying firms to purchasing firms, all the way down to final consumers.

Our accounting framework does not require a fully spelled-out model of market structure, factor markets, or link formation but is consistent with many different structural models. We discipline our growth accounting exercises using our microeconomic regression estimates. When we extrapolate our microeconomic estimates of the inframarginal surplus to the whole of the Belgian economy, we find that as much as half of long-run aggregate productivity growth can be accounted for by churn in the supply chain.

The structure of the paper is as follows. Section 2 contains theoretical microeconomic results. These results motivate our microeconomic empirical strategy, which we describe and report in Section 3. Section 4 introduces the aggregation framework and presents our theoretical macroeconomic results. We use these results, and our earlier microeconomic estimates, to decompose aggregate growth in our data in Section 5. We conclude in Section 6.

Related literature. Our paper is related to three different literatures. First, as discussed above, our analysis contributes to expanding-varieties and quality-ladder models of entry and exit. In these models, a key object of interest and source of welfare gains is either the love for product variety or the gap in quality between incumbents and entrants.

The love-of-variety effect is usually defined using an elasticity of the utility function.[2]

[2]The love-of-variety effect has been theoretically studied by Zhelobodko et al. (2012), Dhingra and Morrow (2019), Baqaee et al. (2020), and Matsuyama and Ushchev (2020), amongst many others. The love-of-variety effect is sometimes viewed with suspicion since it is not easily measured and does not show up in conventional index number statistics. This may be exacerbated by the fact that in models where it plays a central role, it is often described using variables that are unobservable. For example, Vives (1999), Benassy (1996), Zhelobodko et al. (2012), and Dhingra and Morrow (2019) all use definitions that rely on the elasticity of the utility function with respect to quantity — an inherently unobservable object since utility is only defined up to monotone transformations.

In this paper, we define love-of-variety using the area under the demand curve instead. Unlike the elasticity of the utility function, the area under the demand curve is, in principle, observable. Furthermore, this definition clarifies the concept of love-of-variety by showing that it corresponds to changes in marginal cost resulting from significant (non-marginal) changes in input prices. If one is comfortable with the idea that small input price changes have effects on costs and welfare, then one should also be comfortable with the love-of-variety effect. Moreover, our definition, which is based on the area under the demand curve, can be applied to a much broader class of demand systems than standard definitions.

We contribute to the expanding-variety and quality-ladder literatures by directly estimating the inframarginal surplus lost when firms lose access to suppliers. We can do this because our data allows us to measure costs, output quantities, and firms' suppliers. In lieu of this data, researchers have typically relied on very indirect evidence to discipline the consumer surplus from new suppliers in their models. For example, expanding-varieties models typically use a CES demand system, where the price elasticity of residual demand at any point on the demand curve also controls the love-of-variety effect. Similarly, in quality ladder models, researchers typically discipline the step-size between the best and second-best supplier by indirect inference via matching moments on firm employment dynamics, patents, and growth (see Garcia-Macia et al., 2019 and Akcigit and Kerr, 2018 for example).[3,4]

The second literature our paper is related to is the one on production networks, particularly those with an extensive margin. For example, Baqaee (2018) and Baqaee and Farhi (2020) show that cascades of supplier entry and exit in production networks change how aggregate output responds to microeconomic shocks. The response of aggregate output to a microeconomic shock, in turn, crucially depends on the same notion of surplus as discussed above. The importance of the extensive margin of firm-to-firm linkages has also been emphasized and studied by Oberfield (2018), Lim (2017), Tintelnot et al. (2018), Acemoglu and Tahbaz-Salehi (2020), Elliott et al. (2020), Taschereau-Dumouchel (2020), Kopytov et al. (2022), and Bernard et al. (2018). Empirical studies by Jacobson and

[3]There is a large literature that provides reduced-form evidence of how changes in policies (e.g. import tariffs) impact firm outcomes such as productivity, markups, and firm product-scope. See, for example, Amiti and Konings (2007), Brandt et al. (2017), Goldberg et al. (2010), and De Loecker et al. (2016). Although this literature provides suggestive evidence that input variety matters for firm-level outcomes, it does not provide an estimate of how large these gains are.

[4]There is a large body of work that decomposes changes in a weighted-average of firm-level productivities into reallocation, entry, and exit terms (see e.g. Baily et al., 1992; Foster et al. 2001). However, the object these studies decompose is not aggregate productivity in a growth accounting sense — that is, it does not measure the gap between real output and real input growth. See Petrin and Levinsohn (2012), Hsieh et al. (2018), Baqaee and Farhi (2019b), and Baqaee et al. (2020) for more details.

Von Schedvin (2015), Barrot and Sauvagnat (2016), Carvalho et al. (2021), and Miyauchi et al. (2018) have shown that shocks and failures to one firm are transmitted across supply chains and affect the sales and employment of other firms in neighboring parts of the production network. Huneeus (2018) and Arkolakis et al. (2021) study adjustment costs in link-formation between firms and their aggregate consequences using a structural model. Boehm and Oberfield (2020) document that link formation is affected by institutional distortions and that this can reduce aggregate productivity. Our paper complements this literature by providing direct estimates of the value of link formation at the microeconomic level and a growth accounting exercise that quantifies the macroeconomic importance of supplier churn. Unlike this literature, we take the formation and separation of links between firms as given (i.e. we take them from the data), and do not provide a fully specified model for counterfactuals.

Third, our paper is also related to a deep literature on correcting price indices to account for the entry and exit of goods. Our macroeconomic exercise quantifies the importance of supplier entry and exit for *measured* growth. The macroeconomic and trade literatures on the importance of entry and exit, which trace their origins to Hicks (1940), have been greatly influenced by Feenstra (1994) who introduced a methodology for accounting for product entry and exit, or other types of mismeasurement, under a CES demand system. This CES methodology owes its popularity to its simplicity and nondemanding information requirements. Broda and Weinstein (2006) apply it to calculate welfare gains from trade due to newly imported varieties, and Broda and Weinstein (2010) compute the unmeasured welfare gains from changes in varieties in consumer non-durables. Using a similar methodology, Jaravel (2016) calculates the gains from consumer product variety across the income distribution, while Gopinath and Neiman (2014), Melitz and Redding (2014), Halpern et al. (2015), and Blaum et al. (2018) study the welfare gains from trade in intermediate inputs.[5] Aghion et al. (2019) build on this methodology to correct aggregate growth rates for expanding varieties and unmeasured quality growth. Outside of the CES literature, Hausman (1996), Feenstra and Weinstein (2017), and Foley (2022) have provided alternative price index corrections that dispense with the CES assumptions.

A universal theme in this literature is to estimate or calibrate price elasticities of demand and infer the value of entering and exiting products by inverting or integrating demand curves under parametric restrictions (e.g. isoelastic, linear, or translog demand). Our approach differs from this literature in that we attempt to identify the area under the

[5]The methodology of Feenstra (1994) requires knowledge of the elasticity of substitution, which is typically estimated using data on expenditure switching. Blaum et al. (2018) instead uses changes in the buying firm's revenues (and parametric assumptions on the production function and demand for the buying firms' output) to estimate the elasticity of substitution between imports and domestic inputs.

input demand curve directly through its effect on downstream marginal costs rather than via implicit or explicit integration of demand curves. This is because we focus on production, and for producers the value of an input can be measured by its effect on costs. In contrast, the literature typically focuses on the value of new goods in consumption, where there is no observable counterpart to marginal cost.[6]

2 Microeconomic Value of Link Formation: Theory

In this section, we derive expressions for how supplier entry-exit affects a downstream firm's marginal cost. The partial equilibrium results in this section serve as the basis for our firm-level regressions in Section 3. We delay general equilibrium and aggregation to Sections 4 and 5.

2.1 Direct Approach Using Area Under Demand Curve.

Consider a *downstream* firm, indexed by i whose variable cost function is

$$\mathcal{C}_i(\boldsymbol{p}, A_i, q_i) = mc_i\left(\boldsymbol{p}, A_i\right) q_i,$$

where $\boldsymbol{p}$ is the vector of quality-adjusted input prices, A_i indexes technology, and q_i is the total quantity of output. We allow the firm to have fixed costs of operation, but assume that variable production has constant returns to scale. We allow for the possibility that the price of some inputs is equal to infinity (i.e. some inputs are not available).[7]

Assume that there is a continuum of inputs that can be grouped into types. The cost function is symmetric in input prices that belong to the same type but not necessarily symmetric across types. More formally, two inputs belong to the same group if swapping their prices does not affect variable cost. This assumption ensures that the downstream firm's input demand curve for all varieties of a given type j are the same function $x_{ij}(\boldsymbol{p}, A_i, q_i)$.

We do not restrict own-type or cross-type price elasticities. We assume without loss of further generality that inputs of the same type also have the same initial price. We can do

[6]For a producer, marginal costs of production are, at least in principle, observable. However, for a household, the derivative of the expenditure function with respect to utility is an unobservable nuisance parameter that measures how the utility function is cardinalizing the underlying preference relation. This is because unlike quantity produced, utility is only defined up to monotone transformations.

[7]In the body of the paper, we assume that firms take input prices as given. In Appendix B, we show that, under some additional assumptions, our empirical strategy is also valid if firms face a schedule of input prices as a function of input quantities instead. This input price schedule, which we take as given, could, for example, be the outcome of second-degree price discrimination or a bargaining process.

this by defining inputs with the same input demand function that have different initial prices to be different types. To simplify notation, we assume that there is a countable number of types. Let M_{ij} denote the mass of inputs of type j used by firm i.

Almost all popular production technologies used in the macroeconomics and trade literatures feature a notion of "types." For example, for CES, we say two inputs have the same type if they have the same share parameter and price. For the Kimball (1995) demand system, the homothetic demand systems introduced by Matsuyama and Ushchev (2017), and the separable demand system introduced by Fally (2022), we say that two inputs have the same type if they share the same residual demand function and the same price.

