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Renouvellement des produits, pouvoir de marché et distance au produit cœur

Résumé

Le renouvellement des portefeuilles de produits au sein des entreprises est une source importante de croissance. Nous analysons la relation entre l'évolution des portefeuilles de produits, les marges réalisées, et la différenciation des produits au sein des entreprises. Nous estimons par produit une marge et un coût marginal en suivant la méthode développée par De Loecker et al. (2016), appliquée à un large panel d'entreprises industrielles françaises sur la période 2009-2017, et proposons trois nouvelles mesures de similarité de produits. La survie des produits les plus performants expliquerait l'écart de performance entre produits entrants et les produits déjà présents dans le portefeuille, ces derniers étant le fruit d'un mécanisme de sélection basée sur la performance. Reflets de la performance d'un produit, les marges comme les coûts marginaux sont d'égale importance pour expliquer ce mécanisme de sélection. Les entreprises renouvelleraient leur portefeuille en procédant par essais et erreurs, sélectionnant les produits les plus performants, qui se révèlent être les plus proches de leur produit cœur de compétence. Toutefois, au niveau de l'entreprise, la croissance des marges est surtout due à la croissance de la part des ventes des produits les plus performants, avec un rôle mineur pour l'entrée et la sortie des produits à court terme.

Mots-clés : Firmes multiproduits ; Dynamique des produits ; Portefeuille de produits ; Marges

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Product switching, market power and distance to core competency

Abstract

Within-firm product switching is recognised as an important source of growth. We examine how portfolio dynamics is related to product market power, product efficiency and within-firm differentiation. We derive per-product markup and marginal cost following De Loecker et al. (2016) on a large panel of French manufacturers over 2009-2017 and build three novel measures of product similarity. We find that selection based on performance is a leading driver of the performance gap between entrant and incumbent products. Markups are as important as marginal costs in explaining selection patterns. Our results suggest that firms renew their portfolio using trial and error and select the best performing products, closer to their core competency. However at the firm level, most of markup growth is accounted for by a reallocation toward best performing products, with a minor role for product entry and exit in the short run.

Keywords: Multiproduct firms; Product dynamics; Product portfolio; Markups

Classification JEL : D2; D4; L1

I. Introduction

Within-firm product switching is increasingly recognised as a major source of resource reallocation and industry dynamics. In the US, Bernard et al. (2010) find that recently added or about to be dropped products represent a share of output comparable to firms entry and exit. In France, sales' growth attributable to product portfolio renewal accounts for a third of total growth in our panel of manufacturing firms. Product switching is important to understand aggregate fluctuations.[1] When modeling product switching, a large role is given to firm-product heterogeneity (Eckel and Neary, 2010, Bernard et al., 2010, 2011, Eckel et al., 2015, Mayer et al., 2014) while the representation of the latter is often empirically coarse. A related and earlier literature explores firm entry and exit, in particular questioning whether selection operates on firms' productivity or profitability. Foster et al. (2008) find that profitability (partly determined by productivity) explains firms selection. As for product renewal within firms, and its link with product performance, empirical evidence are still scarce. At least two types of factors may describe product performance, related to demand or market conditions on the one hand, or to supply and production conditions on the other hand. Whether products stay in firms' portfolio because they are profitable or produced efficiently may have distinct macroeconomic implications.[2] Yet, to our knowledge no empirical evidence exists to shed light on this phenomenon, at least not at the level of a country's economy.

In this paper, we explore the role of product-level markups and marginal costs in explaining firms' portfolio dynamics, and their implication for firm-level market power. We contrast the role of markups and marginal costs, as well as differentiation (or product relatedness) as determinant of products' selection and survival. In order to estimate the range of markups of firms across their products, we rely on the methodology of De Loecker et al. (2016) which we apply to a large panel of French manufacturers over the period 2009-2017. Several distinctive features of our data are useful. First, the panel dimension and the very detailed level of disaggregation allow us to carefully examine product portfolio and product switching from one year to the next. We replicate on these data the statistics from Bernard et al. (2010) and Goldberg et al. (2010), which describe product switching dynamics in respectively US and Indian manufacturing, and compare our results. Second, our data record both physical output and prices at a very detailed product level which enables the estimation of output-based production functions, allowing to appreciate production efficiency at the product-level with marginal costs as defined by Hall (1988). Markups are then simply defined as the wedge between prices and marginal costs. Theoretically, marginal-cost/markup based selection is a distinctive feature of the models by Eckel and Neary (2010) or Mayer et al. (2014) which feature multiproduct firms. In this paper, we provide a direct test of the relevance of

[1]Product switching has many aggregate implications in growth and innovation, (Aghion et al., 1998, Romer, 1990, Grossman and Helpman, 1991, Funke and Ruhwedel, 2001), trade (Grossman and Helpman, 1989, Bernard et al., 2011)), and business cycles (Broda and Weinstein, 2010, Alvarez and Lippi, 2014, Hamano and Zanetti, 2017)...

[2]If product switching participates to increasing firms' markups, this within-firm margin may participate to the rise in the customer price index, e.g. Hottman et al. (2016). If it is in excess of the increase in overhead costs, it may entail a rise in market power with several potential macro consequences, see De Loecker and Eeckhout (2017). If selection favours low marginal-cost products, it may be considered as efficiency-increasing (when ignoring input prices which may reflect quality, see the assumptions in Garcia-Marin and Voigtländer (2019) needed to consider marginal cost as a measure of efficiency).

product-level markups and marginal costs for selection, and therefore for industry dynamics, as suggested by the models of Mayer et al. (2014) or Eckel and Neary (2010).

One assumption of these models, which has received empirical support in custom data, is that of a "core competency" product. It states the existence of a product ladder ranking products along their marginal costs. Products closer to the firm's core competence have lower marginal costs, and the position in this product ladder determines whether the firm finds it profitable to sell the product in a given competitive environment. The positions in the product ladder determine which products are dropped first, after an adverse shock. In addition, newly added products are farther from the core competence. Without an external definition of similarity (or product ladder) between the core product and the other, researchers typically rely on the ranking of sales' shares to test this assumption. We here construct three distinct measures of similarity between products. They are based on (respectively) the firms' coproduction networks, the products' textual description and the detailed material input expenses in production. They serve several purposes. First, by explicitly defining a distance from the core, we can describe its role in product switching. Second, it allows to alleviate the dependence on the classification when analysing the composition of a portfolio. With these three measures of pairwise product similarity, we analyse their role for product selection and/or performance, and design direct empirical tests of the product ladder assumption.

Before a dynamic analysis, we document the prevalence of a core product in multiproduct firms in terms of markups. We find that multiproduct firms charge higher markups on their core (best selling) product, and the gap with the average markup on other products increases with the scope of the firm. The opposite pattern holds for marginal costs. This is an empirical confirmation of the product ladder assumption. Second, we explore the consequences of this product heterogeneity for product selection. We find that both adding and dropping is a behaviour of productive firms, although we cannot assert the causality direction. We document that product exits are robustly predicted by their current markups and marginal cost, with both almost equally important in predicting this outcome. This points out to product selection based on their performance. Products technologically distant from the core are also more likely to be dropped, and new products are more technologically distant from the core than incumbent products. Further, performance at entry, as well as technological similarity to the core predict products' survival length. In line with a selection process, we find that young products are markedly different from incumbent products, the latter being much more performing. We attribute most of the difference between new products and incumbent products to selection, experience effect being small, at least in the short run (a few years) since we only observe minor within-product variation over tenure. However, conditional on remaining in the firm's product portfolio, the experience effect is significant for products close to the firm's core competency. Our dynamic results suggest that firms renew their portfolio using trial and error and select better performing products, and products closer to their core competency.

However, from one year to the next, entries and exits are of minor importance for firm-level markups. This is partly because turnover (entry/exit) is observed for only about 15% of firms, and partly because newly added products, if better performing on average than dropped products, are performing worse than incumbent products. Most of firm-level markup evolution is driven, in multiproduct firms, by reallocation toward the best performing products, with higher markups and lower marginal costs. To uncover the nature of firm-level markup growth, we decompose firm-level aggregated markups into three terms relative to portfolio modifications: (i) churning (entries and exits), (ii) within-incumbent-product markup growth, (iii) reallocation of sales shares between incumbent products. We find that the dominant term is (iii), although it exists only for multiproducts firms. On average, product churning slightly increases markups.

As multiproduct firms dominate international markets, multiproduct firms and their portfolio structure have been the focus of a considerable trade literature.[3] In particular, the endogenous selection of products, the within-firm adjustment margin, has been studied for its implications for trade flows. While the contribution of the trade literature to multiproduct firms' studies is substantial, it is not sufficient to cover the behaviour of product switching within firms since in that context, firms have mostly been studied with custom data. These data do not represent the whole production, and the choice of products sold in foreign and/or domestic markets is likely to be endogenous. Customs data do not distinguish production from resale as received, and a non-negligible part may not be produced by the firm itself (Bernard et al., 2018). We here focus on domestic firms' production, with survey data which may be used to track product portfolio changes.

The remaining of the paper goes as follows: the second part describes the data, related to the period 2009-2017. The third explains our method, reviews the main points in De Loecker et al. (2016) which are applied here to a large set of French manufacturers, and presents our measures of product similarity. Results on production function and markups estimation are reported in section four, where we derive stylized facts in cross section. The fifth explores the dynamics of a firm's product portfolio: selection of products and implications for firm-level performance.

II. Data

A. Estimation sample

The first dataset is product-level production data (*Enquête annuelle de production*) collected by the French National Statistical Institute Insee for the PRODCOM regulation[4] at yearly frequency. It covers the manufacturing sector, except for agri-food industries, and surveys about 35 000 firms on their production breakdown across products. The exhaustive strata of the sample includes firms with more than 20 workers or with sales revenues over 5 millions euros. The other firms are sampled. A distinctive feature of these data is to record

[3]The role of product-mix reallocation for international-firm size, scope and productivity has for instance been studied in response to demand (Mayer et al., 2016), competition (Mayer et al., 2014) or trade cost shocks (Bernard et al., 2011, Berthou and Fontagné, 2013, Nocke and Yeaple, 2014).

[4]Council regulation 3924/91 and Commission regulation 912/2004

both quantities and sales at a very detailed product level (PRODFRA,[5] 10 digit levels, with more than 4,000 products definition). Table 1 provides examples of the product notion used hereafter. Observation of physical output (instead of revenue output alone) has proven very helpful for neat production function estimation. Moreover, the very detailed features of the data allows us to closely monitor products portfolio changes.

1812125000	Advertising and similar printed matter (excluding commercial catalogues)
1812199010	Administrative or commercial printed matter, flat or continuous, customised or not, and directories
2511235040	Industrial boiler products: not including tanks, boilers, nuclear equipment
3102100010	Wooden kitchen furniture: by mounted elements, including custom
310912502B	Dining and living room furniture other than tables: buffets, credenzas and livings, bookcases, cabinets by element.

Table 1—Examples of products in EAP (PRODFRA classification)

To avoid identifying classification changes as product switching, we aggregate products within the smallest products' envelope which is stable over our time period.[6] From the 3789 products in the survey which are defined with a year-specific classification, from 2009 to 2017, we get 3131 products in a stable classification based on product envelope and use this concept of product throughout the paper.

The second dataset is FARE *Fichier Approché des Résultats d'Esane* data, firm-level compulsory tax files recording firm balance sheets which cover the manufacturing sector (but not only). These data are used in production function estimation, as they contain materials, employment and capital information among others. Employment is computed in full-time equivalent and is therefore a volume of work rather than payroll information (it needs not to be deflated). Materials include raw or source materials that are destroyed in the production process, and the other and external expenses, as they notably include energy expenses (electricity, gas), or outsourcing expenses. These material expenses are deflated with a industry-specific intermediate consumption price index (2 digit, 88 sectors). Capital measure is also derived from the tax record files.[7]

Our main sample merges EAP and FARE datasets (EAP-FARE), and is described in the first panel of Table 2. This sample is used for production function and markups estimation.

[5] A classification slightly more disaggregated than the PRODCOM classification

[6] Derived from a simple connected components algorithm, see appendix A for more details

[7] Measuring capital volume is difficult because assets are recorded at their acquisition price in the books. Tangible assets on the assets side of the balance sheet are broken down into four categories: land, buildings, technical and industrial equipment (which account for most of the assets of industrial enterprises), and other tangible assets (including vehicles and IT equipment). For each of these categories, firms report both the gross acquisition value of fixed assets and the accumulated depreciated value of the assets. In order to deflate by the investment price index which was current at the acquisition date, we calculate the average age of fixed assets, multiplying the depreciated portion of fixed assets by a standard depreciation period. Once the assets age is recovered, the asset book values are deflated with the industry-specific price index (NACE 43 for for building assets, NACE 28 for technical and industrial equipment and electronics industries NACE 27 for other tangible assets, NACE 29 for transportation equipment) at the estimated date of acquisition, and aggregated into a single measure. A robustness was ran using the perpetual inventory method, see appendix B for more details

We kept observations with both non missing quantity and sales to be able to compute a unit price. We exclude as well two concentrated sectors, with few firms: pharmaceutical industry and petroleum processing and coking. Per year, in-sample firms account for about 350 billions of sales, which is two thirds of the corresponding national account total production. They produce about 3,000 distinct products. Multiproduct firms (with more than one product) represent slightly more than 30% of the sample. There is on average 1.8 products per firm a given year. Only 1% of firms produce more than 9 products.

Table 2—Manufacturing firms: sales and number of products

Year	Firms	Product	Total sales (Billions)	Multiproduct	Products per firm p80	p90	p99	Mean
Estimation sample								
2009	22025	2823	313.7	0.36	2	4	10	1.95
2010	24630	2824	343.0	0.34	2	4	9	1.87
2011	26641	2836	367.2	0.34	2	4	9	1.86
2012	28409	2864	361.8	0.33	2	4	9	1.84
2013	31237	2879	355.5	0.32	2	3	9	1.80
2014	31036	2886	353.8	0.32	2	3	9	1.80
2015	31584	2877	361.5	0.31	2	3	9	1.78
2016	31262	2881	361.8	0.31	2	3	9	1.76
2017	31245	2882	383.7	0.30	2	3	9	1.76
Product dynamic sample								
2010	18154	2724	274.5	0.37	2	4	9	1.91
2011	20282	2725	297.1	0.35	2	4	9	1.88
2012	21365	2746	290.3	0.34	2	4	9	1.84
2013	23010	2772	316.5	0.34	2	4	9	1.85
2014	25131	2781	322.5	0.33	2	3	9	1.81
2015	24072	2791	336.2	0.33	2	3	9	1.81
2016	24126	2805	335.9	0.32	2	3	10	1.82

Note: Estimation sample (EAP-FARE), described in section II.A. For an observation of the estimation sample to be in the product dynamic sample, its firm must be in sample the year before and the year after, see section II.B.

In terms of sales growth rate, product portfolio renewal is as important as firms' entry and exit at the industry level, and is an important lever for firms development. In France, as shown in Figure 1, for firms continuously operating from 2009 to 2017, the net contribution of newly introduced and dropped products to sales growth was 0.9 percentage points in yearly average, which is 30% of average yearly sales growth. By contrast, at the level of the entire manufacturing industry, the net contribution of firm entry and exit was negative on average, reducing sales growth by 0.8 percentage points (-25% of sales growth). In addition, the dynamics of entry and exit are quite correlated at the product and the firm level.

B. Product dynamic sample

When investigating product dynamics, we restrict the estimation sample to be able to identify new and dropped products. In our analysis at the product-level, we restrict the

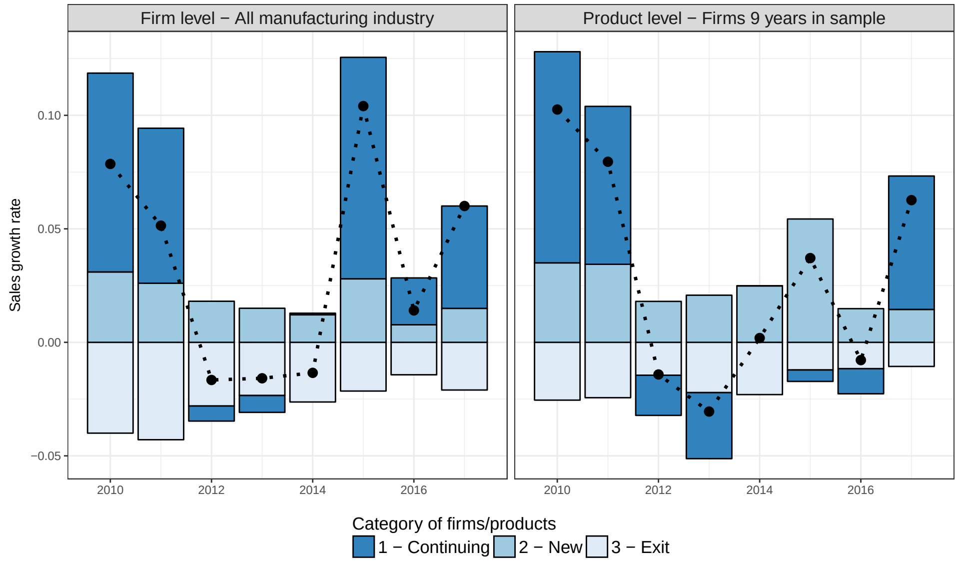

FIGURE 1. CONTRIBUTIONS OF ENTRY AND EXIT OF FIRMS AND PRODUCTS FOR SALES GROWTH

Note: The All manufacturing industry figure is computed on firms with at least 5 workers on average from 2009 to 2017 in FARE (exhaustive on the market sector). Firms 9 years in sample figure are firms that appear continuously in the merged EAP-FARE dataset.

estimation sample to firms present the year before and after, so we can clearly define products' portfolio movement and abstract from firm entry and exit.[8] This sample accounts for 80% of firms and 90% of output of the full estimation sample. Descriptive statistics are shown in the second panel of Table 2. In this reduced sample, on average from one year to the next, 3% of output can be attributed to the introduction of new products within a firm, and about 2% of output is realised on products which will be dropped the following year.

In Table 3, we examine product switching in French manufacturing firms. We find that 12% of firms alter their product-mix from one year to the next, and 14% when comparing product portfolios at the two ends of a 5-year period. When considering the whole seven-year period however, including within-period changes, the percentage of firms which alter their product-mix goes up to 30%. These statistics may be compared to the US Bernard et al. (2010) or to India Goldberg et al. (2010) although, here the product definition is much more detailed.[9] On the one hand, these statistics are in sharp contrast with the US (two to three decades ago) where more than a half of manufacturing firms would alter their mix of 5-digit products between quinquennial censuses. On the other hand, French manufacturers are slightly more active in product switching compared to Indian large manufacturers, although it could be

[8]By definition, a product is new/added at t if it is present in firm's portfolio at time t and not at $t-1$. A product is dropped at $t+1$ if it was in the firm's portfolio at t and is not at $t+1$. Approximately 90% of products' additions were not produced by the firm in the past few years (See Table D1 in the Appendix).

[9]Bernard et al. (2010) work with products at five-digit SIC level (≈1,500 products), on a 5 year frequency using three waves of quinquennial Censuses of Manufacturing from 1987 to 1997. Goldberg et al. (2010) study 5,000 publicly listed companies in the manufacturing sector over 1989-2003 from the Prowess database, producing about 1,900 products defined with an internal product classification.

due to the higher level of aggregation in Goldberg et al. (2010). To ease the comparison, we aggregate our product-level information at the 5-digit[10] level and report the result in Table 3. As expected, a higher-level definition of products lead to underestimate product switching. On this common ground, the comparison is even starker with US manufacturing firms. A similarity with US firms however arises on the predominance of churning (both adding and dropping products, " creative destruction") when product-mix is altered. This is in contrast with Indian manufacturing where dropping is almost non-existent. This may suggest that French firms are less prone to product diversification than American firms.

Table 3—Product-mix changes.

	Product-mix changes							
	All firms				Multi product			
	None	Add	Drop	Both	None	Add	Drop	Both
Percent of firms								
Overall 7 years	70	8	7	16	49	14	11	26
5-year interval, 5 digit	93	3	2	2	93	3	2	2
5-year interval	86	4	4	5	76	7	7	9
Annual average	88	5	4	2	81	8	7	3
Output-weighted percent of firms								
Overall 7 years	43	10	8	38	33	12	10	45
5-year interval, 5 digit	75	9	8	7	75	9	8	7
5-year interval	61	11	11	16	53	14	14	19
Annual average	75	9	8	8	71	10	10	9

Note: The sample is restricted to observation where the firm is present the year before and the year after. *Both* refers to firms which both drop at least one product and introduce at least one new product. In the second panel, we weight each firm-year with its output value. The survey weights were not available.

When a firm adds a new product, in one third of the cases, the firm was already selling products belonging to the same product classification at the 6 digit level (CPA). This figure goes up to 61% for 4 digit classification (CPF). Finally, 78% of newly added product belong to the same NACE 2 digit classification. Newly added products therefore largely correspond to a manufacturing activity the firm is already active in. Very similar figures can be found for product dropping (resp. 36, 66 and 80%).

Finally, Figure 2 shows the dynamics of product portfolio for firms starting with 1, 2, 3 or 4 products in 2009, and staying in the sample until 2016. It shows that independent of firm's number of products (greater than 1), there are both adding and dropping and after eight years, there are more firms ending with fewer products than firm with more products.[11] Echoing Table 3, "inactive" firms are mostly single product firms.

[10]Corresponding to NACE categories
[11]But, in terms of output, the latter represents an increasing share, and in the end a larger share than the former.

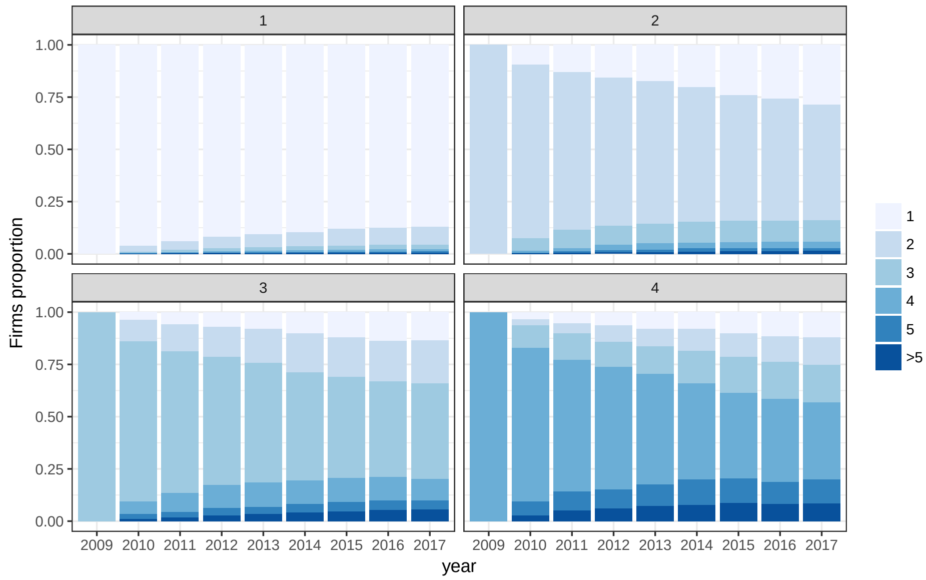

Figure 2. Product portfolio dynamics (number of products) for firms starting with 1, 2, 3 or 4 products.

Note: Among 9-year-present firms in EAP-FARE

C. *Discussion on data quality*

The annual production survey data stems from a strict statistical processing of the raw firms' answers. Each filled questionnaire quality is assessed based on comparisons with external sources (e.g. VAT declarations), and on the gaps between sales declarations and past or aggregated declarations (atypical differences). When considered unsatisfactory, survey managers analyse individually the answers with the help of qualitative collected information and if needed, they may call the firm. However, given our focus on product dynamics and given the degree of disaggregation by product, the data may not be immune to reporting errors from firms. A reassuring feature of the data collection is that from one year to the next, the survey only offers the products from the previous year's replies in the fields to be completed. When applicable, the firm must manually enter sales for a new product. In addition, the firm must report both the aggregate sales value and the breakdown by products. Thus, we do not expect large reporting errors, in particular for product switching.

However, there are some other limitations to this data source. First, a significant portion (about 40% of the sample) of physical quantity observations are imputed, in the best case from a past response. When missing, the physical quantities are imputed by dividing sales (which are generally non missing) by the respondent firms' median price on the same product, or if possible by the same-firm last-year product's price. Two types of issues may be a source for concern. First, there is a risk that this non-response is not random for our purpose: firms could refuse to inform both their sales and their quantities precisely because these two information give an estimate of the average price. This would bias our estimates of markups *levels*, but we have no reason to think it could be the case for markup evolutions, which are the main focus of the paper. Second, the imputation drives the observed price changes downward (either because prices trajectories are constant when imputation is conducted with past responses, or because in practice, we only exploit within-product changes and absorb market-level variations with product fixed effects). However, the data also allow us to identify the imputation and we are able to reproduce all of our dynamics' results on the sample restricted to non-imputed data.

A second limitation of the data concerns the firms' structure, as only the productive legal units are surveyed.[12] This limitation is shared with the existing literature on markups, which is mostly based on administrative or survey data.

III. Method and estimation

A. Theoretical background

We use the terms "markup", "market power" or "product profitability" as referring to the same concept: *the ability of firms to price above marginal cost and for this to be profitable.*[13] In industrial organisation, such ability is reflected into several indicators (Lerner Index, concentration ratios as Herfindahl-Hirschman Index, Upward Pricing Pressure etc.). In our case, markups are simply defined as price divided by marginal cost, and are closely related to the Lerner Index (price minus marginal cost divided by marginal cost). In a general setting of Nash competition, markups depend on product differentiation, number of competitors and own and cross price elasticity of demand,[14] which we refer to as demand and market structure features. Marginal costs reflect input prices, input factor productivity (e.g. workers qualification or capital embodied technology), and organisational efficiency (e.g. managerial ability), which we refer to as supply side features. This distinction, however, remains simplistic. In fact, the market structure (number of competitors) is partly determined by supply-side factors: fixed costs, sunk investment, access to essential facilities, regulatory barriers; conversely, costs are influenced by market structure, e.g. via buyer power. Empirically, measuring markups remains a challenge, first because marginal costs are unobservable, and because prices are hardly ever observed in administrative data. Two classes of methods are available, the production approach and the demand approach, which are compared in De Loecker and Scott (2016). Following Basu and Fernald (1997), Petrin and Sivadasan (2013), De Loecker and Warzynski (2012) and De Loecker et al. (2016), we use here the production approach. [15]

We present the theoretical model, due to Hall (1988) and recently applied in the context of multiproduct firms by De Loecker et al. (2016) to infer per-product marginal cost from the data.

[12]Some corporate groups choose to organise their production into a productive unit and a commercial unit, where the latter sell the products after buying it from the former. In these cases, the markup we estimate may not reflect the market power of the whole firm, but an intra-group margin.
[13]Glossary of terms used in EU competition policy Antitrust and control of concentrations
[14]see De Loecker and Warzynski (2012)
[15]The demand approach, as in Berry et al. (1995), requires to estimate a demand system to recover own and cross price elasticities from which markups can be recovered. In the production approach, the most critical assumptions concern the estimation of the production function while markups do not depend on demand and market structure assumptions, and the opposite holds for the demand approach. De Loecker and Scott (2016) however find very similar results using both approaches on brewing industry data.