Our paper focuses on the creation and destruction of buyer-supplier relationships. These events are typically discrete in the sense that when suppliers are added or dropped, expenditures change discontinuously. To account for this phenomenon, we introduce the concept of a *jump* in the price of an input j, which is defined by the size of the jump or the *step-size* $z_{ij} = \Delta \log p_j$. This means that for each input type j, there is a possibility of a discontinuous change in its price.

A jump in the quality-adjusted price of inputs can capture both quality-ladder and expanding-variety models of entry-exit. In quality-ladder models, an input's price jumps when a new supplier displaces an incumbent. If the new (quality-adjusted) price is greater than the initial price, this represents a move down the quality ladder, and if the new (quality-adjusted) price is less than the initial price, this represents a move up the quality ladder.[8]

In expanding-variety models, prices jump to infinity when a variety is dropped and become finite when a new variety is added. This means that in expanding-variety models, the step-size is plus or minus infinity.[9] Empirically, we identify jumps in the data that can be attributed to exogenous supplier additions and separations. We do not investigate price jumps that may be occurring within continuing buyer-supplier relationships, which could be caused by process or product innovation from continuing suppliers.

[8] In many quality-ladder models, the best supplier limit-prices the second-best supplier and provides the input at the marginal cost (quality adjusted) of the second-best supplier. This means that each time a supplier is replaced by a better supplier, the change in the input price is the gap between the marginal cost of the second- and third-best supplier. If the step-size is constant, then this is the same as the gap in the marginal cost of the best and second-best supplier. In some models, however, like Fontaine et al. (2022), the step-size is not constant. Nevertheless, the surplus for the downstream firm is determined by the jump in the (quality-adjusted) input price, which may or may not be equal to the jump in the marginal cost of the supplier.

[9] Technically, the price need only jump to/from the reservation or choke price (the price at which demand is zero). However, since demand is zero beyond the choke price, we can also think of the price as jumping to/from infinity.

Define the *inframarginal surplus ratio* associated with a change in the price of input j (holding the price of all other inputs constant) to be

$$\delta_{ij}(p_j, p_j') = \frac{\int_{p_j}^{p_j'} x_{ij}(\xi) d\xi}{p_j x_{ij}(p_j)} \geq 0, \tag{1}$$

where we define p_j to be the lower price and p_j' to be the higher of the two possible prices for input i. Equation (1) is the surplus to i from the jump in the price of input j per unit of expenditures. Since we define p_j to always be the lower of the two possible prices, δ_{ij} is always a non-negative number. As long as the demand curve is strictly downward sloping, δ_{ij} is strictly positive.[10] If the demand curve is perfectly horizontal, then $\delta_{ij} = 0$.

Denote the input share of each type-j variety purhcased by firm i to be Ω_{ij}:

$$\Omega_{ij} = \frac{p_j x_{ij}(\boldsymbol{p}, A)}{\mathcal{C}_i(\boldsymbol{p}, A_i, q_i)}.$$

The next proposition loglinearizes the downstream firm's marginal cost.

Proposition 1 (Downstream Marginal Cost)**.** *Consider a change in the vector of input prices by type $\Delta \boldsymbol{p}$, the vector of the measure of inputs whose price jumps $\boldsymbol{m}_i$, and the technology parameter ΔA_i. To a first-order approximation in these primitives, the change in the downstream firm's marginal cost is*

$$\Delta \log mc_i \approx \underbrace{\sum_j \Omega_{ij} M_{ij} \Delta \log p_j}_{\textit{marginal changes}} + \underbrace{\sum_j \Omega_{ij} m_{ij} \delta_{ij} \left[\mathbb{1}(z_{ij} > 0) - \mathbb{1}(z_{ij} < 0)\right]}_{\textit{inframarginal jumps}} + \underbrace{\frac{\partial \log \mathcal{C}_i}{\partial \log A_i} \Delta \log A_i}_{\textit{own technology}}. \tag{2}$$

In words, the change in the marginal cost of the downstream firm depends on the costs of its inputs, captured by the first two summands, as well as its own technology, the last summand. The price of inputs can change on the margin or they can jump. If the change in input prices is small, then their effect on the downstream firm's marginal cost depends on the expenditures on the input. On the other hand, if input prices jump discretely, then their effect on the downstream firm's marginal cost depends on the area under the input demand, which is captured by the product of δ_{ij} and expenditures on the inputs whose price jumps $\Omega_{ij} m_{ij}$. That is, movements along the quality ladder and variety

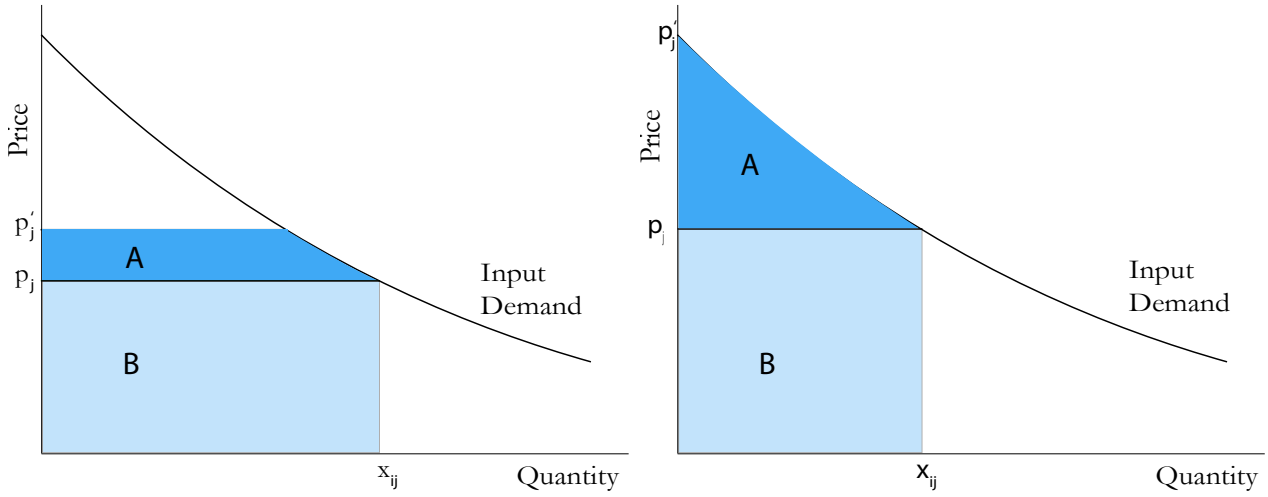
[10] In equation (1), we suppress dependence of the conditional input demand x_{ij} on arguments other than the price of j since those other arguments are being held constant. We include the additional arguments when it helps the exposition.

creation generate surplus for the downstream producer according to the area under the input demand curve.

The inframarginal surplus ratio, δ_{ij}, is depicted in Figure 1. The left panel depicts a jump along the quality ladder where the price jumps from p_j to p_j'. The right panel depicts the case where the price p_j jumps to infinity. The former is a quality-ladder model and the latter is an expanding-variety model. In both cases, the inframarginal surplus ratio is given graphically by

$$\delta_{ij} = \frac{A}{B} \geq 0.$$

Either way, this jump in input price raises the costs of production by an amount commensurate with δ_{ij}, and this is weighted by expenditures on this input.



(a) Quality ladder

(b) Expanding variety

Figure 1: Graphical illustration of input price jump. In both figures, the inframarginal surplus ratio δ_{ij} is A/B.

To better understand Proposition 1, we work through some simple examples.

Example 1 (CES with Quality Ladders)**.** Consider the CES special case, in which the demand for an input variety of type j takes the form

$$x_{ij} = \frac{b_{ij} p_j^{-\sigma} q_i}{\left(\sum_k b_{ik} p_k^{1-\sigma} M_{ik}\right)^{\frac{-\sigma}{1-\sigma}}}, \tag{3}$$

where b_{ij} and b_{ik} are exogenous parameters. Suppose that the producer of the best input with price p_j exits and is displaced by the next-best competitor whose quality-adjusted

price p_j' is higher. The inframarginal surplus ratio associated with this jump is

$$\delta_{ij} = \frac{\int_{p_j}^{p_j'} x_{ij}(\xi)d\xi}{p_j x_{ij}} = \frac{1}{\sigma - 1}\left(1 - \left(\frac{p_j'}{p_j}\right)^{1-\sigma}\right) \geq 0.$$

Proposition 1 implies that the change in the downstream firm's marginal cost in response to the destruction of a mass m_{ij} of input j is

$$\Delta \log mc_i = \Omega_{ij} m_{ij} \delta_{ij} = \frac{1}{\sigma - 1}\Omega_{ij} m_{ij}\left(1 - \left(\frac{p_j'}{p_j}\right)^{1-\sigma}\right). \tag{4}$$

In the $\sigma \to 1$ limit, the inframarginal surplus ratio δ_{ij} is equal to the innovation step-size $\log(p_j'/p_j)$, and $\Delta \log mc_i = \Omega_{ij} m_{ij} \log(p_j'/p_j)$.

Example 2 (CES with Expanding Varieties)**.** Now suppose that when j exits, there is no next-best producer of that input, so that the new price is infinite, $p_j' = \infty$ in (4). In this case, δ_{ij} simplifies to $1/(\sigma - 1)$. Hence, in response to a change in the availability of some varieties of type j, the change in the downstream marginal cost is

$$\Delta \log mc_i = \Omega_{ij} m_{ij} \delta_{ij} = \frac{1}{\sigma - 1}\Omega_{ij} m_{ij}. \tag{5}$$

This is the so-called "love-of-variety" effect and is just the limiting case of quality-ladders where the step size is infinitely large.

Due to the near-ubiquitous use of the CES demand system, "love-of-variety" is sometimes conflated with the price elasticity of demand. However, as pointed out by Dixit and Stiglitz (1977), outside of the expanding-variety CES model, these two statistics are not the same. In fact, under a plausible condition, we can show that the surplus produced by new varieties is maximized by the CES demand system.