Firms are assumed to minimise their cost $C(M_{fjt}, L_{fjt}, K_{fjt}) = W^m_{fjt} M_{fjt} + W^l_{fjt} L_{fjt} + W^k_{fjt} K_{fjt}$, where W_{fjt} is the vector of input prices (for materials M, labor L and capital K) faced by the firm for a given product. Given its production function $= Q_{fjt}(.)$, the firm pursue a physical output objective for each of its products: $Q_{fjt} = Q_{fjt}(V_{fjt}, K_{fjt})$, which is a constraint in the optimisation problem. Thus, the Lagrangian associated to its choice of inputs $(M_{fjt}, L_{fjt}, K_{fjt})$ is:

$$\mathcal{L} = W^m_{fjt} M_{fjt} + W^l_{fjt} L_{fjt} + W^k_{fjt} K_{fjt} + \lambda_{fjt}[Q_{fjt} - Q_{fjt}(V_{fjt}, K_{fjt})]$$

Optimal input choice satisfies the first order condition, for a given input, here M:

$$\frac{\partial \mathcal{L}}{\partial M_{fjt}} = 0 = W^m_{fjt} - \lambda_{fjt} \frac{\partial Q_{fjt}(.)}{\partial M_{fjt}}$$

The Lagrange multiplier, at the optimal choice of inputs, is by the envelope theorem equal to the marginal cost of a unit of output.

$$\lambda_{fjt} = \frac{dC(M^*_{fjt}, L^*_{fjt}, K^*_{fjt})}{dQ_{fjt}}$$

Therefore, we may use the first order condition to evaluate the marginal cost thanks to

$$\lambda_{fjt} = \frac{\frac{W^m_{fjt} M_{fjt}}{Q_{fjt}}}{\frac{M_{fjt}}{Q_{fj}} \frac{\partial Q_{fj}(.)}{\partial M_{fjt}}}$$

where the numerator displays the average cost per physical unit and the denominator the elasticity of production with respect to materials input. Both terms may be estimated from the data, provided some further assumptions which we explain in the following section. The first order condition on materials is used, and not on the other inputs, as the assumption that the firm is optimising on a yearly basis for the choice of the input is all the more credible that the input is indeed variable, not subject to adjustment constraints or considerations on future periods.

From this expression, it appears that marginal cost may vary due to input prices (W^m_{fjt}), or more generally due to average unit cost, but also decreases with technical efficiency embodied in the elasticity of production with respect to materials. Importantly, if input prices reflect input quality, marginal cost may be increasing in output quality. This latter remark involves that although we may use the term “technical efficiency” to qualify lower marginal costs, we should ideally correct for quality.

Then, firms are assumed to choose prices, which are here observed. Their markup behaviour is left completely free of assumptions. Markups are defined based on observed prices, and estimated marginal costs:

$$\mu_{fjt} = \frac{p_{fjt}}{\lambda_{fjt}}$$

Markups may here reflect a number of product attributes: market structure, the degree of competition, idiosyncratic demand shifters, consumer preferences, differentiation, overhead costs... That is, any factor which allows a firm to price over its marginal cost, which is the very definition of market power.

B. *Deriving markup and marginal costs by product within firms*

This section largely builds on De Loecker et al. (2016), which develop a framework to estimate product-level markups in multiproduct firms.[16] We reproduced here their main estimation method insights for the reader not familiar with the estimation procedure and also clarify some estimation details. A more complete description of the method can be found in Appendix B.

Firms are assumed to minimise costs and thus to choose optimally their inputs under on a production level objective. In this context, markups can be expressed as the ratio of the output elasticity with respect to one input (production efficiency) to the share of the same input cost in output revenue (cost in revenue). Importantly, the analysis is conducted at the product level: the goal is to derive markups and marginal costs per firm-product. A firm f producing product j from industry s_j at time t has the following production function:

$$Q_{fjt} = \Omega_{ft} F_{s_j}(M_{fjt}, L_{fjt}, K_{fjt}) \tag{1}$$

Q is physical output, Ω_{ft} is firm-year productivity and F_{s_j} is the production technology which takes as input materials M, labor L and capital K. For our purpose, output elasticities are recovered with the estimation of F_{s_j}, and inputs must be broken down by product (this breakdown is unobserved): inputs are indexed by j.

The estimation procedure proceeds as follows. First, F_{s_j} is estimated on the sample of single-product firms with production function estimation following Wooldridge (2009) and Ackerberg et al. (2015), with an input price correction as in De Loecker et al. (2016). For single-product firms, no assumption on the input allocation across products is needed (as we directly observe $M_{fjt} = M_{ft}$). Except for the input price correction,[17] the estimation of the production functions is rather classical. Even though we would ideally estimate one production function per product, data limitations constrain us to run a pooled production function estimation for each industry (2 digit NACE), as it is commonly done in the production function estimation literature. By industry, the coefficients of a translog production function are

[16] Other recent proposals include Dhyne et al. (2017), or a method close to De Loecker et al. (2016) by Blum et al. (2018) using the hindsight by Gandhi et al. (2016).

[17] As we do not observe input prices at the firm-level, and deflate input values with sector-level price index, we model the input prices as a function of firm's output prices and market shares, as in De Loecker et al. (2016). Plugging the assumed expression in the estimation, we derive on top of the production function coefficients, a proxy for input prices w_{fjt}. Appendix B describes more thoroughly the method.

derived. Translog production functions are flexible in the sense that they allow for heterogeneity in elasticities of substitution and returns to scale across firms, as the output elasticities are a function of the set of inputs. The production features F_{s_j} are assumed representative: they apply to products in both single and multiproduct firms. Namely, the production function estimates of a multiproduct firm consists in (1) total factor productivity $\widehat{\Omega}_{ft}$ and (2) translog coefficients for each of its products $\widehat{F}_{s_j}$. The latter is given by the corresponding estimates in single-product firms. The former is estimated in a second step: it allows multiproduct firms to be more efficient than single-product firms although the production technology is common across firms producing the same product.

For the second step estimation for multiproduct firms, a challenge remains: allocating inputs across products in multiproduct firms. For this step, for each multiproduct firms producing J_{ft} products, to determine its J_{ft} production processes (one per product) we shall estimate (1) its productivity Ω_{ft}, invariant across its product (1 unknown), (2) how its inputs are spread over products i.e. $\rho_{jft} = \frac{M_{fjt}}{M_{ft}}$($J_{ft} - 1$ unknown shares, as shares sum to one).[18] This boils down to J_{ft} unknown in J_{ft} production equations, which can be solved numerically. To wrap up, to estimate markups and marginal costs, we needed (i) output elasticities and (ii) the ratio of input cost over product revenue. After solving the J_{ft} production equations for multiproduct firms, we have recovered all the parameters needed.[19]

C. Similarities between products

The study of the dynamics of product portfolios can largely depend on the nomenclature at hand. Their definition is not always based on economic concepts (substitutability, complementarity, relevant markets ...). Depending on the industry, two distinct products in the classification may in fact be very close technologically, so that it is very easy for a firm which produces one to produce the other as well.[20] To quantify product differentiation outside of the nomenclature categories, we build three similarity measures between products. We call them *coproduction*, *text-based* and *materials* similarities. The first defines close products as those who are often produced together (in the same firm). The second defines close products as those whose descriptions are found close using textual analysis. The third defines close products as those whose production need similar intermediate consumption.

Cosine similarity. — Our three similarities between products are build on *cosine similarities*, which measure the extent of products' attributes overlap. More formally, for two products i and j, and given product characteristics as a N dimensional vector A_i, we define :

$$s_{ij} = \frac{A_i' A_j}{\|A_i\| \cdot \|A_j\|}$$

[18]Here the assumption is that for each given product, the inputs are used in the same proportion of their total.

[19]For (i), $\frac{\partial \hat{F}_{s_j}(M_{fjt}, L_{fjt}, K_{fjt})}{\partial M_{fjt}}$; and $M_{fjt} = \rho_{fjt} \times M_{ft}$ which enters (ii) with observed revenue.

[20]For instance, two windows may be located in distinct industries depending on the frame materials (e.g. wood or plastic).

- For the **coproduction similarity**, the products' characteristics is the universe of N^f in-sample firms. $A_i^{cop} = (a_{i1}^{cop}, ...a_{ik}^{cop}, ...a_{iN^f}^{cop})$, where $a_{ik}^{cop} = 1$ if product i belongs to firm k portfolio for at least a period. This similarity counts the coproduction links. In practice, we use a slightly modified expression so as to ignore the first coproduction link.[21]

- For the **text-based similarity**, the products characteristics is the universe of N^w words used to describe products: $A_i^{tex} = (a_{i1}^{tex}, ...a_{ik}^{tex}, ...a_{iN^w}^{tex})$, where a_{ik}^{tex} is the count of word k used to describe product i in its description. The description of the product comprises its labels both in the PRODFRA classification and of its CN8 sub-products, and the description of the CN8 sub-products as defined in European law.[22]

- For the **materials similarity**, the similarity is built on a cosine similarity between firms (and not products) in a first step, in the 81-dimensional space of 2017's intermediate consumption expenses from the "expense survey" collected by Insee. It is well suited to encompass technological similarities between firms, although the space of intermediate consumption is rather coarse (intermediate consumption are allocated by NACE 2-digit industry). We therefore suspect this measure to be less precise. Two products are similar if firms selling them are similar in terms of the former cosine similarity. We refer to the Appendix C for complements on the computation method and the data source.

Cosine similarity is a useful tool in analysing similarities or differences in abstract universes such as "technological spaces". Its main advantages are the simplicity of the concept and its computational tractability. Jaffe (1986) uses it to compute firms' similarity in R&D positioning using firms' distribution of technology-based patents across patent classification. Hwang et al. (2010) use it to build similarities between US supermarkets based on the range of brands that consumers can buy within certain products. Based on textual description of products given by firms, Hoberg and Phillips (2016) use the cosine similarity to build firms' clusters that differ from the official and unchanging classification, capturing product and industry evolutions as well as cross-industries relatedness. With between firms' similarities, they are able to identify firms' competitors more precisely. Our text-based similarity is very similar to the one used by Hoberg and Phillips (2016), except that the product description we use is less detailed and that we seek to calculate similarities between products rather than between firms.

With the text-based similarity, we capture technological relatedness, at least to the extent that the text substance reflects it. In contrast, the coproduction similarity, based on firms'

[21]The coproduction similarity is corrected so that newly introduced products are not considered by design as close to the firms' other products. A coproduction link between two products which is observed only once do not participate in the similarity. A new product is therefore considered as similar with another ($s'_{ij} > 0$) if this link exists elsewhere in the productive network (see Appendix C).

[22]The latter is available at https://eur-lex.europa.eu/legal-content/FR/TXT/HTML/?uri=CELEX:52011XC0506(05)rid=1 and comprise descriptions such as (in French) " Turbocompresseurs - Dans un turbocompresseur, l'axe de la roue est entraîné par un moteur externe et l'air ou les autres gaz à comprimer sont mis en mouvements par la roue à aubes. Les turbocompresseurs peuvent être monocellulaires ou multicellulaires et travailler de façon axiale ou radiale. Les turbocompresseurs bicellulaires du type simple sont, par exemple, utilisés dans les aspirateurs."

decisions, is not a pure measure of technological closeness. Indeed, this measure likely encompasses both supply and demand side elements. On the supply side, if when possessing the capital, the skills of the employees and suppliers of raw materials necessary to produce A, it is easy to produce B, which is technologically close, then the A-B pair is likely to be produced jointly by a large number of firms. On the demand side, complementary products from a buyer's point of view may appear similar with our measure. Typically, hand brakes and on-board electronics can be found to be similar because they are both produced by the same firms, namely, auto parts suppliers.

We provide descriptive statistics on these similarity measures in Appendix C, in particular we show the closest products according to each of them in four industries. The text-based similarity is able to find products which are technologically very close but vary according to an attribute (e.g. size, cylinder, material...). The materials similarity often finds links between products belonging to distinct industries, in particular between a base product and the one which follows in the value chain (e.g. between a motorcycle and its chassis, or between a chassis and various metals). The three distances often find links between products which do not belong to the same industry.

IV. Estimation results

In this section, we present the output elasticities derived from the production function estimation, followed by the implied markups. We discuss in particular empirical stylized facts, constrasting core products and secondary products. A core product is defined as the product with maximal sales. We show that our estimates are highly coherent with the product ladder hypothesis.

Table 4 reports the output elasticities for both multiproduct and single-product firms. They are a function of estimated $\hat{\beta}$ (translog coefficients, or 'technology'), $\hat{\rho}_{fjt}$ (share of firm-level input going to product j), $\hat{w}_{jft}$ (estimated input price) and observed inputs. For instance, as the production function is a translog, the output elasticity for materials is equal to

$$\hat{\beta}_m + 2\hat{\beta}_{mm}\hat{m}_{fjt} + \hat{\beta}_{mk}\hat{k}_{fjt} + \hat{\beta}_{ml}\hat{l}_{fjt} + \hat{\beta}_{mlk}\hat{l}_{fjt}\hat{k}_{fjt}$$

where lower-case letters indicate logs. Physical inputs are unobserved at the product levels, but can be recovered by taking into account the estimated input price correction and the estimated input shares, i.e. $\hat{m}_{fjt} = \log \hat{\rho}_{fjt} + \tilde{m}_{ft} - \hat{w}_{fjt}$ ($\tilde{m}_{ft}$ are the input materials expenses observed at the firm level, corrected with the estimated share used for product j and deflated with the estimated price of inputs). It is apparent that output elasticities vary by firms (and across products within firms) even though technology does not, so we report the mean output elasticities and their standard deviations over firms. Returns to scale are the sum of the three elasticities: with respect to labor, materials and capital. Across all firms, the average output elasticities with respect to labor, materials and capital are respectively 0.31, 0.66, and 0.02. We find slightly decreasing returns to scale, but constant returns to scale cannot be rejected at our level of precision. Output elasticities with respect to capital are estimated particularly low.