Proposition 2 (Inframarginal Surplus with Marshall's Second Law)**.** *Denote the own-price elasticity of i's demand for input j by*

$$\sigma_{ij}(\boldsymbol{p}) = -\frac{\partial \log x_{ij}(\boldsymbol{p})}{\partial \log p_j} > 1.$$

Marshall's second law of demand *holds if* $\partial\sigma_{ij}/\partial p_j > 0$. *Under this condition,*

$$\delta_{ij}(\boldsymbol{p}, p_j') < \frac{1}{\sigma_{ij}(\boldsymbol{p}) - 1}\left[1 - \frac{p_j' x_{ij}(p_j')}{p_j x_{ij}(p_j)}\right] \tag{6}$$

as long as $\sigma_{ij}(\boldsymbol{p}) \geq 1$.

Note that the right-hand side of (6) is the inframarginal surplus ratio implied by a CES demand system calibrated to match the initial price elasticity of demand, the initial expenditure share, and the change in the expenditure share caused by the price jump.[11] Hence, if we match the initial price elasticity of demand, and the pre- and post-jump expenditure share, then the inframarginal surplus ratio implied by CES is strictly larger than the true one, as long as as Marshall's second law holds.[12] For a specific example, see Appendix B.

3 Empirical Microeconomic Results

Motivated by the results in Section 2, we consider regressions aimed at identifying the inframarginal surplus ratio associated with gaining access to a new supplier or losing access to existing suppliers. We model the benefits of gaining additional suppliers as the price of some inputs jumping down. On the other hand, we model the losses from losing access to existing inputs as the price of some inputs jumping up.

To estimate the average inframarginal surplus ratios associated with such events, consider the following regressions

$$\Delta \log mc_{it} = \hat{\delta}^{\text{exit}} \times \text{separation share}_{it} + \text{controls}_{it} + \varepsilon_{it}, \tag{7}$$

and

$$\Delta \log mc_{it} = \hat{\delta}^{\text{entry}} \times \text{addition share}_{it+1} + \text{controls}_{it} + \varepsilon_{it}. \tag{8}$$

The separation share is the share of i's total variable cost spent on suppliers who separate between t and $t+1$. The addition share is the share of i's total variable cost spent on suppliers who are added between t and $t+1$. If suppliers are only added due to prices jumping down ($z_{ij} < 0$) and they are only dropped due to prices jumping up ($z_{ij} >$

[11] Compare with the expression in (4) and use the fact that $(p_j'/p_j)^{1-\sigma} = (p_j' x_i(p_j'))/(p_j x_i(p_j))$.

[12] The proof builds on similar results in Matsuyama and Ushchev (2020) and Grossman et al. (2021). They prove a similar result assuming the input demand system belongs to the HSA/HDIA/HIIA class and the step size is infinite.

0), then Proposition 1 implies that the estimated coefficients $\hat{\delta}^{\text{exit}}$ and $\hat{\delta}^{\text{entry}}$ (the latter with a negative sign) should reflect inframarginal surplus ratios associated with positive and negative jumps. For example, if every input supplier sells a differentiated good and technology is CES with elasticity σ, then $\hat{\delta}^{\text{exit}} = -\hat{\delta}^{\text{entry}} = 1/(\sigma - 1)$.

However, Proposition 1 also elucidates some threats to identification if we rely on an OLS regression. First, the error term includes own technology shocks and changes in the prices of those continuing suppliers that we do not directly control for, both of which are plausibly correlated with the share of added and lost suppliers. For example, suppliers may be dropped or added due to shocks to the downstream firm's technology or changes in other suppliers' prices.

A second threat to identification is that unconditionally we do not know if a given separation or addition can be associated with a negative or positive price jump. That is, we do not observe if $z_{ij} > 0$ or $z_{ij} < 0$ for any given entry-exit event. A supplier could be dropped because the input price jumps up (i.e. the input becomes unavailable because the supplier ceases to sell the input) or because the input price jumps down (i.e. the supplier is replaced by a better alternative). To identify the inframarginal surplus ratios, we need to use supplier additions or supplier subtractions that are associated with input price jumps of a common sign.

To overcome the identification challenges, we use an instrumental variables strategy. Before we describe our instruments, we first describe our data.

3.1 Data

In this section, we describe how we map our model to data. Our empirical analysis makes use of a rich micro-level data structure on Belgian firms in the period 2002-2018. The data structure brings together information drawn from six comprehensive panel-level data sets: (i) the National Bank of Belgium's (NBB) Central Balance Sheet Office (CBSO), which we refer to as the annual accounts; (ii) the Belgian Prodcom Survey, which covers firms that produce goods covered by the Prodcom classification and that have at least 20 employees or 5 million euros turnover in the previous reference year; (iii) the NBB Business-to-Business (B2B) Transactions data; (iv) International Trade data at the NBB; (v) VAT declarations; and (vi) the Crossroads Bank of Enterprises (CBE) which we use to identify mergers and acquisitions. Additional details are provided in Appendix C.

Network of Suppliers. We construct the network of domestic suppliers of Belgian firms using the confidential NBB B2B Transactions data set. This data set contains the values of

yearly sales relationships among all VAT-liable companies for the years 2002 to 2018, and is based on the VAT listings collected by the tax authorities. At the end of every calendar year, all VAT-liable in Belgium have to file a complete listing of their Belgian VAT-liable customers over that year. An observation in this data set refers to the sales value in euro of enterprise j selling to enterprise i within Belgium, excluding the VAT amount due on these sales. The reported value is the sum of invoices from j to i in a given calendar year. As every firm in Belgium is required to report VAT on all sales of at least 250 euros, the data has nearly universal coverage of all businesses active in Belgium. To control for misreporting errors, we drop a transaction if its value is higher than the seller's aggregate sales and higher than the buyer's total intermediate input purchases (which is reported separately).

We drop from the network those suppliers that produce capital goods, identified from the Main Industrial Groupings (MIG) Classification of the EU (we report sensitivity to including these suppliers in the network). Finally, we also drop from the network the small subset of suppliers with unknown VAT numbers or that that are part of the downstream firm (due to mergers and acquisitions).

Downstream firms. Our sample of downstream firms comes from the Prodcom survey, where we observe data on quantities sold (which are required to measure marginal costs). We restrict the sample to non-financial corporations that file the annual accounts. To ensure that Prodcom variables are representative of a firm's overall activities, we restrict the sample to those whose Prodcom sales are at least 30% of the firm's total sales.[13] Our micro sample contains between roughly 2,000 and 4,000 downstream firms per year. We now describe how we measure a number of key variables for these firms.

Sales and value-added. We define firms' total sales as the highest value between sales reported in the annual accounts (reported mainly by large firms) and sales reported in the VAT declarations. We replace this measure of sales by the sum of exports reported in the international trade data set and sales to other Belgian firms reported in the B2B data set if the latter exceeds the former. We obtain value added from annual accounts.

Total variable costs. Firms' input costs consist of labor costs, the user cost of capital, and purchases of intermediates (excluding purchases of capital goods). We let a fraction of la-

[13]Total sales may differ from Prodcom sales because, for example, firms sell products that they do not produce (Bernard et al. 2019) or they sell services along with the goods they produce (Ariu et al. 2020). The ratio of Prodcom sales to total sales is 0.89 for the median firm in our sample, as shown in Column (ix) of Table A6.

bor and capital be overhead inputs, but assume intermediates purchases are fully variable inputs. Labor costs are reported in the annual accounts. The cost of capital is defined as the product of the capital stock reported by firms in the annual accounts (which includes plants, property, equipment, and intellectual property) and an industry-specific user cost of capital. The latter is the sum of a risk premium (set as 5 percent), the risk-free real rate (defined as the corresponding governmental 10 year-bonds nominal rate minus consumer price inflation at that time period), and the industry-level depreciation rate, $(1 - d) \times g$, where d is the industry level depreciation rate (defined as consumption of fixed capital as a ratio of net capital stock) and g is the expected growth of the relative price of capital at the industry level (defined as the growth in the relative price of capital computed from the industry-specific investment price index relative to the consumer prices index in each year). Intermediate input purchases are defined to be sales minus value added, which are obtained from the annual accounts.[14]

We allow a fraction ϕ of labor and capital costs are variable and the remaining fraction $1 - \phi$ are overhead costs. To calibrate ϕ, we follow a similar strategy to Dhyne et al. (2022). We regress the change in labor and capital costs on the change in intermediate costs (which we assume are fully variable) instrumented using a demand shock. We set $\phi = 0.42$ because our estimates indicate that labor and capital costs rise by roughly 0.4 percent when intermediate purchases rise by 1 percent in response to a demand shock. See Appendix C for more details. Our estimate of ϕ is similar to that found by Dhyne et al. (2022), but our final estimates are very robust to what value we use for ϕ. Given uncertainty over the extent of overhead costs, we redo our analysis under three alternative assumptions. First, we set $\phi = 0.7$. Second, we assume that capital costs are all overhead and keep $\phi = 0.42$ for labor costs. Third, we abstract from overhead costs all together, setting $\phi = 1$. We report these robustnesses in the appendix.

Prodcom quantities and unit values. We construct changes in output quantities and unit values for the sample of firms in the Prodcom survey. Products are identified at the 8-digit level of the Prodcom product code (PC) classification, which is common to all EU member states.[15] Sales values (in euros) and quantities are available at the firm-PC8-month level. Quantities are reported in one of several measurement units (over two thirds of observation are in kilograms; other units include liters, meters, square meters, kilowatt,

[14] In the regressions, we drop observations where domestic purchases of intermediates from the B2B dataset (excluding purchases of capital goods) exceed total variable costs. This ensures that the separation and addition shares as less than one.

[15] As product codes tend to vary from year to year, we use the correspondence of 8-digit products in the Prodcom classifications that trace products over time used by Duprez and Magerman (2018).

and kg of active substance). We aggregate monthly observations to yearly values to match the other data sets, and calculate log differences in quantities and unit values by PC8 product from year t to $t+1$. As quantities and unit values can be noisy, we trim changes in these two variables at the 5-95th percentile level. For multi-product firms (defined as Prodcom firms that produce multiple PC8 products), we aggregate changes in quantities of individual products to the firm-level using a Divisia index, with weights given by the firm's sales share of each product in the corresponding year. This quantity index is valid if we assume that demand for multi-product firms in Prodcom is homothetic. In this case, a Divisia index reliably aggregates multiple products into a single product bundle. For each firm, we also construct changes in unit values as log changes in Prodcom sales minus the Divisia quantity index.[16]

Marginal cost. For each firm in the Prodcom survey, we calculate the log change in marginal cost as

$$\Delta \log mc = \Delta \log \text{total variable costs} - \Delta \log \text{total quantity}, \tag{9}$$

which is valid as long as the scale elasticity of the variable cost function is constant. Unfortunately, we observe changes in Prodcom quantities and not changes in total quantities. To address this, write

$$\Delta \log \frac{\text{total quantity}}{\text{Prodcom quantity}} = \Delta \log \frac{\text{total sales}}{\text{Prodcom sales}} + \text{error},$$

where the unobserved error term is the difference in log changes of average unit values between Prodcom and non-Prodcom sales of the same firm. We use this equation to impute the log change in total quantity, which we then use in (9). This imputation is innocuous as long as the unobserved error term is uncorrelated with our instrument.

We provide sensitivity analysis where we measure changes in marginal costs as log changes in Prodcom unit values minus log changes in markups. We calculate markups either as total sales relative to total variable costs, or using the methodology of De Loecker and Warzynski (2012) with production function estimates using the approach in Levinsohn and Petrin (2003).

Separation and addition share. Having described how we construct the left-hand side variable in (7) and (8), we now discuss how we construct the right-hand side variables.

[16] We obtain very similar results if we calculate changes in unit values as a Divisia index (sales-weighted) of changes in unit values by product rather than deflating sales by the quantity Divisia index

For each Prodcom firm i and period t, using the B2B data, we identify the set of separating suppliers as those the firm buys from in t but does not buy from in $t+1$. Similarly, the set of added suppliers are those that i does not buy from in t but does buy from in $t+1$. We calculate the share of lost suppliers$_{it}$ as the ratio of purchases of i from separating suppliers relative to variable costs at t. We calculate the share of added suppliers$_{it}$ as the ratio of purchases of i from added suppliers relative to variable costs at $t+1$.

Controls. In our regressions, we control for changes in the other components of marginal cost to the extent possible. For continuing upstream suppliers that happen to belong to Prodcom, we construct and control for the change in the unit values (see Duprez and Magerman, 2018 and Cherchye et al., 2021). We also measure and control for the price of labor by dividing total labor costs by total full time employed workers. We measure and control for the price of capital services via the user cost of capital as described above. We measure and control for changes in unit values of imported inputs using a firm-level Divisia index of changes in unit values faced by firm i at the CN8 product level, trimming changes in unit values at the 5th-95th percentile. We also construct, for each Prodcom firm, a price index of general input costs using industry-level price indices from Eurostat, with weights given by the firm's industry shares in non-Prodcom input purchases.

Table A6 in Appendix C reports summary statistics about the level and changes in the continuing share of suppliers, as well as basic information on the number of suppliers each downstream firm has and the share of intermediate materials as a share of total costs for our Prodcom sample.

3.2 Identification Strategy and Results

In this section, we discuss our identification strategy and report our results.

Instrument. We instrument for separations using a subset of firm deaths. Let $S_{i,t}$ be the sales of firm i in period t. For each Prodcom firm i in year t, we construct the following instrument for supplier separations:

$$Z_{it}^{separation} = \sum_j \Omega_{ij,t} \mathbf{1}(S_{j,t+1} = 0) \mathbf{1}\left(p_{j,t} x_{ij,t} / S_{j,t} < 0.05\right). \tag{10}$$

In words, we add up the expenditure share relative to variable costs, $\Omega_{ij,t}$, on suppliers of i who exit the market between t and $t+1$, so that $S_{j,t+1} = 0$, and for whom i is a

small customer. The requirement that j exit the market ensures that the relationship is not broken because of an idiosyncratic choice made by i to switch suppliers. The requirement that i be a small customer for j is to ensure that shocks to i do not drive j's decision to exit the market. In our regressions, we control for 6-digit industry by year fixed effects to control for the possibility that j's decision to exit the market may be caused by changes in its competitors.

Similarly, we instrument for added suppliers using a subset of firm births. For each Prodcom firm i in year t, we construct the following instrument for supplier additions:

$$Z_{it}^{addition} = \sum_j \Omega_{ij,t+1} \mathbf{1}(S_{j,t} = 0) \mathbf{1}\left(p_{j,t+1} x_{ij,t+1} / S_{j,t+1} < 0.05\right). \tag{11}$$

In words, we add up the expenditure share relative to variable costs, $\Omega_{ij,t}$, on suppliers of i who enter the market between t and $t+1$, so that $S_{j,t} = 0$, and for whom i is a small customer. The requirement that j enter the market ensures that the relationship is not started because of an idiosyncratic choice made by i to switch suppliers. The requirement that i be a small customer for j is to ensure that shocks to i do not drive j's decision to enter the market. In our regressions, we control for 6-digit industry by year fixed effects to control for the possibility that j's decision to enter the market may be caused by changes in its competitors.

In both cases, we say that i is a small customer for j if less than 5% of j's sales come from i. We perform sensitivity analysis with respect to this cut-off value of 5% and show that our results are reasonably robust as long as the cut-off value is not increased too much (e.g. to more than 15%).

Baseline estimates of regressions (7) **and** (8)**.** The regression results for (7) are shown in Table 1. We start with the OLS result in Column (i) showing that increases in the separation share are associated with no change in the downstream firms' marginal cost.

Column (ii) is a reduced-form regression of changes in marginal cost directly on our instrument. This shows that exogenous supplier deaths significantly raise marginal costs for downstream firms. Column (iii) is an IV regression showing that for every 1% of suppliers exogenously lost, marginal costs rise by around 0.25%. Column (iv) adds the full suite of price controls, and they do not affect our point estimates. Our IV and reduced-form regressions have similar point estimates, suggesting that variations in the separation share are primarily due to the exogenous exits. Columns (i)-(iv) include 6 digit product code by year and firm fixed effects.[17] Column (v) replaces the 6 digit product code by

[17]For multi-product firms, we use the product code of the product with the greatest sales share.

year fixed effect with a simple year fixed effect, and our point estimate for $\delta^{separation}$ is unchanged. Column (vi) weighs observations by employment and this raises our point estimate to 0.39 but also raises the standard errors. The final column, (vii), shows how unit values respond to the shock. We find a point estimate of 0.16. That is, exogenously losing 1% of suppliers raises marginal costs by 0.25% and prices by 0.16%. This implies a reduced-form pass-through that is very close to that estimated by Amiti et al. (2019) using the same sample of firms but with a different instrument.

Table 1: Estimates of δ for supplier separations

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
			$\Delta \log mc$				$\Delta \log p$
Separation share	0.004		0.248***	0.251***	0.255***	0.396**	0.163**
	(0.013)		(0.096)	(0.097)	(0.088)	(0.166)	(0.074)
Exogenous exit share		0.236***					
		(0.090)					
F-stat			279	279	376	225	281
Specification	OLS	RF	IV	IV	IV	IV	IV
Controls	Y	Y	N	Y	Y	N	Y
Industry × year FE	Y	Y	Y	Y	N	Y	Y
Year FE	N	N	N	N	Y	N	N
Firm FE	Y	Y	Y	Y	Y	Y	Y
Employ. weights	N	N	N	N	N	Y	N
Obs	37,450	37,450	37,450	37,450	40,813	37,450	37,571

Notes: Columns (i)-(vi) report estimates of regression (7), and column (vii) uses changes in unit values instead of marginal cost. Exogenous exit share is the instrument in the IV regressions and is defined by equation (10). Controls are log changes in the price of imported inputs, log changes in the price of inputs purchased from other Prodcom firms and service industries, changes in log wages, and changes in the log user cost of capital. All regressions are unweighted except (vi), which is weighted by firm employment. Industry fixed effects are at the 6-digit. Standard errors are clustered at the firm-level, and F-stat is the Kleibergen-Paap (KP) statistic.

The regression results for (8) are shown in Table 2. The table is analogous. We start with the OLS result in Column (i) showing that new suppliers are associated with very small, but statistically significant, increases in the downstream firms' marginal cost. As before, OLS is subject to severe omitted variable bias. Firms may be adding suppliers in response to idiosyncratic productivity shocks, for example, a negative productivity shock may induce firms to outsource some activity. Or, firms may switch to worse suppliers if their top supplier exits. Our OLS estimates would be biased towards zero as they reflect a mix of input price increases and decreases.

Column (ii) is a reduced-form regression regressing changes in marginal cost directly

on our instrument. This shows that exogenous supplier entry significantly lowers marginal costs for downstream firms. Column (iii) is an IV regression showing that for every 1% of suppliers exogenously gained, marginal costs fall by around 0.25%. Column (iv) adds the full suite of price controls, and they do not affect our point estimates. Our IV and reduced-form regressions have similar point estimates, suggesting that variations in the share of new suppliers are primarily due to the exogenous entry. Columns (i)-(iv) include 6 digit product code by year and firm fixed effects. Column (v) replaces the 6 digit product code by year fixed effect with a simple year fixed effect, and our point estimate for $\delta^{addition}$ is unchanged. Column (vi) weighs observations by employment and this lowers our point estimate to -0.20. The final column, (vii), shows how unit values respond to the shock. We find a point estimate of 0.14. That is, exogenously gaining 1% of suppliers lowers marginal costs by 0.25% and prices by 0.14%. This reduced-form pass-through is very similar to what we find for supplier separations.