Table 4—Average output elasticities by sector

Industry (NACE code)		Labor	Materials	Capital	Returns to scale	Obs.	Firms
Textiles	13	0.35	0.63	0.01	0.99	15079	1842
		[0.16]	[0.16]	[0.02]	[0.07]		
Wearing apparel	14	0.28	0.70	0.03	1.01	27236	1499
		[0.23]	[0.25]	[0.03]	[0.07]		
Leather and related products	15	0.38	0.70	-0.11	0.97	4399	553
		[0.26]	[0.32]	[0.11]	[0.18]		
Wood products	16	0.34	0.65	0.02	1.01	28011	3070
		[0.20]	[0.18]	[0.02]	[0.08]		
Paper and paper products	17	0.28	0.66	0.02	0.95	12632	1304
		[0.13]	[0.11]	[0.03]	[0.05]		
Printing	18	0.35	0.64	0.05	1.04	25843	3071
		[0.14]	[0.13]	[0.03]	[0.10]		
Chemicals products	20	0.23	0.72	0.04	0.99	33666	1963
		[0.06]	[0.05]	[0.02]	[0.05]		
Rubber and plastic products	22	0.29	0.67	0.00	0.97	29774	3474
		[0.12]	[0.11]	[0.01]	[0.03]		
Other non-metallic mineral products	23	0.36	0.62	0.04	1.02	33668	3600
		[0.15]	[0.20]	[0.07]	[0.06]		
Basic metals	24	0.23	0.66	0.04	0.93	10261	957
		[0.15]	[0.19]	[0.04]	[0.06]		
Fabricated metal products	25	0.32	0.64	0.01	0.97	58902	8060
		[0.14]	[0.14]	[0.02]	[0.03]		
Computer, electronic products	26	0.30	0.67	0.00	0.97	12264	1694
		[0.10]	[0.09]	[0.04]	[0.04]		
Electrical equipment	27	0.26	0.66	0.02	0.94	16386	1809
		[0.15]	[0.18]	[0.04]	[0.03]		
Machinery and equipment n.e.c.	28	0.31	0.66	0.01	0.98	32065	3908
		[0.19]	[0.18]	[0.01]	[0.04]		
Motor vehicles, trailers	29	0.29	0.65	0.00	0.94	11040	1497
		[0.21]	[0.20]	[0.03]	[0.04]		
Other transport equipment	30	0.18	0.85	-0.03	1.01	3022	488
		[0.22]	[0.16]	[0.05]	[0.02]		
Furniture	31	0.34	0.62	0.02	0.98	35796	3069
		[0.15]	[0.11]	[0.04]	[0.07]		
Other manufacturing	32	0.36	0.59	0.04	1.00	9609	1578
		[0.15]	[0.14]	[0.02]	[0.01]		

Note: This table reports output elasticities from the production function estimates, for both single-product and multi-product firms. Averages are across firms within sectors, as well as standard deviations in brackets. Source : EAP-FARE

These orders of magnitudes are however robust across alternative specifications (Appendix B). Markups estimates only rely on the estimation of the material elasticities, and our results are unchanged when using the alternative production function estimations described in the Appendix B. Therefore, we do not expect the likely underestimation of capital elasticity to endanger our results.[23]

Table 5—Markups by sector

		All product-firms (1)		Core products within multiproduct firms (2)		Product with maximal markup (3)	
	Sector	Mean	Median	Mean	Median	Mean	Median
Textiles	13	1.75	1.00	4.10	1.83	2.18	1.09
Wearing apparel	14	1.77	0.92	4.21	2.20	3.42	1.53
Leather and related products	15	2.51	1.15	5.57	2.16	3.21	1.32
Wood products	16	1.57	1.00	2.90	1.74	2.09	1.18
Paper and paper products	17	1.66	0.95	3.31	1.76	2.09	1.06
Printing	18	1.71	1.05	3.56	2.07	2.22	1.19
Chemicals products	20	2.45	0.89	6.15	2.81	4.52	1.34
Rubber and plastic products	22	2.04	1.07	3.89	1.77	2.40	1.14
Other non-metallic mineral products	23	1.81	1.00	3.42	1.75	2.34	1.16
Basic metals	24	2.62	0.99	5.08	1.68	3.69	1.14
Fabricated metal products	25	1.65	1.08	3.33	1.73	1.88	1.13
Computer, electronic products	26	2.61	1.12	4.96	1.79	2.99	1.21
Electrical equipment	27	2.41	1.05	5.33	1.97	2.92	1.15
Machinery and equipment n.e.c.	28	2.03	1.04	4.35	1.90	2.40	1.11
Motor vehicles, trailers	29	2.15	1.01	4.80	1.72	2.44	1.05
Other transport equipment	30	2.38	1.26	4.47	2.07	2.71	1.34
Furniture	31	1.95	1.10	3.41	2.05	2.97	1.50
Other manufacturing	32	1.96	1.10	4.46	1.57	2.10	1.16

Note: This table reports markups recovered from production function estimates, input price correction and shares attribution. These statistics are computed first for all firm-products-years estimates in columns (1), only for the year-specific core product within multi-product firms in columns (2) and only for the year-specific product where maximal markup is realized in each firm, be it because it is the only product (single-product firms) or because its markups is higher than on other products (3). They are computed excluding both extreme percentiles.

Table 5 provides the results for markups. In column (1), we show markups over all product-firm pairs by industry. The mean markup across all product-firm is 1.94, with a standard deviation of 3.99. The median markup is 1.04. In some industries, the median markup is below 1, which means that for more than half of the products in this sector, prices are set below marginal costs. However, if we restrict the sample to a specific product per firm, the product where the maximal markup is realised (column (3) of Table 5, which comprises single-product firms where the maximal markup is achieved on its only product), the median is above one and the mean markup considerably higher. Column (2) shows the mean and median markups for

[23]See Gandhi et al. (2016) for a discussion on the identification and estimation of gross output production functions, and the empirical differences with value added production functions.

core product (with maximal sales value) within multiproduct firms. Here as well, markups are higher and clearly above 1. We interpret these findings as supporting the idea that revenue is borne by some products (core product, or product with maximal markups), and firms accept markups under 1 for some of their products, whose production is *de facto* sustained by the other products in the firm portfolio. In our estimation, marginal costs above prices may arise for several reasons. First, the production processes for products recently introduced by the firm may not yet be fully optimised. We provide some evidence in the next section studying product dynamics that added products are characterised by noticeably lower markups and higher marginal costs. Second, we use a unit price over a full year, which is an average price. Firms could adopt more strategic pricing behaviour (discounts, markdowns, two part tariffs), which could imply that the average price is actually lower than the marginal cost. Another example of behaviour that could explain margins below unity is the limit pricing strategy, with which firms agree to reduce their profits in the short term in the hope of deterring market entry and maintain a favourable oligopolistic structure in the long run. Finally, note that a marginal cost above the price does not in itself imply a financial loss for the firm. A firm only loses profit on a product if the selling price is lower than the average cost.

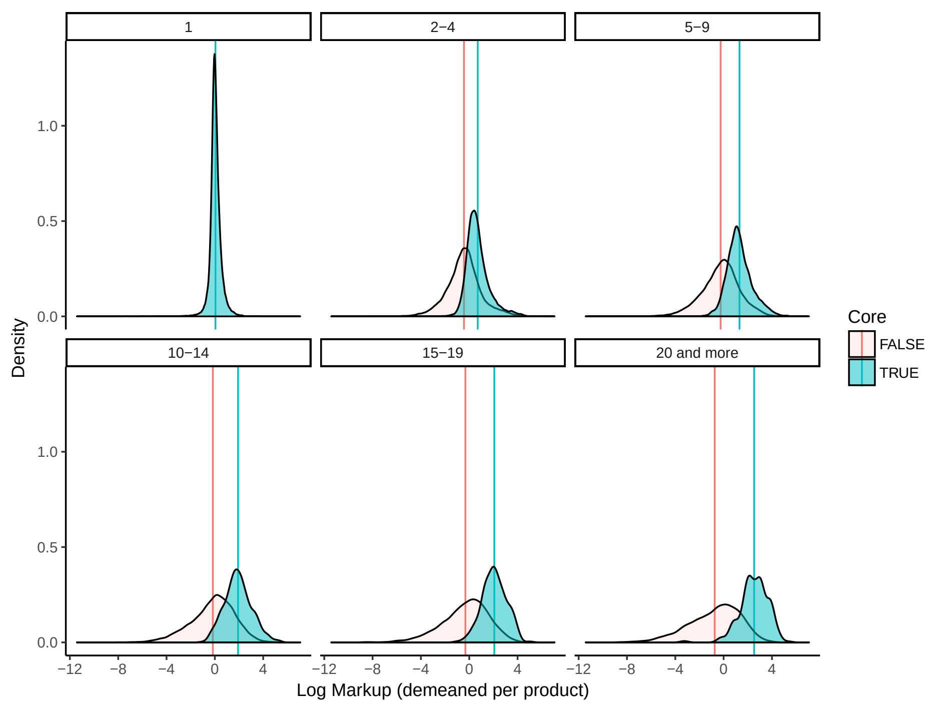

Figure 3. Mark-up within multiproduct firms, by product portfolio size

Note: The product with maximal sales value is the core product. Log mark-up are demeaned by product. The markup (relative to the product market) are generally higher on the core product. Source : EAP-FARE 2009-2017.

Figure 3 shows how markups are spread across product within multiproduct firms. Here log markups are demeaned by product in order to exclude potential selection of multiproduct firms into highly profitable products. The larger the size of the product portfolio, the larger is the difference between the markup on the core product (the product with maximal sales value) and the markup on the other products. This may reflect a size effect, as large firms are known to be more efficient than small ones, they may be able to exercise higher markups. Further, the larger the portfolio, the higher markup on the core product. This could reflect that firms with a large portfolio are particularly dominant on their core product, which they are able to produce particularly efficiently, and generating enough economies of scope to sustain a large product portfolio. In diversified firms, markups on secondary products are much more spread than in firms with a few products. A similar pattern is observed for marginal costs (see Figure D1 in Appendix).[24] This echoes the product ladder hypothesis and its implications on variable markups derived in Mayer et al. (2014). Assuming marginal costs are (strongly) increasing with the distance to the core competency: $\nu_1 < \nu_2 < \cdots < \nu_J$, the more products J are produced by the firm, the largest is the distance between ν_1 and the other marginal costs. The same applies to markups which are a linear function of $\frac{1}{\nu}$.

According to this theory, product's markup should be an increasing function of the product's similarity to the core competency of the firm. In Figure 4, we assess the link, for secondary products in multiproduct firms, between markups (relative to core's markup) and similarity to the core product, with our three similarity measures defined in section III. The three measures robustly point at the expected relationship. On average, secondary products perform worse than core products and all-the-more that they are distant in terms of technology (text-based and materials similarities) or productive links (coproduction similarity). This can be interpreted as knowledge (for marginal cost) or reputation (for markups) linkages between products technologically close within firms, as similar products may benefit from efficiency and market power of the core products.

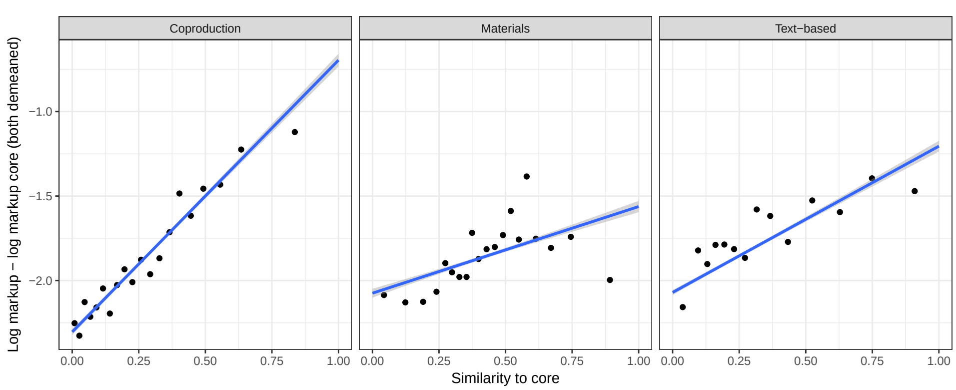

Figure 4. Markups on secondary product and similarity to core product along the (i) coproduction similarity (ii) materials similarity (iii) text-based similarity

Note: We represent on top of the regression lines the average by similarity percentile groups.

[24]Meanwhile, prices are not distinct for core products and secondary products (See Figure D2 in Appendix).

These cross-sectional statistics provide evidence and new results in favor of the product ladder hypothesis. Multiproduct firms have a core product, with a relatively high market power and strong efficiency. Secondary products can be ranked according to their technological distance to the core, and perform better when closer. Empirically, the sales' share of secondary products are also positively associated with the similarity to the core. However, the correlation is stronger for markups.