Table 2: Estimates of δ for supplier additions

	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
			$\Delta \log mc$				$\Delta \log p$
Additions share	0.043***		-0.259***	-0.261***	-0.189***	-0.201**	-0.139**
	(0.012)		(0.076)	(0.076)	(0.070)	(0.096)	(0.059)
Exogenous entry share		-0.273***					
		(0.079)					
F-stat			393	393	416	175	393
Specification	OLS	RF	IV	IV	IV	IV	IV
Controls	Y	Y	N	Y	Y	N	Y
Industry × year FE	Y	Y	Y	Y	N	Y	Y
Year FE	N	N	N	N	Y	N	N
Firm FE	Y	Y	Y	Y	Y	Y	Y
Employ. weights	N	N	N	N	N	Y	N
Smallness cut-off	N	N	N	N	N	Y	N
Obs	37,472	37,472	37,472	37,472	40,828	37,472	37,472

Notes: Columns (i)-(vi) report estimates of regression (8), and column (vii) uses changes in unit values instead of marginal cost. Exogenous entry share is the instrument in the IV regressions and is defined by equation (11). Controls are log changes in the price of imported inputs, log changes in the price of inputs purchased from other Prodcom firms and service industries, changes in log wages, and changes in the log user cost of capital. All regressions are unweighted except (vi), which is weighted by firm employment. Industry fixed effects are at the 6-digit. Standard errors are clustered at the firm-level, and F-stat is the Kleibergen-Paap (KP) statistic.

Sensitivity analyses. Table 3 displays the results of the IV regression for different cut-off values of what constitutes a small customer. The benchmark results in Tables 1 and 2

use 5%. Table 3 shows that our results are reasonably robust to this choice and the point estimates remain between 0.2 and 0.3, in magnitude, for both entry and exit of suppliers as long as the cut-off value is not too high. The point estimates do start to change if the cut-off value becomes too large however. Unconditional entry and exit is problematic, since once we include entrants and exiters for whom the downstream is a major customer, the coefficients change significantly and tend towards zero.

Table 3: Sensitivity of point estimate of δ to cut-off for small customer

	$\Delta \log mc$										
Separation share	0.296***	0.284***	0.251***	0.265***	0.277***	0.273***	0.264***	0.224***	0.190**	0.115**	0.097**
	(0.113)	(0.101)	(0.097)	(0.090)	(0.088)	(0.086)	(0.083)	(0.081)	(0.076)	(0.058)	(0.045)
Addition share	-0.193**	-0.188**	-0.261***	-0.245***	-0.230***	-0.217***	-0.212***	-0.200***	-0.177***	-0.036	0.058
	(0.080)	(0.075)	(0.076)	(0.074)	(0.071)	(0.069)	(0.068)	(0.067)	(0.060)	(0.051)	(0.044)
Specification	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV	IV
Controls	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
6-digit by year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Smallness cut-off	3%	4%	5%	6%	7%	8%	9%	10%	15%	50%	100%
Obs	37,450	37,450	37,450	37,450	37,450	37,450	37,450	37,450	37,450	37,450	37,450

Notes: Each column reruns the benchmark regression, column (iv) in Table 1 and 2 but varies the cut-off value for what constitutes a small customer from 3% to 100%. The benchmark regressions use a value of 5%. The separation and addition regressions are run separately but are shown in a single table for compactness.

Table A1 in the appendix shows how our results for supplier separation change if we use alternative measures of marginal cost or change our sample selection criteria. Columns (i)-(iii) show that our results are robust to what fraction of labor and capital we treat as being fixed. Specifically, even when we assume all costs are variable, $\phi = 1$, we find that the elasticity of marginal cost to supplier separation is around 0.25. In column (iv), we use production function estimation to measure the change marginal cost. Column (v) restricts attention to downstream firms that do not change the mix of products they offer and column (vi) focuses only on single product firms. In both cases, we find similar results as in our benchmark regression. Column (vii) considers a more demanding formulation of the instrument where the downstream firm has to be a small customer for exiting suppliers not just in the year they exit, but also in the year prior to their exit. The results are similar to our benchmark. The final column, (viii), considers two year changes in marginal costs. We find that the effect of supplier exits is persistent and we do not find much evidence of mean reversion.

Table A2 is analogous to Table A1 but focuses on supplier additions instead. Once again, Columns (i)-(iii) show that our results are robust to what fraction of labor and capital we treat as being fixed. In column (iv), we use production function estimation to

measure the change marginal cost. Columns (v) and (vi) restricts attention to downstream firms that do not change their product mix or only offer a single product, respectively. In both cases, the results are similar to those in our benchmark regression. Column (vii) considers a more demanding formulation of the instrument where the downstream firm has to be a small customer for the entering suppliers not just in the year they enter, but also in the year after they enter. The results are similar to our benchmark. The final column, (viii), considers two year changes in marginal costs. We find that the effect of supplier exits is persistent and we do not find much evidence of mean reversion.

We provide additional robustness exercises, including placebo tests, in the appendix.

4 Macroeconomic Value of Link Formation: Theory

In the previous section, we estimated the area under the input demand curve and found that input suppliers generate a considerable amount of inframarginal surplus for their downstream customers. In this section we develop a growth accounting framework to decompose the fraction of aggregate productivity growth that can be accounted for by observed churn in supply chains. The model explicitly accounts for how changes in one firm's marginal cost, due to entry and exit of its suppliers, spill over to that firms' customers, customers' customers, and so on.

We discipline our macro growth accounting results using estimates from the micro sample which, recall, are estimated using only the Prodcom sample of manufacturing firms. However, we apply our growth accounting formulas to a much larger sample of Belgian firms.

We specify minimal structure on the aggregative model and do not fully specify the environment. This is because we take advantage of the fact that endogenous variables, like changes in factor prices, are directly observable and capture whatever resource constraints the economy is subject to.

4.1 Definitions and Environment

Consider a set of producers denoted by N, called the *network*. There is a set of *external inputs* denoted by F. An external input is an input used by producers in the network, N, that those producers do not themselves produce. In practice, the set F includes labor, capital, and intermediate inputs purchased from firms not in the network N. The firms in N collectively produce *final outputs*. Final output is the production by firms in N that firms in N do not themselves use. A stylized representation is given in Figure 2 showing

the flow of goods and services.

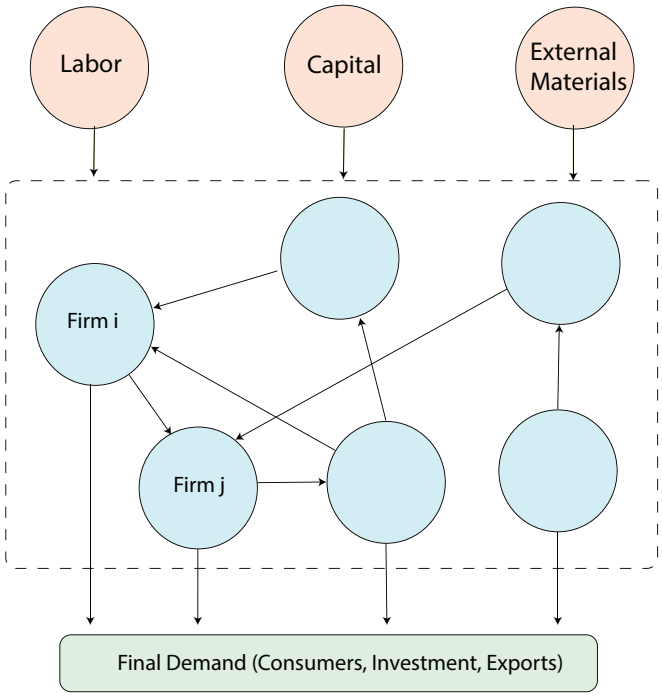


Figure 2: Graphical illustration of the economy. External inputs are red nodes and final output are green nodes. The set N is depicted by the dotted line.

Production. Each producer $i \in N$ has a constant-returns-to-scale production technology in period t given by

$$q_{i,t} = A_{i,t} F_{i,t} \left(\{x_{ij,t}\}_{j \in N}, \{l_{if,t}\}_{f \in F} \right).$$

In the expression above, $l_{if,t}$ is the quantity of external input f and $x_{ij,t}$ is the quantity of intermediate input j used by i at time t. The exogenous parameter $A_{i,t}$ is a technological shifter. There may be fixed overhead costs that must be paid in addition to the variable production technology defined above, but we do not take a stance on these fixed costs for the time being. We abstract from multi-product firms and associate each firm with a single output.

After having paid fixed costs, which could include the costs required to access specific inputs, the total variable costs of production paid by firm i are

$$\sum_{j \in N} p_{j,t} x_{ij,t} + \sum_{f \in F} w_{f,t} l_{if,t},$$

where $p_{j,t}$ and $w_{f,t}$ are the prices of internal and external inputs. The markup charged by each producer i, $\mu_{i,t}$, is defined to be the ratio of its price $p_{i,t}$ and its marginal cost of

production.

We say that good i is a *continuing* good between t and $t+1$ if $q_{i,t} \times q_{i,t+1} > 0$. Denote by C_t the set of all goods who are continuing at time t.

Resource constraints. We construct a measure of net or final production by the set of continuing, C_t, firms. Let the total quantity of external inputs used by continuing firms be

$$L_{f,t} = \sum_{i \in C_t} l_{if,t} + \sum_{i \in C_t} l_{if,t}^{\text{fixed}},$$

where $l_{if,t}$ is used in variable production and $l_{if,t}^{\text{fixed}}$ are fixed costs. Firm i's final output is defined to be the quantity of its production that is not sold to other firms in C_t:

$$y_{i,t} = q_{i,t} - \sum_{j \in C_t} x_{ji,t}.$$

That is, final output of good $i \in C_t$, denoted by $y_{i,t}$, is the quantity produced of i that is not used by any $j \in C_t$ and is either consumed by households, used for investment, sold as exports, or sold to other suppliers that are not in the network of continuing producers.

Aggregate growth. We measure aggregate growth by deflating nominal final output by a price index. Growth in *real final output* of the set of continuing goods, denoted by $\Delta \log Y_t$, is the change in nominal final output minus the final output price deflator:

$$\Delta \log Y_t = \Delta \log \left(\sum_{i \in C_t} p_{i,t} y_{i,t} \right) - \Delta \log P_t^Y. \tag{12}$$

The change in the *final output price deflator* between t and $t+1$ is defined to be the share-weighted change in the price of continuing goods

$$\Delta \log P_t^Y = \sum_{i \in C_t} b_{i,t} \Delta \log p_{i,t},$$

where, as in a Tornqvist index, the weights are the average of shares in t and $t+1$:

$$b_{i,t} = \frac{1}{2} \frac{p_{i,t} y_{i,t}}{\sum_{j \in C_t} p_{j,t} y_{j,t}} + \frac{1}{2} \frac{p_{i,t+1} y_{i,t+1}}{\sum_{j \in C_t} p_{j,t+1} y_{j,t+1}}.$$

To calculate growth in real final output between t and $t+T$, we cumulate $\Delta \log Y$:

$$\log Y_{t+T} - \log Y_t = \sum_{s=t}^{t+T} \Delta \log Y_s.$$

This measure of aggregate growth is similar to, but is not the same, as GDP. The primary difference is in how we treat external materials (e.g. imported intermediate inputs). GDP-style measures subtract the value of imported intermediate inputs from final output. By not subtracting the value of external materials from final output, we treat external materials like factors of production (labor and capital).[18] The objective of this section is to decompose the contribution of supplier churn to growth in real final output.

4.2 Theoretical Results

To state our decomposition result, we need to first set up some input-output notation. Define the $C_t \times C_t$ cost-based input-output network of continuing firms to have ijth element equal to:

$$\Omega_{ij,t} = \frac{p_{j,t} x_{ij,t}}{\sum_{k \in C_t} p_{k,t} x_{ik,t} + \sum_{f \in F} w_{f,t} l_{if,t}}.$$

Let Ω^F be the $C_t \times F$ matrix of external input usages, where the ifth element is

$$\Omega^F_{if,t} = \frac{w_{f,t} l_{if,t}}{\sum_{k \in C_t} p_k x_{ik} + \sum_{f \in F} w_f l_{if}}.$$

Group inputs of continuing suppliers of i into $\mathcal{J}_i$ types (similar to Section 4). Let $M_{iJ,t}$ be the mass of inputs of type $J \in \mathcal{J}_i$ used by firm i at time t. Firm i adds suppliers of type J if $\Delta M_{iJ,t} > 0$ and removes suppliers if $\Delta M_{iJ,t} < 0$. Denote the per-variety expenditure share on type J inputs by $\Omega_{iJ,t}$. The average inframarginal surplus for entering suppliers is

$$\bar{\delta}^{\text{entry}}_{i,t} = \sum_{\substack{\Delta M_{iJ,t} > 0 \\ J \in \mathcal{J}_i}} \frac{\Omega_{iJ,t} \Delta M_{iJ,t}}{\sum_{\substack{\Delta M_{iK,t} > 0 \\ K \in \mathcal{J}_i}} \Omega_{iK,t} \Delta M_{iK,t}} \delta_{iJ,t}(p_{J,t}, \infty),$$

[18] If we subtract the value of external materials from final output, then our growth accounting expressions have an additional term involving the difference between expenditures on external materials and the elasticity of aggregate output with respect to external materials. This difference is nonzero in the presence of wedges. See Baqaee and Farhi (2019a) for more details.

and the average inframarginal surplus for exiting suppliers is

$$\bar{\delta}_{i,t}^{\text{exit}} = \sum_{\substack{\Delta M_{iJ,t}<0 \\ J\in\mathcal{J}_i}} \frac{\Omega_{iJ,t}\Delta M_{iJ,t}}{\sum_{\substack{\Delta M_{iK,t}<0 \\ K\in\mathcal{J}_i}} \Omega_{iK,t}\Delta M_{iK,t}} \delta_{iJ,t}(p_{J,t},\infty).$$

This representation can capture both expanding variety models and quality-ladder models as long as $\delta_{iJ,t}(p_{J,t},\infty) < \infty$. To capture a movement along a quality ladder, we consider the simultaneous addition and removal of supplier-pairs. That is, if an input climbs the quality ladder, a low quality supplier is eliminated and a high quality supplier is added. See Appendix B for more details and an example.

Define the set of continuing suppliers for firm i by $C_{i,t}$. That is,

$$C_{i,t} = \{j \in C_t : x_{ij,t} \times x_{ij,t+1} > 0\}.$$

We assume that $C_{i,t}$ is non-empty. Define the separating-supplier term for firm i to be

$$\Delta\mathcal{X}_{i,t} = \underbrace{\left(\sum_{J\in\mathcal{J}_i} M_{iJ,t}\Omega_{iJ,t}\right)}_{\substack{\text{material share of} \\ \text{total variable cost}}} \underbrace{\left(1 - \frac{\sum_{j\in C_{i,t}} p_{j,t}x_{ij,t}}{\sum_k p_{k,t}x_{ik,t}}\right)}_{\substack{\text{share of} \\ \text{lost suppliers}}} \geq 0.$$

This is the share of firm i's variable cost spent on suppliers that are lost between t and $t+1$. Define the entering-supplier term for firm i to be

$$\Delta\mathcal{E}_{it} = \underbrace{\left(\sum_{J\in\mathcal{J}_i} M_{iJ,t}\Omega_{iJ,t}\right)}_{\substack{\text{material share of} \\ \text{total variable cost}}} \underbrace{\left(1 - \frac{\sum_{j\in C_{i,t}} p_{j,t+1}x_{ij,t+1}}{\sum_k p_{k,t+1}x_{ik,t+1}}\right)}_{\substack{\text{share of} \\ \text{added suppliers}}} \geq 0.$$

This is the share of firm i's variable cost spent on suppliers that are added between t and $t+1$.

The following lemma, which is a consequence of Proposition 1, shows that the effect of supplier churn on the downstream firm's marginal cost can be written in terms of $\Delta\mathcal{E}_{i,t}$ and $\Delta\mathcal{D}_{it}$.

Lemma 1 (Decomposition of Marginal Cost)**.** *Consider a change in the price of inputs $\Delta\boldsymbol{p}_t$ and $\Delta\boldsymbol{w}_t$, the measure of inputs by type $\Delta M_{iJ,t}$, and the technology parameter $\Delta A_{i,t}$. Let $\Delta\mu_{i,t}$ be the change in markups. Assume $\delta_{iJ}(p,\infty) < \infty$ for every J. Then to a first-order approximation,*

the change in the price of each continuing firm i is given by

$$\Delta \log p_{i,t} \approx \Delta \log \frac{\mu_{i,t}}{A_{it}} + \sum_{j \in \mathcal{J}_i} \Omega_{ij,t} \Delta \log p_{j,t} + \sum_{f \in F} \Omega^F_{if,t} \Delta \log w_{f,t} + \bar{\delta}^{exit}_{i,t} \Delta \mathcal{X}_{i,t} - \bar{\delta}^{entry}_{i,t} \Delta \mathcal{E}_{it}.$$

The first three summands are standard, reflecting changes in i's own markup and technology as well as changes in the prices of i's continuing suppliers and external inputs (e.g. wages and user cost of capital). The fourth summand reflects changes in i's marginal cost due to churning of suppliers assuming that the average inframarginal surplus created by entering and exiting suppliers is the same. The final term accounts for the discrepancy between the average inframarginal surplus of entering and exiting suppliers.

Lemma 1 is a useful reformulation of Proposition 1 since it allows us to summarize heterogeneous extensive margin effects into two sufficient statistics: $\bar{\delta}^{\text{exit}}$ and $\bar{\delta}^{\text{entry}}$. These sufficient statistics are multiplied by observable statistics: changes in the share of added and separated suppliers. If we calibrate $\bar{\delta}^{\text{exit}}$ and $\bar{\delta}^{\text{entry}}$, then using observational data on expenditures on suppliers (from, say, VAT returns), we can infer the effect of extensive margin adjustments on every firm's price without needing to measure the price of every firm in the economy.

The following corollary specializes Lemma 1 to the CES special case.

Corollary 1 (CES Special Case)**.** *If i's production technology is CES with elasticity of substitution $\sigma > 1$, then*

$$\bar{\delta}^{exit} = \bar{\delta}^{entry} = \frac{1}{\sigma - 1}.$$

Hence,

$$\Delta \log p_{i,t} \approx \Delta \log \frac{\mu_{i,t}}{A_{it}} + \sum_{j \in \mathcal{J}_i} \Omega_{ij,t} \Delta \log p_{j,t} + \sum_{f \in F} \Omega^F_{if,t} \Delta \log w_{f,t} - \frac{1}{\sigma - 1} \left(\Delta \mathcal{E}_{i,t} - \Delta \mathcal{X}_{i,t} \right).$$

CES input demand is a useful benchmark since it greatly simplifies the expression in Lemma 1. Under CES, the treatment effect associated with each entry or exit event is just the expenditure share of that supplier multiplied by $1/(1-\sigma)$ — there is no heterogeneity in inframarginal surplus and entry is as beneficial as exit is costly per dollar of spending. Furthermore, since inframarginal surplus is constant, if we know it, then changes in the continuing input share are all we need to measure over time to see the effect of the extensive margin on marginal cost.[19]

[19] As long as input demand is CES, Lemma 1 applies, regardless of whether supplier churn occurs according to a quality-ladder or expanding-varieties model. As mentioned before, we model a movement along the quality-ladder as the simultaneous addition and subtraction of a supplier pair. With CES input demand,

Lemma 1 is about a single firm, but we can build on it to decompose aggregate growth $d \log Y_t$. To do this, note that Lemma 1 can be rewritten in matrix notation as

$$\Delta \log \boldsymbol{p}_t \approx \Delta \log \boldsymbol{\mu}_t - \Delta \log \boldsymbol{A}_t + \Omega_t \Delta \log \boldsymbol{p}_t + \Omega_t^F \Delta \log \boldsymbol{w}_t + \bar{\boldsymbol{\delta}}_t^{\text{exit}} \Delta \mathcal{X}_t - \bar{\boldsymbol{\delta}}_t^{\text{entry}} \Delta \mathcal{E}_t.$$

Define the *cost-based continuing* Leontief inverse to be

$$\Psi_t = (I - \Omega_t)^{-1} = \sum_{s=0}^{\infty} \Omega_t^s.$$

Then, we can solve out for changes in the prices of continuing firms:

$$\Delta \log \boldsymbol{p}_t \approx \Psi_t \left[\Delta \log \boldsymbol{\mu}_t - \Delta \log \boldsymbol{A}_t + \Omega_t^F \Delta \log \boldsymbol{w}_t + \bar{\boldsymbol{\delta}}_t^{\text{exit}} \Delta \mathcal{X}_t - \bar{\boldsymbol{\delta}}_t^{\text{entry}} \Delta \mathcal{E}_t \right]. \tag{13}$$

That is, changes in the price of continuing goods depend on changes in markups, $\Delta \log \boldsymbol{\mu}_t$, productivity shifters, $\Delta \log \boldsymbol{A}_t$, prices of external inputs, $\Delta \log \boldsymbol{w}_t$, as well as the extensive margin terms, $\Delta \mathcal{X}_t$ and $\Delta \mathcal{E}_t$. All of these effects are mediated by the forward linkages in the Leontief inverse Ψ_t.