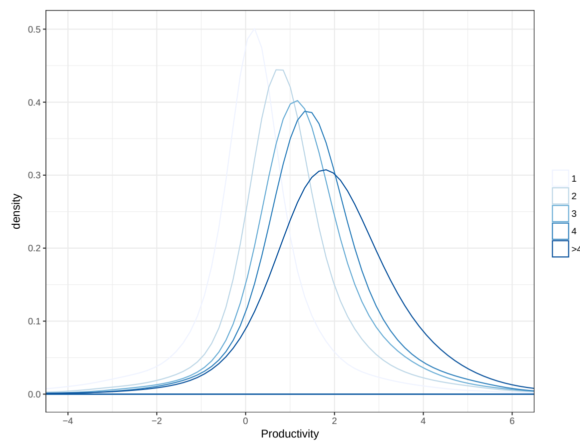

Figure 5. Productivity of firms with 1, 2, 3, 4 or more than 4 products

We check a final stylized fact in Figure 5: firm scope is positively associated with its productivity. Our estimates of firm productivity are increasing with the number of products produced by the firm. Going back to our marginal cost estimates:

$$\lambda_{fjt} = \frac{1}{\Omega_{ft}} \times \frac{\frac{W^m_{fjt} M_{fjt}}{F_{s_j}(M_{fjt}, L_{fjt}, K_{fjt})}}{\hat{\epsilon}_{Q,M}(\hat{\beta}, M_{fjt}, K_{fjt}, L_{fjt})}$$

we note that at constant product-specific technology (output elasticities, factor allocations and production function) and input prices, higher productivity firms have lower marginal costs across all their products. Our estimates point out that economies of scope are indeed present as firm productivity is positively associated with the number of products.

V. The dynamic of firm's product portfolio

This section focuses on understanding the dynamics of product portfolio, its determinants and consequences for firm-level markups. For results using similarity measures, we use the coproduction similarity, although materials and text-based similarities give qualitatively the same results.

A. *Entry, exit and selection of products*

Firm-level productivity and product switching. — We first comment on the determinant of product switching at the firm level. Table 6 reports OLS regressions of a dummy variable indicating firm's product portfolio movement M_{ft} (at least a new product at t, at least a product drop at $t+1$, at least one or the other) on firm-year productivity:

$$\mathrm{M}_{ft} = \beta\omega_{ft} + \alpha_f + \delta_{s,t} + \epsilon_{ft}$$

Sector-year fixed effects $\delta_{s,t}$ control for macroeconomic fluctuations. In the second specification, firm fixed effects α_f control for invariant firm-level characteristics such as average productivity level or average size, or industry. We therefore exploit variations from year to year within a firm, but we also report results without firm fixed effects, and results with both lagged productivity and productivity evolution. We find that positive productivity shocks are associated with product switching: a 1% higher productivity is associated to a probability of adding a product almost 1.4 percentage point higher, a probability of dropping a product by 1.3 p.p higher and a probability of alteration of product-mix (either dropping or adding a product) by 2.1 p.p. higher. New products are launched in firms which experience positive productivity shocks. It is a simultaneous phenomenon, the direction of causality is not clear. These results are however in line with the literature : Navarro (2012), on Chilean data, as well with Tewari and Wilde (2019), on Indian data, find that changes in product mix are associated with an increase in productivity. In the latter case, the authors state a causal effect of product portfolio changes on productivity following a deregulation in the product market. In our case, more strikingly, products are dropped after a positive productivity shock. In particular, the combination of adding and dropping characterises productive firms, or firms experiencing a productivity shock. Within the most productive firms, we observe more trial and errors.

Product exit, marginal costs and markups. — We extend the analysis at the product level, by investigating the role of marginal costs and markups on product exit and thereby on product selection. We regress a dummy indicating that the product will be dropped (it is absent from the firm portfolio at t+1, and present at t) over its estimated markup μ_{fjt} and marginal cost λ_{fjt} and various set of fixed effects:

$$\mathrm{Exit}_{fjt} = \alpha\log(\mu_{fjt}) + \beta\log(\lambda_{fjt}) + \delta_{jt} + \nu_{fj} + \epsilon_{fjt}$$

Table 6—Productivity and firm product portfolio dynamics

	At least ..					
	A product adding (t)		A product dropping (t+1)		One or the other	
Productivity (firm-year)	0.013***	0.014***	0.014***	0.013***	0.021***	0.021***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Observations	156,140	156,140	156,140	156,140	156,140	156,140
Lagged productivity	0.006***	0.012***	0.019***	0.014***	0.020***	0.021***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Productivity evolution	0.020***	0.022***	0.018***	0.012***	0.027***	0.026***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.001)
Observations	122,556	122,556	122,556	122,556	122,556	122,556
Firm FE	No	Yes	No	Yes	No	Yes
Sector-Year FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: Product dynamic sample (observations with firm present the year before and after), at the firm-year-level. Standard errors are clustered at the firm level. *p<0.1; **p<0.05; ***p<0.01

where δ_{jt} is a product-year fixed effect capturing fluctuations at the product level such as aggregate demand (more or less turbulent product markets, cyclical churning...), and ν_{fj} is a firm-product fixed effect which captures all invariant characteristics specific to the pair firm-product, such as average markup and marginal costs over the product life cycle in this firm. In this specification, we exploit the variations of marginal cost and markups within a firm-product pair. The results of this regression are reported in Table 7, column (4), along with other fixed effects specifications. On one hand, when the marginal cost of a product is higher by 1%, relative to either product-year standard (columns 2,3), or relative to both product-year standard and its own average marginal cost (columns 4,5), the probability of its exit is higher by 0.3 to 1.6 percentage points. This is true while controlling for markups. On the other hand, a markup higher by 1%, again relative notably to the firm-product average markup, lowers the probability of exit by 0.6 p.p. In column (5), we take specification (4) further and attempt to control as well for firm-level year-specific shocks, such as productivity shocks, and exploit the variation left between products within firm-year. In this last specification, it appears that in the arbitrage between products in a given year if one has to exit (say because of a negative competitive shock), the marginal cost is of primary importance and the highest marginal cost product is the more likely to exit. All in all, a higher markup and a lower marginal cost seem to be robust features for product survival.[25] We also test the effect of products' similarity to core products. We find that products further from the firms' core product are more likely to be dropped the following year. This result is robust when we lead the estimation on a restricted sample excluding core products.

[25]If we perform the same regressions but replacing markups and marginal costs by prices, we find no significant effects: exiting products are not distinct from the others as their price is concerned.

TABLE 7—PRODUCT EXIT, MARGINAL COSTS AND MARKUPS

	Dependent variable:				
	Exit next year				
	(1)	(2)	(3)	(4)	(5)
Log markups	-0.008^{***}	-0.009^{***}	-0.007^{***}	-0.006^{***}	0.001
	(0.0005)	(0.0005)	(0.001)	(0.001)	(0.002)
Log marginal costs	0.008^{***}	0.008^{***}	0.011^{***}	0.003^{***}	0.016^{***}
	(0.0004)	(0.0005)	(0.001)	(0.001)	(0.002)
Similarity to core product	-0.076^{***}	-0.063^{***}	-0.059^{***}		
	(0.001)	(0.001)	(0.002)		
Product-year	No	Yes	Yes	Yes	Yes
Firm	No	No	Yes	No	No
Firm-Year	No	No	No	No	Yes
Firm-Product	No	No	No	Yes	Yes
Observations	287,180	287,180	287,180	287,180	287,180
R^2	0.033	0.138	0.309	0.589	0.841

Note: Product dynamic sample: observations for which the firm is present both the next and the previous year are kept. Standard errors are clustered at the firm level. Results are very similar on the subsample of non-core products, or when the alternative distance is used. *p<0.1; **p<0.05; ***p<0.01

OLDER PRODUCTS HAVE BOTH HIGHER MARKUPS AND LOWER MARGINAL COSTS. — The selection process governing exit should create markup and marginal cost differentials between incumbent product and young or newly introduced products. Aside selection, these differentials may as well be fed by product and firm learning.

We investigate how prices, markups and marginal costs vary along the product life-cycle with these phenomena in mind. For each observation, we compute an age variable which indicates either product age, or anteriority in the sample when age is unobserved. Age is observed as long as we observe an entry (absence in firm portfolio at $t-1$, and presence at t). It is unknown when we observe the product starting the first year the firm appears in our sample (left censorship). Incumbent and older products most likely belong to this last category, but anteriority is also tied to firm entry and exit in the sample. In this case, anteriority in the sample gives a partial information (the product is older than x years). Although imprecise, it conveys information on longer run age effects. We regress prices, markup and marginal cost over this age variable. For markup, the specification writes

$$(*) \qquad \log(\mu_{fjt}) = a \star \text{age}_{fjt} + \delta_{jt} + \underbrace{\nu_{fjt}}_{\text{Various specifications}} + \epsilon_{fjt}$$

where age_{fjt} enters as a categorical variable, with the youngest category (products which enter at t, which is therefore younger than a year) as the reference category. age_{fjt} also includes sample anteriority when age is unknown. δ_{jt} are product-year fixed effects. They are meant to control for unobserved and time-varying product-specific heterogeneity. We exploit three different specifications of fixed effects ν_{fjt}, to disentangle selection and experience effects.

First, $\nu_{fjt} = \nu_f$ is taken as a firm fixed effect. In this specification, we estimate the effect of age on product performance *within firms between products* (1). These estimates confound three mechanisms.

1) Selection effect. Better performing products survive longer, and under-performing products are quickly removed from the firm product portfolio. Hence, observing an older product means that it is profitable enough to survive in the portfolio.

2) Product experience. Learning by doing, namely, the process through which productivity depends positively on accumulated past production received considerable attention starting with Arrow (1962). Numerous empirical evidence of this effect can be found in the literature, even though its magnitude is to be considered with caution, because it is particularly difficult to disentangle the learning effect to the capital embodied technological change (Dunne et al. (1989), Bahk and Gort (1993)). Product performance may improve after the product introduction because firms acquire knowledge about how to better produce and sell their products. It may come from (on the supply side) better use of tools and production processes from workers (Jovanovic and Nyarko (1995)), investment in more adapted machines, better organisation of the production chain, or (on the demand side) better product reputation, marketing or market targeting.

3) Firm-level performance. Firms may experience changes that increase or decrease the performance of all their products, for instance, productivity gains thanks to better organisation processes. Consequently, even without selection or learning, product performance may improve with age, following firm-level productivity gains.

In order to cancel out the firm-level performance effect, we use a firm-year fixed effect : $\nu_{fjt} = \nu_{ft}$. These estimates *within firm-year between products* (2) compare products ages and performance (markup, marginal cost) relative to average ages and performances in the same firm, the same year, orthogonally to firm-level trajectories. In order to cancel out the selection effect, we have to focus on individual product-level sequences. We use a firm-product fixed effect : $\nu_{fjt} = \nu_{fj}$, the estimates are *within product-firm between years* (3). In this specification, the age effect on product performance can be interpreted as learning, or experience effect (at the firm and product level). It combines the improvement on about to be dropped products, and products meant to succeed. To illustrate this heterogeneity, we also run the latter specification while restricting the sample to products that are still in the firms' portfolio the following year (4) - who are therefore probably learning at a faster rate.

We graphically present estimation results in Figure 6, where it appears that markups and marginal costs display large differentials following product's age.[26] We find no significant

[26]Complete results can be found in Table D2.

effect of product age on prices, except slightly lower prices for the most anterior products (those for are inseparable from the firms). In general, within a firm-year portfolio, products' prices do not differ significantly according to their age. It is strikingly not the case as markups and marginal costs are concerned.

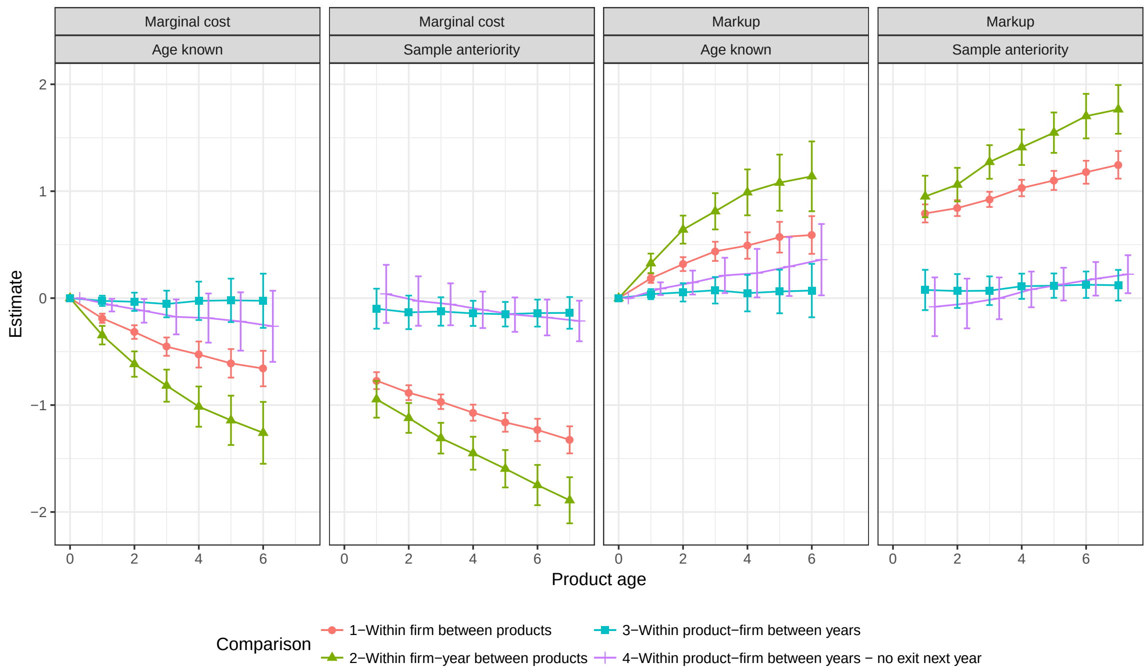

Figure 6. Product age and markups and marginal costs profiles

Note: Estimates from equation (*). In 1, $\nu_{fjt} = \nu_f$, firm fixed effect. In 2, $\nu_{fjt} = \nu_{ft}$, firm year fixed effect. In 3 and 4, $\nu fjt = \nu_{fj}$ firm product fixed effects. In 4, the sample is restricted to products remaining in firms portfolios the following year. Error bars correspond to the 5% confidence interval. All standard errors are clustered at firm-level.