Define the *revenue-based Domar weight* of $i \in C_t$ and $f \in F$ to be

$$\lambda_{i,t} = \frac{p_{i,t} q_{i,t}}{\sum_{j \in C_t} p_{j,t} y_{j,t}}, \quad \text{and} \quad \Lambda_{f,t} = \frac{\sum_{i \in C_t} w_{f,t} l_{f,t}}{\sum_{j \in C_t} p_{j,t} y_{j,t}},$$

and the *cost-based continuing Domar weights* for $i \in C_t$ and $f \in F$ to be

$$\tilde{\lambda}_{i,t} = \sum_{j \in C_t} b_{j,t} \Psi_{ji,t}, \quad \text{and} \quad \tilde{\Lambda}_{f,t} = \sum_{j \in C_t} \tilde{\lambda}_{j,t} \Omega_{f,t}^F.$$

The cost-based and revenue-based Domar weights are the same when there are no markups and the extensive margin is inactive. The cost-based continuing Domar weight $\tilde{\lambda}_{i,t}$ measures the exposure of each continuing firm j to each continuing supplier i, captured by $\Psi_{ji,t}$, and averages this exposure by j's share in the final output price deflator $b_{j,t}$. Substituting (13) into the definition of the final output price deflator yields the following first

both the entering and exiting supplier's inframarginal surplus per unit of expenditure is $1/(\sigma - 1)$, and the downstream firms' marginal cost will rise or fall depending on whether expenditures on the entering supplier are higher or lower than the exiting supplier. The derive this corollary, we must assume that $\sigma > 1$ because $\bar{\delta}^{\text{exit}} = \bar{\delta}^{\text{entry}} = \infty$ when $\sigma \leq 1$.

order approximation for the change in the output price deflator

$$\Delta \log P_t^Y \approx \sum_{i \in C_t} \tilde{\lambda}_{i,t} \left[\Delta \log \frac{\mu_{i,t}}{A_{i,t}} + \bar{\delta}_{i,t}^{\text{exit}} \Delta \mathcal{X}_{i,t} - \bar{\delta}_{i,t}^{\text{entry}} \Delta \mathcal{E}_{i,t} \right] + \sum_{f \in F} \tilde{\Lambda}_{f,t} \Delta \log w_{f,t}.$$

That is, shocks to i are transmitted into the final output price according to the cost-based Domar weight $\tilde{\lambda}_{i,t}$. Similarly, changes in the price of external input f affects the final output price deflator according to its cost-based Domar weight $\tilde{\Lambda}_{f,t}$.

Plugging this into the definition of real final output in equation (12) yields the following decomposition.

Proposition 3 (Growth-Accounting with Entry-Exit)**.** *The change in real final output is given, to a first-order, by*

$$\begin{aligned} \Delta \log Y_t \approx & \underbrace{\sum_{i \in C_t} \tilde{\lambda}_{i,t} \Delta \log A_{i,t}}_{\textit{technology}} + \underbrace{\sum_{f \in F} \tilde{\Lambda}_{f,t} \Delta \log L_{f,t}}_{\textit{factor quantities}} \\ & - \underbrace{\sum_{i \in C_t} \tilde{\lambda}_{i,t} \Delta \log \mu_{i,t}}_{\textit{markups}} \underbrace{- \sum_{f \in F} \tilde{\Lambda}_{f,t} \Delta \log \Lambda_{f,t}}_{\textit{factor shares}} \\ & + \underbrace{\sum_{i \in C_t} \tilde{\lambda}_{i,t} \left(\bar{\delta}_{i,t}^{entry} \Delta \mathcal{E}_{i,t} - \bar{\delta}_{i,t}^{exit} \Delta \mathcal{X}_{i,t} \right)}_{\textit{extensive-margin}}. \end{aligned}$$

Aggregate output growth can be broken down into different components. We describe the different terms in sequence starting with the first line. The first term is exogenous productivity growth weighted by cost-based Domar weights. This accounts for how exogenous improvements in technology affect output, accounting for the fact that improvements in each firm's technology will mechanically raise production by its consumers, and its consumers' consumers, and so on. The second term captures a similar effect but for changes in factor quantities — if the quantity of factor f rises, then that raises the production of all firms that use factor f, which raises the production of all firms that use the products of factor f, and so on.[20]

The second line captures the way changes in markups and factor prices affect output. An increase in i's markup will raise i's price, which raises the costs of production for i's consumers, and i's consumers' consumers, and so on. Similarly, if the Domar weight Λ_f

[20]For counterfactuals, we need to be able to solve for changes in factor shares $d \log \Lambda$. This requires modelling the details of fixed costs and entry decisions. However, conditional on changes in factor shares, we do not need to specify these details.

of factor f rises more quickly than the quantity L_f of factor f, then this means that the relative price of factor f has increased. An increase in f's price will raise the costs of production for all firms.

The last line is what this paper is focused on and captures the effects of supplier churn. It measures the reduction in the final-goods price deflator caused by jumps in input prices due to supplier churn, holding fixed technologies of continuing firms, markups, and factor prices. Churn at the level of each individual firm percolates to the rest of the economy through the input-output network and this effect is captured by weighing the extensive margin terms from Lemma 1 by the cost-based Domar weight of each firm and summing across all firms. This captures the idea that if one firm's marginal costs change from entry-exit of its suppliers, then those marginal cost changes will propagate to that firms' consumers, its consumers' consumers, and so on.

5 Empirical Macroeconomic Results

In this section, we apply Proposition 3 to decompose aggregate growth for a large subset of the Belgian economy.[21] In the first part of this section, we describe how we map the data to the terms in Proposition 3. In the second part of this section, we show the results.

5.1 Mapping to Data

To apply Proposition 3, we need to define the set of continuing firms C_t, the average inframarginal surplus parameters $\bar{\delta}_{i,t}^{\text{exit}}$ and $\bar{\delta}_{i,t}^{\text{entry}}$, the matrices Ω_t and Ω_t^F for all continuing firms in Belgium, markups $\mu_{i,t}$, the growth in external input quantities (labor, capital, and external materials), and the growth in final real output. We discuss these in turn.

Assigning the continuing network set. We calculate an output measure for continuing, non-financial domestic Belgian corporations. We exclude from the set N of firms that we track self-employed and financial activities (NACE codes 64-66) and non-market services including government entities (NACE codes 84 and higher) because these sectors are not well-covered by VAT data (for example, hospitals and health centers are not required to submit VAT declarations) and markups are hard to measure.[22] Even though we exclude

[21] When we apply Proposition 3 to decompose output growth, we use a Tornqvist second-order adjustment. That is, although Proposition 3 is a first order approximation, when we average the t and $t+1$ coefficients on each shock, it provides a second order approximation (see Theil, 1967). For example, we weigh $\Delta \log L_{f,t}$, the change in factor quantity f between t and $t+1$, using the average of $\tilde{\Lambda}_{f,t}$ and $\tilde{\Lambda}_{f,t+1}$.

[22] We exclude self-employed because of data-privacy considerations. Non-markets services, such as government entities, education, health, art and entertainment, are not well-covered by VAT data. We exclude

from N self-employed, government, and financial entities, we include purchases from these suppliers in variable costs and treat them as a separate external factor.[23]

We define a firm in N to be continuing in t if the following conditions are met: its sales are positive in t and $t+1$, its employment is at least one in t and $t+1$, and its capital stock is positive in t and $t+1$. This gives us the set C_t, which covers around 70% of both value-added and total employment of the non-financial corporate sectors in Belgium as measured by the National Accounts Institute (see Table A5). Crucially, our output measure is much broader than the Prodcom sample that we used in Section 3. Whereas our Prodcom sample contains roughly 3,000 downstream firms per year, the growth accounting sample contains roughly 90,000 firms per year.

Calibrating $\bar{\delta}_{i,t}^{\text{exit}}$ and $\bar{\delta}_{i,t}^{\text{entry}}$. We calibrate the average inframarginal surplus over exiting and entering suppliers per unit of expenditures according to our benchmark estimates, column (iv), in Tables 1 and 2. That is, we set $\bar{\delta}_{i,t}^{\text{exit}} = 0.251$ and $\bar{\delta}_{i,t}^{\text{entry}} = 0.261$. We perform robustness exercises where we vary these two numbers and report how our results change.