Youngest products are markedly different from older ones. In the basic specification, *within firm between product effects*, 3 year-old (6 year-old) products have on average, a marginal cost lower by 0.43 (0.66) log point compared to new entrants, which means that they are significantly less costly than new entrants. For the most anterior products (in practice, left censored), marginal costs are only a quarter of that of new entrants (within the same product-year). Since there is no effect on price, all efficiency gains from marginal cost are transferred into markups, that rise proportionally to the fall in marginal cost. As stated above, these estimates confound product selection, product-level learning and firm-level performance. When controlling for firm-level performances, in the within firm-year between products specification, we find as well a markedly decreasing profile of marginal costs along age. Thus, firm-level trajectories are not the first driver of the effect of age on product performance. In specification (3), most of the variation due to age disappears (at conventional degree of statistical significance). Experience effect is not apparent in the first years, although a small effect appears for incumbent products with the oldest sample age.[27] Contrasting these last results with the two other specifications suggests that in the first years of a products' life cycle, selection based on intrinsic (or constant in time) product-firm pair performance may be the driver of the marked difference between entrants and older products. Indeed, if experience effect was first-order we would expect to observe it in specification (3).[28] Older products may survive through a selection process and therefore be better performing than the entrants. We note however that learning may happen at a later stage in product life cycle, although we cannot date it precisely. However, if learning is not a systematic feature of product life cycles, it would be misleading to state that it is nonexistent. For surviving products (4), marginal costs and markups display a non-flat age profile in the short run. Conditional on remaining in a firm's portfolio, these performance measures increase with age. We interpret this as evidence that learning is heterogeneous across products, and that an inefficient learning is associated with lower performances and a higher probability of being dropped. On this restricted sample, the rate of learning is not negligible, as it is roughly half of the age effect of specification (1). Learning also seems to be heterogeneous according to technological proximity to the firms' core product. In Figure D3, we present suggestive evidence that, conditional on survival, the rate of learning is higher for products close to the firms' core product than for product further from the core.

Exit-driven selection has been found partly explained by technological similarity between the added products and the firm's core product, with product closer to the core less likely to exit. In Figure 7, we show the results of specification (1) where the dependent variables are the three similarity measures to the core product.[29] Learning is completely absent by definition of the similarity (it does not vary with time), only a selection effect may play. The estimates suggest a strong bias in the selection effect toward products that are technologically similar to the core. The older a product, the more similar it is to the core product.

New product survival. — The previous section has shown that on the first years of a product introduction, there is no significant evolution of markups and marginal costs for a given firm's product, but that entrant products are significantly underperforming compared to incumbent products, as both markups and marginal costs are concerned. This suggests that entrants go through a selection process based on their inherent performance, that do not vary significantly in the first years. Underperforming products are dropped, while better performing products may survive. If it were the case, we could predict with the relative performance at entry the subsequent survival length. To test the latter, we restrict the sample to products whose entry was observed, and compute how long they did survive in years (a length which is right-censored, except when we observe exit). We also consider their relative log markups and marginal cost at entry, that is their deviation from the respective

[27]As a rough test, we may as well look at persistence characteristics of markups and marginal costs, which are quite high: the autoregressive coefficients are respectively of 0.81 and 0.80. As a comparison, the autoregressive coefficient of productivity is 0.72.

[28]The absence of learning on average may explain that the age profile in specification (2) - which does not encompass learning - is steeper than in specification (1), which encompass learning, driving downward the age profile.

[29]The core product is excluded from these regressions.

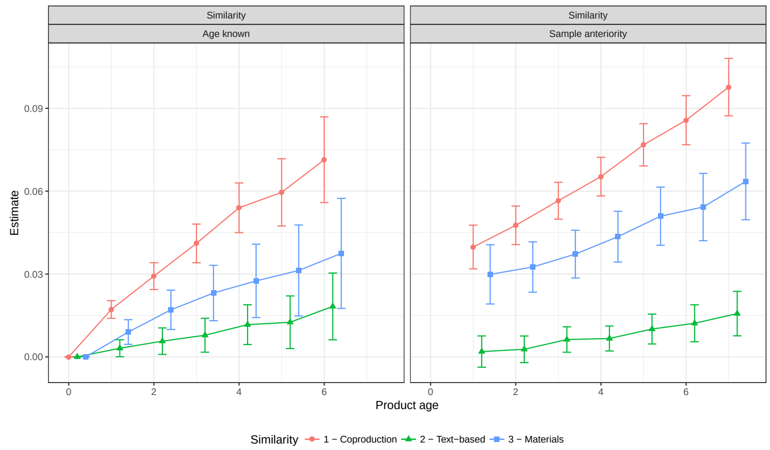

Figure 7. Product age and similarity to core product

Note: Estimates from equation (*). With firm fixed effects : $\nu_{fjt} = \nu_f$ Estimates slightly offset for clarity purposes. Error bars correspond to the 5% confidence interval. All standard errors are clustered by firms.

product-year mean. Table 8 presents the results of a regression of survival times over these relative performance measures. A markup higher by about 5% relative to the average markup predicts a survival time higher by 0.3 year. On the other side of the coin, a marginal cost higher by 5% predicts a survival time lower by about 0.3 year.

Discussion. — Taken together, our results suggest a large role for trials and errors in production, with the most productive firms engaging in more product switching than other firms. This behaviour also finds echoes in management and innovation literature. Maidique and Zirger (1985) states that new products failure in the electronics industry generate knowledge useful for future commercial successes, an idea also supported by Zirger (1997). With patent data in pharmaceutical R&D, Magazzini et al. (2012) argue that "firms build their product development strategies both on successes and failures". In these works, trials and errors are part of the innovation process, and extensive product renewal can be associated with high productivity level and growth as a reflection of a high innovation activity. Product turnover may also be seen as a risk diversification tool, with positive implications for firms' finance (Carvalho et al. (2017)).

In our case, trials and errors are at the root of the strong selection effect. Worst performing products, i.e. products with both lower markups and higher marginal costs are far more likely to be dropped from the firms' portfolio, and, worst performing new products survive for a shorter time in portfolios. These findings for the manufacturing industry are in line with Asplund and Sandin (1999). Using beer market data and a survival analysis, they show that newly launched products have high failure rate since half of them are dropped by firms four years after introduction, and that products with lower or decreasing market shares are more likely to be removed from firms portfolio. Further, we find that at equal performance, products closer to the firms' core product (or core competency) have better chances of survival.

Table 8—Entrants' prediction of survival based on first year markup and marginal cost

	Dependent variable:					
	Survival times (year)					
	All entrants			Entrants with observed exit		
Relative log markup at introduction	0.063*** (0.012)	0.044*** (0.010)	0.048*** (0.011)	0.062*** (0.013)	0.047*** (0.011)	0.051*** (0.012)
Relative log marginal cost at introduction	−0.065*** (0.013)	−0.049*** (0.010)	−0.050*** (0.011)	−0.070*** (0.014)	−0.053*** (0.011)	−0.056*** (0.012)
Similarity to core	0.296*** (0.045)	0.333*** (0.034)	0.325*** (0.038)	0.295*** (0.047)	0.339*** (0.037)	0.317*** (0.041)
Product FE	No	No	Yes	No	No	Yes
Year-of-entry FE	No	Yes	Yes	No	Yes	Yes
Observations	18,888	18,888	18,888	17,283	17,283	17,283
R^2	0.027	0.317	0.434	0.028	0.287	0.418

Note: On the sample of entrant products (the firm is in sample since at least a year when we observe entry), we regress survival time (which is right censored) over markups and marginal cost at entry. The left panel keeps all entrant products, the right panel keeps only those for which we observe exit (no right-censoring). We obtain very close results when restricting the sample to firms present all along the 8 years (so that exit is at the product-level). Both log markups and marginal cost are demeaned by product. Standard errors are clustered at the firm level.

These results may be read in light of the theories of industry dynamics. In these models with learning ("active" Ericson and Pakes (1995) and Pakes and Ericson (1998) or "passive" Jovanovic (1982) Hopenhayn (1992)), new firms choose whether to enter the market or not and do not know their costs *ex ante*, even though they have a prior knowledge about the distribution from which it will be drawn. If they decide to enter the market, they observe profits and learn about their true cost with a Bayesian process, when they observe their profits. This framework is conceptually close to the case of a firm deciding or not to launch a product. A large literature has explored the view that firms are uncertain about demand (product appeal or level of demand) before launching new products, learn about it by observing profits and decide whether or not to continue production (see e.g. Asplund and Sandin (1999), Hitsch (2006), Timoshenko (2015) or Iacovone and Javorcik (2010)). In our case, the profiles of markups and marginal costs along product age indicate a strong selection effect, but no systematic experience effect at short term. Our results suggest that firms launch new products, with uncertainty about profitability and efficiency, learn about product appeal and production costs, and decide to keep newly launched products only if they are good performers.

Technology and product similarity also plays a role in the experience effect on performance. We find that, conditional on remaining in a firm portfolio, experience effect is significant, but it seems that only the products closer to the core product benefit from it. This finding echoes management literature: knowledge transfer is easier when product technologies are overlapping (Egelman et al. (2016)), and learning by working on close problems can even be faster than learning under full specialisation (Schilling et al. (2003)).

New products are notably underperforming compared to incumbent products and represent a small share of output, but altogether bear a substantial part of output growth. Their performance at entry is predictive of how many years they will survive. Incumbent products are probably the results of such a selection process. This portfolio dynamics may impact markup growth at the firm-level. In the next section, we explore the consequences of portfolio dynamics for firm-level performance.

B. Markups and marginal costs implications at the firm-level

In this section, we study the implication of product portfolio movement at the firm-level. For aggregation, prices and therefore marginal costs are normalized with the average marginal cost of product j at t, $\mathrm{mc}_{j,t}$. We aggregate prices, markups and marginal costs at the firm-level using geometric means, to preserve the intuitive relationship $p^{(r)}_{ft} = \mu_{ft} \times \mathrm{mc}^{(r)}_{ft}$.

$$p^{(r)}_{ft} = \prod_{j \in P_{f,t}} \left(\frac{p_{fjt}}{\mathrm{mc}_{j,t}}\right)^{s_{fjt}} \qquad \mu_{ft} = \prod_{j \in P_f} \mu_{fjt}^{s_{fjt}} \qquad \mathrm{mc}^{(r)}_{ft} = \prod_{j \in P_f} \left(\frac{\mathrm{mc}_{fjt}}{\mathrm{mc}_{j,t}}\right)^{s_{fjt}}$$

where $P_{f,t}$ is the set of product of firm f at t, and s_{fjt} are product shares in sold production. Using $p_{fjt} = \mu_{fjt}\mathrm{mc}_{fjt}$, this definition implies $p_{ft} = \mu_{ft}\mathrm{mc}_{ft}$.

We decompose the evolution of markups and marginal costs at the firm level. We quantify the respective contribution of churning (entry/exit), growth in markups within product-firm and reallocation of market shares between products, using the following decomposition:

$$\frac{\mu_{f,t}}{\mu_{f,t-1}} = \underbrace{\frac{\prod_{j \in N_{f,t}} \mu_{fjt}^{s_{fjt}}}{\prod_{j \in X_{f,t-1\to t}} \mu_{fjt-1}^{s_{fjt-1}}}}_{\text{Entry and exit}} \times \underbrace{\prod_{j \in P_{f,t-1\to t}} \frac{\mu_{fjt}^{s_{fjt-1}}}{\mu_{fjt-1}^{s_{fjt-1}}}}_{\text{Markups growth}} \times \underbrace{\prod_{j \in P_{f,t-1\to t}} \frac{\mu_{fjt}^{s_{fjt}}}{\mu_{fjt}^{s_{fjt-1}}}}_{\text{Reallocation}} \tag{2}$$

where $X_{f,t-1\to t}$ denotes products which have exited between $t-1$ and t; $N_{f,t}$ are new products at t; and $P_{f,t-1\to t}$ are products which are in the firm's portfolio in both years. On average, these terms are 1.06 for firm-level markup growth (1.10 when the average is weighted with sales), 1.01 for entry and exit (resp. 1.01), 1.05 for within-firm markup growth (resp. 1.07) and 1.03 for reallocation (resp. 1.05). To maintain additivity, we first take the logs of equation 2 and then average each term in the addition.

We report in Table 9 the results of this decomposition, in log points, that is for the left-hand side $100\times < \Delta \log \mu_{ft} >$. For single-product firms which stay single-product, reallocation and churning are non-existent. We report the decomposition when restricting to multiproduct firms. In all cases, we find evidence of a reallocation toward both (i) products with higher markups, (ii) products with lowest marginal costs. Without a clear distinction between technical efficiency and quality in marginal costs, it is hard to tell whether this reallocation operates toward a better (more productive) allocation of resources. But this reallocation appears as a leading force in markup evolution at firm-level, and in particular in large firms where it accounts for most of markup (and marginal cost) growth. Products entries and exits, as opposed to their role in output dynamics, are of minor importance in markups and marginal costs dynamics at the firm-level, compared to reallocation or within-product growth, at least at short-term. Within-product growth is more difficult to interpret. While before taking logs, on average, within-product markup growth is positive, it is negative in the final decomposition. Both averages hide the high heterogeneity in this term, which is therefore more ambiguous than the two others.[30]

Table 9—Decomposition of markups and marginal cost growth within firms.

	Unweighted		Sales weighted	
	Markups	Marginal costs	Markups	Marginal costs
All firms				
Firm-level growth	0.06	−0.37	1.09	−1.41
- : due to reallocation	1.11	−0.99	2.34	−1.51
- : due to within-product growth	−1.08	0.69	−1.38	0.42
- : due to entry and exit	0.05	−0.09	0.10	−0.30
Multiproduct firms				
Firm-level growth	1.52	−2.29	2.29	−2.60
- : due to reallocation	3.41	−2.97	3.87	−2.46
- : due to within-product growth	−2.43	1.22	−1.93	0.48
- : due to entry and exit	0.57	−0.55	0.28	−0.59

Note: This table shows the yearly average evolution (in log points) of firm-level prices, markups and marginal costs, and the decomposition in the three terms form equation 2. Only evolutions in the range of $\times 10$ or $/10$ are kept.