Calibrating input-output shares and markups. As in Section 3, we construct the $C_t \times C_t$ network of domestic suppliers of Belgian firms using the NBB B2B Transactions data set. As mentioned before, almost all firms in Belgium are required to report sales of at least 250 euros, and the data has universal coverage of all businesses in C_t. We drop from the network purchases of capital inputs and outlier transactions as described in Section 3. There are four external inputs: labor, capital, imported materials, and materials from outside the set N (i.e. purchased from self-employed firms, finance, and government entities). We construct the $C_t \times F$ matrix of external input requirements using data from the annual accounts, B2B transactions, and customs declarations. For capital, as in Section 3, we multiply the industry-specific user cost of capital by firms' reported capital stocks. We measure firm-level markups by dividing sales by total variable costs. Total variable costs is the sum of all material purchases (domestic and foreign, from continuing and non-continuing firms, and including self-employed, finance, and government suppliers but excluding capital suppliers), plus the non-overhead component of the wage bill and

financial entities because (i) banks fill special annual accounts that we do not have access to, and (ii) interest receipts by banks and insurance premia receipts by insurance companies are not included in the VAT data.

[23] We also include in this external factor purchases from suppliers that do not report VAT and intra-firm purchases (due to mergers and acquisitions). Column (iii) in Table A10 shows that our micro estimates are similar to our baseline if we exclude input purchases from self-employed, government, and finance suppliers.

the cost of capital (which we assume is $\phi = 0.42$). Any other expenditures the firm incurs are treated as overhead costs.

Calibrating final output. Final output is defined to be the sales of C_t minus sales of materials to other firms in the production network. That is, final output are sales to households, exports, investment, and any other sales that are not considered to be intermediate purchases by firms in N.[24] We convert nominal final output into a real measure by deflating nominal growth in final output using the Belgian GDP deflator from the national accounts. That is, we assume that the price deflator of our measure of final output grows at the same rate as the Belgian GDP deflator.

Calibrating external input quantities. We measure growth in labor quantity using total equivalent full time employees for firms in our sample. We measure growth in the capital stock of each firm by deflating the nominal value of its capital stock (which includes plants, property, equipment, and intellectual property) using the aggregate investment price deflator from the national accounts of Belgium. We measure the growth in imported materials by deflating the nominal imported material input growth with the import price deflator used for constructing the national accounts in Belgium. We cannot measure growth in the quantity of materials purchased from excluded domestic firms (self-employed, finance, and government entities), so growth in the quantity of these materials is part of the residual.

Table A5 in Appendix D reports information on the fraction of Belgian value-added in our sample and compares how aggregate growth rates in our sample compare to Belgian national accounts data. Table A5 in Appendix D reports information on the fraction of Belgian value-added in our sample and compares how aggregate growth rates in our sample compare to Belgian national accounts data. Table A7 in Appendix D reports basic statistics on the level and changes in the continuing share of suppliers, as well as basic information on the number of suppliers each firm has, and the share of intermediate materials as a share of total costs for our sample. Each firm has, on average, 68 suppliers while the sales-weighted average number of suppliers is 658. Therefore, the number of suppliers rises with the size of the firm. Furthermore, the expenditure share on continuing suppliers falls, on average, by around 5% per year.

[24] Given data on sales ($p_i q_i$) for each firm $i \in C_t$, and the input-output matrix relative to sales, $\Omega^s_{ij} = \frac{p_j x_{ij}}{p_i q_i}$, we calculate total final output as $E = \sum_{i \in C_t} p_i q_i - \sum_{i \in C_t} p_i q_i \sum_{j \in C_t} \Omega^s_{ij}$. Final demand shares are given by $b_i = (p_i q_i - \sum_{j \in C_t} \Omega^s_{ji} p_j q_j)/E$.

5.2 Results

Before showing our benchmark results, we start with a special case of Proposition 3 where the extensive margin is irrelevant, $\bar{\delta}^{\text{entry}} = \bar{\delta}^{\text{exit}} = 0$. That is, Figure 3 implements a Baqaee and Farhi (2019b) style decomposition. This is a generalization of Solow-Hulten growth decompositions to an environment with markups. The technology residual accounts for about 14 log points of cumulative growth. The markup and factor share terms, which captures changes in markups and factor prices, does not play a large role in cumulative growth rates.

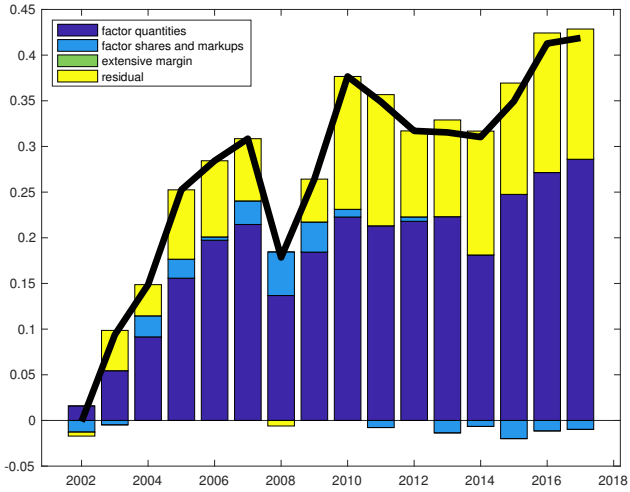


Figure 3: $\bar{\delta}^{\text{entry}} = \bar{\delta}^{\text{exit}} = 0$.

Figure 4 shows the role of supplier churn in growth using the benchmark point estimates from Tables 1 and 2: $\bar{\delta}^{\text{entry}} = 0.261$ and $\bar{\delta}^{\text{exit}} = 0.251$. The extensive margin of supplier addition and separation accounts for about 8 log points out of a total of 14 log points of unexplained cumulative growth in the technology residual over the sample period. This more than halves the size of the technology residual. We obtain similar, but slightly lower, results if we set the surplus for entry and exit to be the same and equal to the average of our two benchmark point estimates $\bar{\delta}^{\text{entry}} = \bar{\delta}^{\text{exit}} = 0.256$. In a CES expanding varieties model, this corresponds to setting the elasticity of substitution equal to 4.9. These results are shown in Figure 5. The technology residual is slightly bigger, but the extensive margin still can account for around half of the cumulative growth in the residual.

Since we can observe the extensive margin term is not a residual, it is not affected by measurement error in the other terms in the growth accounting expression. The extensive margin term does however depend strongly on the value of $\bar{\delta}^{\text{entry}}$ and $\bar{\delta}^{\text{exit}}$. As we raise both, the technology residual falls. This is because in a typical year, the expenditure share

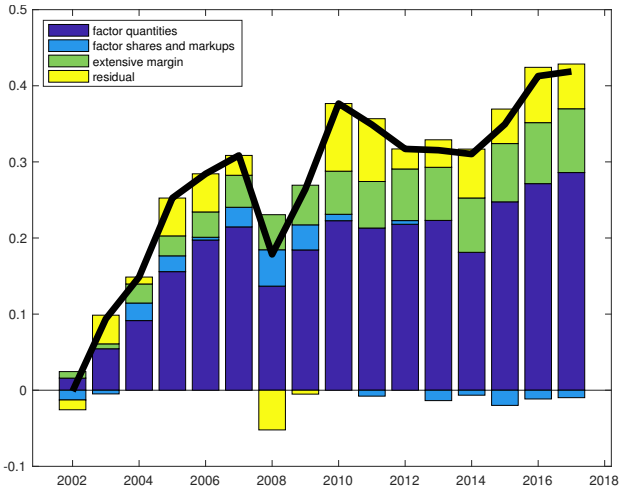


Figure 4: $\bar{\delta}^{\text{entry}} = 0.261$ and $\bar{\delta}^{\text{exit}} = 0.251$.

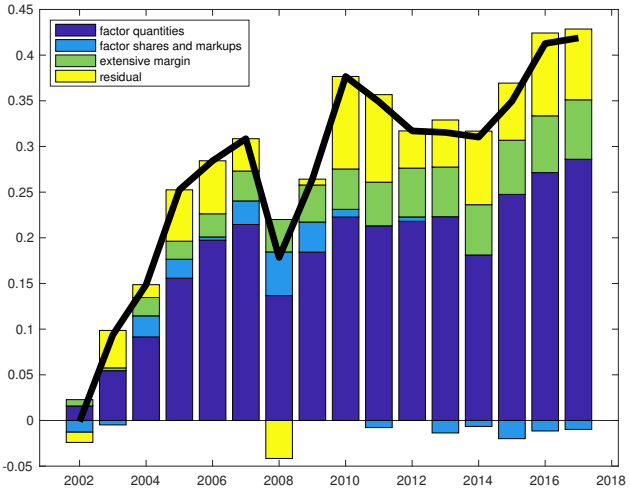


Figure 5: $\bar{\delta}^{\text{entry}} = \bar{\delta}^{\text{exit}} = 0.256$.

on newly acquired suppliers exceeds that on separating suppliers (when weighed by $\tilde{\lambda}$).[25] The residual also depends strongly on the gap between $\bar{\delta}^{\text{entry}}$ and $\bar{\delta}^{\text{exit}}$. If $\bar{\delta}^{\text{entry}}$ is higher than $\bar{\delta}^{\text{exit}}$, then this significantly shrinks the residual.

Of course, these results are very speculative since they involve extrapolating estimates from the Prodcom manufacturing sample of firms to a much broader subset of Belgian firms (including ones outside the manufacturing sector). In practice, the inframarginal surplus ratio, δ, is likely highly heterogeneous and varies by both the characteristics of the suppliers being added or dropped as well as by the characteristics of the purchasing firm. Investigating such heterogeneity is an important area for future research. However,

[25] Interestingly, we also find that firms that contribute positively through supplier churn — add more suppliers than they lose — are also firms with growing sales shares.

our aggregation exercise suggests that the extensive margin of supplier entry and exit is plausibly an important driver of aggregate productivity growth.

6 Conclusion

This paper analyzes and quantifies the microeconomic and macroeconomic importance of creation and destruction of supply linkages. Our analysis shows that downstream firms' marginal costs are significantly affected by supplier entry and exits, and this enables us to directly calculate the area under the input demand curve. Our estimates can be used to calibrate love-of-variety effects in an expanding variety models and the innovation step-size in a quality-ladder models. Additionally, we demonstrate that supplier entry and exit can plausibly account for a large part of the growth component of the unexplained residual in a Solow (1957)-style growth accounting exercise. Future research can refine and replicate these estimates by exploring heterogeneity in δ, using other identification strategies, or data from other countries.

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