On average, both churning and reallocation play a role in increasing markups and decreasing marginal costs at firm-level. Within-product markup growth is more heterogeneous, and slightly negatively correlated with the reallocation term. Reallocation toward the best performing products appear as a robust feature of the data, playing a major role in increasing firm-level markups.[31]

[30]In Appendix E we link firm-level markup and marginal costs decomposition to international demand shocks. The results suggest that demand shocks have no significant effect on the reallocation component of firm level markup and marginal cost, but improves within-product performances.

[31]In Figure D4 in Appendix, we show that this is also true year by year, the reallocation term being very stable year on year, and the within-growth term being determining the cycle of firm-level markup and marginal cost growth.

VI. Conclusion

In this paper, we use a large panel on French manufacturing to study within-firm product's dynamics, the role of market power and of distance to core competency in product's selection and survival. Following the PRODCOM regulation, this type of data is becoming increasingly available in European countries. Notable examples include Amiti et al. (2018) or Dhyne et al. (2017). From the cross-sectional analysis of product portfolios, our main findings confirm the main hypothesis of trade models relying on a product ladder. Firms have one core competency, characterised by larger sales, market power and efficiency. The larger the product scope, the larger are the differences between the core and the secondary products in terms of performance, and the products' performances are positively related to their closeness to the core. We draw these results by building three simple measures of product similarities, which although very distinct in their economic sense, all agree. We believe that they could be useful for further research as they convey complementary information to nomenclatures, as already noted by Hoberg and Phillips (2016). From the dynamics' point of view, we rely on a new source to examine product switching at a very detailed level, and cautiously define products so as to avoid spurious product switching because of classification changes. We show that product renewal is significantly lower in France than in the United States. Although we cannot identify what drives this result, if not from data particularities, it would suggest that French firms are less likely to diversify or innovate. It would be particularly interesting to compare switching using other European countries production survey data. Then, we characterise product portfolio dynamics with product-level heterogeneity conveyed in their markup and marginal costs. Both dimensions are powerful at predicting products' survival. In light of the theories of industry dynamics, our results suggest that firms are uncertain about both efficiency (production cost) and product appeal (market power) before product launch, learn about supply and demand side characteristics when selling the product, and decide to keep or drop the product from their portfolio. In that sense, demand and supply side features appear equally important to explain selection, where most models in trade or industry dynamics tend only to focus on one of the two sides.

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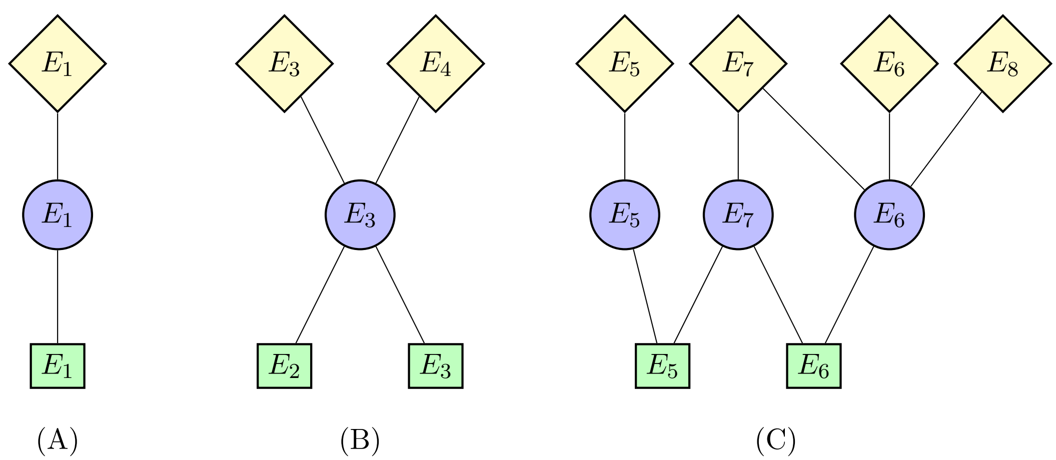
Classification concording procedure

The classification we used in our data (Annual production survey) is the PRODFRA classification, based on the PRODCOM classification. A common feature of disaggregated product classifications (shared with, for instance, the combined nomenclature for custom data) is to significantly change over time (from 3 to 5% of product definitions are changed each year). Product items are split, or merged. These variability sources are to be taken into account for analysis at the product level since the classification evolution is to generate considerable noise and mis-attribute product switching.

The goal of the concording procedure is to define a classification which is stable over time, to avoid spurious product switching, exit or entry. We use a dataset giving the evolutions over time of PRODFRA classification (provided by Insee). It provides all links between $t-1$ and t year-specific product codes. These links can be seen as edges of a graph. The product envelopes (or bundle) correspond to the isolated subgraphs or connected components. An algorithm of connected components search gives the bundles of nodes which constitute a classification which is stable over time.

Figure A1 gives three examples of stable bundle products. Green squares are codes at t, blue circles are codes at $t+1$ and yellow diamonds codes at $t+2$. (A) represents a stable code (E_1 with no ambiguation. (B) represents a merge of two codes in $t+1$ and a split in $t+2$; (C) represents a more complex evolution of codes. In our classification, products will correspond to (A), (B) or (C).

Figure A1. Examples of connected components



This method is identical to the one used by Bergounhon et al. (2018) for custom data classification. In practice, we implement the algorithm using the functions `clusters(as.undirected(graph.adjacenc` of the library `igraph` in R (Csardi and Nepusz (2006)), where `MATRIX` is a N-N sparse matrix populated by links between product codes. The function `connected_components(.)` of library `networkx` in Python (Hagberg et al. (2008)) can also be used. For the analysis with custom data, the same stable product envelopes method was used. In addition to time evolution of PRODFRA classification, we added evolution of custom data classification (NC8), as well as links between custom and PRODFRA classification (one table of link by year). HS6 classification (which is unambiguously linked to NC8 classification) was also introduced to link envelopes with BACI data.

Complements on estimation method : De Loecker et al. (2016)

B1. Production function estimation

We detail the estimation of $f_{s_j} = \log(F_{s_j})$, restricting to single-product firms. Taking the logs of equation 1, where lower cases indicates the logs,

$$q_{ft} = \omega_{ft} + f_j(m_{ft}, l_{ft}, k_{ft}; \beta) + \epsilon_{ft} \tag{B1}$$

We drop the subscript j in inputs as $J_f = 1$ for all firms considered. We assume a flexible translog form for f_j, which can be seen as a second order approximation of a general production function.[32] β is the parameter we wish to estimate. In this equation, we link physical quantities. However, we observe physical quantities only for output and labor. We denote $\tilde{m} = m + \log(W^m) - \log(I^m)$ and $\tilde{k} = k + \log(W^k) - \log(I^k)$ the deflated materials and capital which are observed (because material costs are observed, and I is a sector-specific deflator). Production can be written:

$$q_{ft} = \omega_{ft} + f_{s_j}(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta) + \underbrace{B(.)}_{f_{s_j}(m_{ft}, l_{ft}, k_{ft}; \beta) - f_{s_j}(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta)} + \epsilon_{ft} \tag{B2}$$

B quantifies the bias of not observing input prices as ideally, we should deflate with a firm-specific input price index. It is explicitly defined by $f_{s_j}(m_{ft}, l_{ft}, k_{ft}; \beta) - f_{s_j}(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta)$. As noted by De Loecker et al. (2016), if we assume the errors in input prices to be proportional across inputs,[33] B(.) is proportional to the error in input price w_{ft}. This remark is important as it provides an estimation strategy to dampen the input price bias, while identifying the parameters of f_j. In Equation B2, all the terms due to the input price bias appear in interaction with the error in input prices. For instance, even though $\tilde{m}$ enters both f_j and B, it does in B only in interaction with the input price control, which ensures identification here of β_m, provided moment conditions. The strategy is therefore as follows: (i) assume a control proxy for $w_{ft} = \log(W_{ft}) - \log(I)$, (ii) estimate Equation B2 by substituting for w_{ft}. In practice, we approximate B at first order, $B(.) \approx -w_{ft} \times (\beta_l + \beta_k + \beta_m)$.[34]

[32] Namely, $f_j(m, l, k) = \beta_l l + \beta_m m + \beta_k k + \beta_{ll} l^2 + \beta_{mm} m^2 + \beta_{kk} k^2 + \beta_{lk} lk + \beta_{mk} mk + \beta_{ml} lm + \beta_{lmk} klm$

[33] That is $w_{ft} = \log(W^k) - \log(I^k) = \alpha_j + \log(W^m) - \log(I^m)$. For instance, the distance between the firm pricing and the sector pricing is due to both inputs' quality which is reflected in their higher prices. See De Loecker et al. (2016) for a discussion.

[34] In our main specification, we correct for input prices for labor as well and have checked that our results were robust to this choice. For the estimation of production function, there is a debate on how should be introduced labor (e.g. Demirer (2020)) . As the estimation of production function is not the main focus of the paper, we let this debate for further research.

The deviation of firms input prices with respect to the sector deflator is assumed to reflect output quality. It is a proxy measure to account for unobserved heterogeneity in input prices and quality, since we do not have firm-specific deflators. To proxy for unobserved prices quality, we assume

$$w_{ft} = a_1 p_{ft} + a_2 p_{ft}^2 + a_3 ms_{ft} + a_4 p_{ft} ms_{ft} + \\ a_5 \text{EXP}_{ft} + a_6 \text{COM}_{ft} + a_7 \text{Age}_{ft} + a_8 R_{ft} + \delta_j + \nu_{ft} \tag{B3}$$

where p_{ft} is final product price, ms_{ft} are firm market shares,[35] and the following dummies: at t, is the firm (1) exporter, (2) having retail activities, (3) which category of age it belongs, (4) its regional location. Finally, we introduce product dummies. In what follows, we denote $z_{ft} = (p_{ft}, ms_{ft}, \text{EXP}_{ft}, \text{COM}_{ft}, \text{Age}_{ft}, R_{ft}, \delta_j)$ and $B(.) = z_{ft}\alpha$.[36]

After its detour to tackle input price bias, we combine Equations B2 and B3 to get

$$q_{ft} = \omega_{ft} + f_j(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta) + z_{ft}\alpha + \tilde{\epsilon}_{ft} \tag{B4}$$

We then follow the literature on production function estimation, starting from Olley and Pakes (1996), Levinsohn and Petrin (2003) to deal with unobserved productivity. We use a control function inverting the demand for a subset of intermediates: external consumption.[37] These expenses correspond to all operating costs (i.e. excluding investment, financial charges, taxes or exceptional charges), which are not linked to the remuneration of workers, the purchase of raw materials, intermediate components of products, or finished products for resale as-is. They notably include outsourcing, energy expenses, temporary workers, or advertising. We do not use materials as a whole because we aim at estimating their production function coefficients as well. Gandhi et al. (2016) have discussed the difficulty in estimating the material coefficients in gross output production function when using material as a proxy variable. External consumption is a good candidate to be a proxy function for productivity since firms can fairly flexibly adapt these expenses to the expected level of productivity. The demand for external consumption is assumed to reflect productivity level and to be adjusted by the firm which observes its productivity and other variables $\tilde{e}_{ft} = e_t(\omega_{ft}, \tilde{k}_{ft}, z_{ft})$. Inverting this equation gives the control function: $\omega_{ft} = h_t(\tilde{e}_{ft}, \tilde{k}_{ft}, z_{ft})$.

We follow Ackerberg et al. (2015) and more precisely the one step GMM version in Wooldridge (2009) and estimates the parameters in (B4) by forming two types of moments. First, $\tilde{\epsilon}_{ft}$ is assumed conditionally mean independent of all inputs and state variables (past and contemporaneous). Second, we form moment on the innovation ξ_{ft} in the productivity process:

$$\xi_{ft} = \omega_{ft} - E[\omega_{ft} | \omega_{f,t-1}]$$

[35]Following Berry et al. (1995), product market shares reflect product quality, conditional on product prices

[36]$\alpha_1 = -(\beta_l + \beta_k + \beta_m) \times a_1$ etc..

[37]In the firms' tax files, it corresponds to *Autres achats et charges externes*, which translates in *Other supplies and external expenses*.

which is assumed conditionally mean independent of contemporaneous dynamic factors, past variables factors and state variables. Specifically, we use in a one-step GMM the following moment conditions:

$$E[(\xi_{ft} + \tilde{\epsilon}_{ft})(k_{ft}, l_{f,t-1}, m_{f,t-1}, \text{EXP}_{ft}, \text{COM}_{ft}, \text{Age}_{ft}, R_{ft}, \delta_j)] = 0 \tag{B5}$$

and

$$E[\tilde{\epsilon}_{ft}(k_{ft}, l_{ft}, m_{ft}, k_{f,t-1}, l_{f,t-1}, m_{f,t-1}, \text{EXP}_{ft}, \text{COM}_{ft}, \text{Age}_{ft}, R_{ft}, \delta_j)] = 0 \tag{B6}$$

In practice, to identify all the terms in the translog, we introduce the corresponding squares and interaction terms. In the above moment conditions, we use that $\xi_{ft} + \tilde{\epsilon}_{ft}$ depend on (α, β) the vector of parameter to estimate, as

$$\xi_{ft} + \tilde{\epsilon}_{ft} = q_{ft} - f_j(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta) - z_{ft}\alpha - E[\omega_{ft}|\omega_{f,t-1}]$$

and that $E[\omega_{ft}|\omega_{f,t-1}] = g(\omega_{f,t-1}) = g(h_{t-1}(\tilde{e}_{f,t-1}, \tilde{k}_{f,t-1}, z_{f,t-1}))$ can be approximated by a flexible function in its argument. Equations B5 and are estimated with a GMM procedure which allows to recover α and β, by industry.[38]

B2. Share of inputs attributable to each products in multi-product firms

For multiproduct firms, there is an additional challenge: spreading inputs across products. For firm j producing J_{ft} products, its J_{ft} production processes are as follows for $j \in J_{ft}$, which mobilize a share $\exp \rho_j$ of each input:

$$q_{fjt} = \omega_{ft} + f_j(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta) + \underbrace{f_j(m_{ft}, l_{ft}, k_{ft}; \beta) - f_j(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta)}_{B(.)} + \underbrace{f_j(\rho_j + m_{ft}, \rho_j + l_{ft}, \rho_j + k_{ft}; \beta) - f_j(\tilde{m}_{ft}, l_{ft}, \tilde{k}_{ft}; \beta)}_{A(.)} + \epsilon_{ft}$$

If we assume the technology to be product-specific, in this equation, β and $B(.)$ (parametrized with α) are recovered from the previous section method. The remaining unknowns of these J_{ft} equations are ρ_j and ω_{ft}. We have $J_{ft} + 1$ unknowns for the same number of equations (if we add that $\sum_{j=1}^{J_{ft}} \exp \rho_j = 1$). We approximately[39] solve this problem for each firm-year pair.

B3. Robustness of coefficient estimates

In order to ensure our results consistency, we ran several robustness checks by changing the assumptions on which identification is based. In our baseline estimates, we use a GMM

[38] Note that implementing the selection correction as in De Loecker et al. (2016) to tackle the possible difference in productivity of single-product firms do not change our results; so that we omit it for simplicity.

[39] Note that the problem is not linear (it contains a polynomial of order three in ρ_j).

specification as Wooldridge (2009), using the variable part of the inputs named in tax files "other expenses and external charges". For several robustness specifications,[40] the average absolute deviation to the benchmark of the materials (and labor) coefficients across industries are inferior to 7%. Moreover and most importantly, our markups' estimates are not significantly changed across these robustness checks. One specification led to inconsistent estimates of the production function elasticities: using lagged materials in the control function and twice lagged materials as instrument in the GMM specification, an inconsistency which might be linked to the Gandhi et al. (2016) critique.

Complements on similarity measures

Let us denote $\{1, \cdots, J\}$ our set of products. We want to define similarities between any products j, l so as to quantify how close a new product is to the core product of a firm (in an effort to abstract from nomenclatures). We introduce three ways to do so.

C1. The coproduction similarity

Let us denote $\mathcal{J}_f = \{j_1, \cdots, j_{J_f}\}_f$ the set of products which have been in firm's f portfolio at any time between $t_{0,f}$ and $t_{T_f,f}$ (the intervals where f is observed). We define the similarity between two given products with the (normalised) number of firms having produced both (for at least one period). Formally, for two products j and l, and given product characteristics as a N_f dimension vector $A_j^{cop} = (a_{j1}^{cop}, \cdots, a_{jN^f}^{cop})$, where $a_{jk}^{cop} = 1$ if firm product j belongs to firm k portfolio for at least a period, we define :

$$s_{j,l} = \frac{A_j' A_l}{\|A_j\| \cdot \|A_l\|} = \frac{\sum_{\text{firms} f} 1\{j \in \mathcal{J}_f\} 1\{l \in \mathcal{J}_f\}}{\sqrt{N_j}\sqrt{N_l}} = \frac{S_{j,k}}{\sqrt{N_j}\sqrt{N_l}}$$

Where we denote $N_k = \sum_{\text{firms} f} 1\{k \in \mathcal{J}_f\}$ the square-root number of firms with k at least once in their portfolio. We note $S_{j,k} = \sum_{\text{firms} f} 1\{j \in \mathcal{J}_f\} 1\{k \in \mathcal{J}_f\}$ the number of firms' linking two products. With such a definition, each existing link (because of the common presence in a firm's portfolio) participates to this measure. We are then careful in excluding closeness "by design": we modify this definition to adopt a similarity defined from the point of view of a firm f', excluding f' from the computation. From the firm's f' point of view, products j and l are defined as close only if at least another firm has produced or will produce both of them (and not because firm f' itself produces both, as this is directly what we want to evaluate). This is also important to evaluate new product closeness.

We therefore introduce the same definition, but excluding f'.

$$s_{j,l}(f') = \frac{\sum_{\text{firms} f \neq f'} 1\{j \in \mathcal{J}_f\} 1\{l \in \mathcal{J}_f\}}{\sqrt{\sum_{\text{firms} f \neq f'} 1\{j \in \mathcal{J}_f\}}\sqrt{\sum_{\text{firms} f \neq f'} 1\{l \in \mathcal{J}_f\}}}$$

[40]In particular, when the control function is taken as investment or investment interacted with capital, as in Olley and Pakes (1996). We also checked if results were changed when using the perpetual inventory method to compute the capital coefficient.

If we restrict to the case where $1\{j \in \mathcal{J}_{f'}\}1\{l \in \mathcal{J}_{f'}\} = 1$ (closeness is biased by design), and $\sum_{\text{firms} f} 1\{j \in \mathcal{J}_f\}1\{k \in \mathcal{J}_f\} > 1$ (otherwise, set $s_{j,k}(f') = 0$ as only f' produces both products), $s_{jl}(f')$ simply writes

$$s_{j,k}(f') = \frac{S'_{j,k}}{\sqrt{N'_j}\sqrt{N'_k}} = \frac{S_{j,k} - 1}{\sqrt{N_k - 1}\sqrt{N_j - 1}}$$

Therefore, for all couple j, k we have a firm-specific distance $s_{j,l}(f')$ which may be written, for all j, l in firms' f' at some point:

$$s'_{j,l}(f') = s'_{j,l} = 1\{S_{j,k} > 1\} \times \frac{S_{j,l} - 1}{\sqrt{N_l - 1}\sqrt{N_j - 1}}$$

which is defined independently of firm f' producing both j and k, and therefore no computational burden is incurred. We use s' as a similarity measure, and we name it the "coproduction" similarity. $s'_{j,l}$ is positive only if there exists at least two firms with both j and l in their portfolio.

C2. The materials similarity and the expenses survey

The rationale behind the intermediate consumption similarity is that products are similar in a technological sense if the materials used for their production are similar. Although we do not observe the intermediate consumption at the product-level, for a subset of our sample, we observe at the firm-level breakdown of intermediate consumption across 2-digit industries. The data come from the "expenses survey", which has been conducted for the 2017 year for the need of the Input-Output matrix of the national accounts. Firms are asked to break down their expenses into 75 common core fields, with about 40 more fields for manufacturing firms. Firms are sampled, with an exhaustive strata for firms with more than 250 workers or more than 28 millions in intermediate consumption expenses. About 14% of firms in our (2017) sample (as described in section II) are surveyed, representing 50% of the total sales in the sample.

We define a production-side similarity between firms thanks to their intermediate consumption vector $c_f = (c_{1,f}, \cdots, c_{H,f})$ where each $c_{i,f}$ represents consumption from industry i (approximately corresponding to NAF88, with 81 dimensions - we exclude some uninformative dimensions for our purpose such as merchandise, leasing, real estate, outsourcing). For two firms, their similarity in intermediate consumption is defined by

$$s_{f,f'} = \frac{c_f c_{f'}}{\|c_f\|\|c_{f'}\|}$$

It is equal to one if both firms use exactly the same repartition of intermediate consumption along industries, and to zero if they consume from a disjoint set of industries.

From this similarity at the firm-level, we derive a similarity in production at the product-level. For each firm f, we observe its product portfolio $\mathcal{P}_f$. We define for two products j and k

$$s_{j,k} = \sum_{f:j\in\mathcal{P}_f} \sum_{f'\neq f:k\in\mathcal{P}_{f'}} w_{ff'jk} \times s_{ff'}$$

where we take a weighted-sum of similarities between firms over all couple of firms respectively producing each product. The weights are defined so as to give a maximal weight to couples only producing j and k (whose intermediate consumptions should be representative of these products) and a reduced weight to firms producing other products (whose intermediate consumptions also serve other products). With this rationale, we define

$$W_{ff'jk} = \frac{1 + 1\{(j,k) \in \mathcal{P}_f | (j,k) \in \mathcal{P}_{f'}\}}{|\mathcal{P}_f||\mathcal{P}_{f'}|}$$

and $w_{ff'jk} = \frac{W_{ff'jk}}{\sum_{f:j\in\mathcal{P}_f} \sum_{f'\neq f:k\in\mathcal{P}_{f'}} W_{ff'jk}}$ These weights decreases with the number of products of both firms, and are maximum for firms focusing on products j and k.

C3. The text-based similarity

The analysis is conducted in French, starting from two types of text inputs. For each envelope product (the concept of product used throughout the paper to accommodate classification change), we concatenate (i) its (short) PRODFRA label(s), and (ii) the (longer) description of its subproducts (the 8-digit Combined Nomenclature is included within the PRODFRA nomenclature), as available in European law at https://eur-lex.europa.eu/legal-content/FR/TXT/HTML/?uri=CELEX:52011XC0506(05)rid=1. A third of the product labels (i) are enriched with (ii) descriptions, with on average 330 characters.

We apply the following cleaning/harmonizing steps: we remove classic stepwords and nomenclature-specific stop words (“sous-position”, ”alinéa”,“articles”, “mutatis” and “mutandis”...), we keep only nouns and adjectives, words of more than 2 characters, we apply a stemmer (remove affixes from words, leaving only the word stem). A product is on average described with 13 words after this step. On the universe of the N^w left words, a product is described with a vector $A_i^{tex} = (a_{i1}^{tex}, ...a_{ik}^{tex}, ...a_{iN^w}^{tex})$, where a_{ik}^{tex} is the count of word k used to describe product i. The text-based similarity we use is defined by

$$s_{j,l} = \frac{A_j' A_l}{\|A_j\| \cdot \|A_l\|}$$

For instance, the following raw text description

(i) Moules pour le moulage par injection ou compression du caoutchouc et des matières plastiques
(ii) Machines de traitement de l'information, comportant sous la même enveloppe, au moins une unité centrale de traitement, une unité d'entrée et une de sortie
(iii) Autres instruments et appareils pour analyses et essais physiques ou chimiques n.c.a. autres Relèvent par exemple de cette sous-position les armoires d'essai à conditionnement d'air équipées d'une chambre pressurisée, d'un chauffage électrique, d'un dispositif humidificateur d'air et d'une commande électrique et dans lesquelles des composants électroniques sont exposés, en vue de contrôler leur aptitude fonctionnelle, leur isolation, etc., aux différentes conditions de pression, température et humidité simulant des influences ambiantes se produisant lors de leur utilisation ultérieure.

become, after the harmonizing steps, where each of the unique word is a dimension in A_i:
(i) moul moulag inject compress caoutchouc mati plastiqu
(ii) machin trait inform envelopp unit central trait unit entré sort
(iii) autr instrument appareil analys essais physiqu chimiqu n.c.a autr exempl armoir essai condition air chambr chauffag électr disposit humidif air command électr compos électron vu aptitud fonctionnel isol condit pression températur humid influenc ambi utilis ultérieur

Finally, Table C1 provide descriptive statistics on the three distances, while Figures D5, D6, D7, D8 give the closest products according to each similarities, for four distinct industries. For the three similarities, the within-firm similarity is higher than the between-firm within-industry similarity (firms are represented by their core product). New products are systematically farther from the core than the incumbent products for the first two similarities, but not from the materials similarity (which is however more coarse, and less discriminating).

Table C1—Descriptive statistics on the similarity measures

	Within firms similarities (multiproduct only)			Between firms similarities (firms represented by their core product)		
	All products to core product	All pairs	Entrants to core product	Prop. of non-zero	Between industry's firms (including zeros)	Between industry's firms (excluding zeros)
Coproduction similarity						
13	0.44	0.40	0.32	0.95	0.21	0.22
14	0.32	0.30	0.18	0.71	0.16	0.23
15	0.26	0.25	0.22	0.62	0.10	0.16
16	0.30	0.24	0.20	0.64	0.10	0.15
17	0.37	0.35	0.29	0.99	0.53	0.54
18	0.32	0.29	0.21	0.47	0.06	0.13
20	0.17	0.15	0.13	0.52	0.05	0.10
22	0.32	0.31	0.26	0.42	0.10	0.24
23	0.35	0.31	0.27	0.22	0.06	0.26
24	0.17	0.16	0.17	0.47	0.08	0.16
25	0.16	0.14	0.12	0.37	0.03	0.08
26	0.22	0.19	0.14	0.60	0.06	0.10
27	0.17	0.15	0.13	0.12	0.01	0.11
28	0.16	0.14	0.14	0.63	0.19	0.31
29	0.30	0.26	0.25	0.25	0.06	0.23
30	0.30	0.29	0.22	0.85	0.22	0.25
31	0.23	0.22	0.14	0.17	0.06	0.35
32	0.26	0.24	0.20	0.52	0.12	0.24
All	0.18	0.16	0.15	0.46	0.07	0.16
Text-based similarity						
All	0.27	0.27	0.21	0.33	0.12	0.37
Materials similarity						
All	0.46	0.45	0.50	1	0.38	0.38

Additional Figures and tables

Table D1—Detecting reentries by backward-looking periods

Backward horizon (years)	Prop. entries not detected as reentry	Entries considered (in thousands)
6	0.92	7.6
5	0.89	10.2
4	0.88	13.4
3	0.88	17.3
2	0.91	21.5

Note: By definition, a product entry happens when a product which was not in firm's portfolio at $t-1$ appears at t. To detect reentry, we define a time window B (the backward horizon). For firms which where continuously present over $[t, t-B]$, a product entry is a reentry if the same product was in firm's portfolio at least once in $[t-2, t-B]$. Note that "same" refers here to a (detailed) classification code.

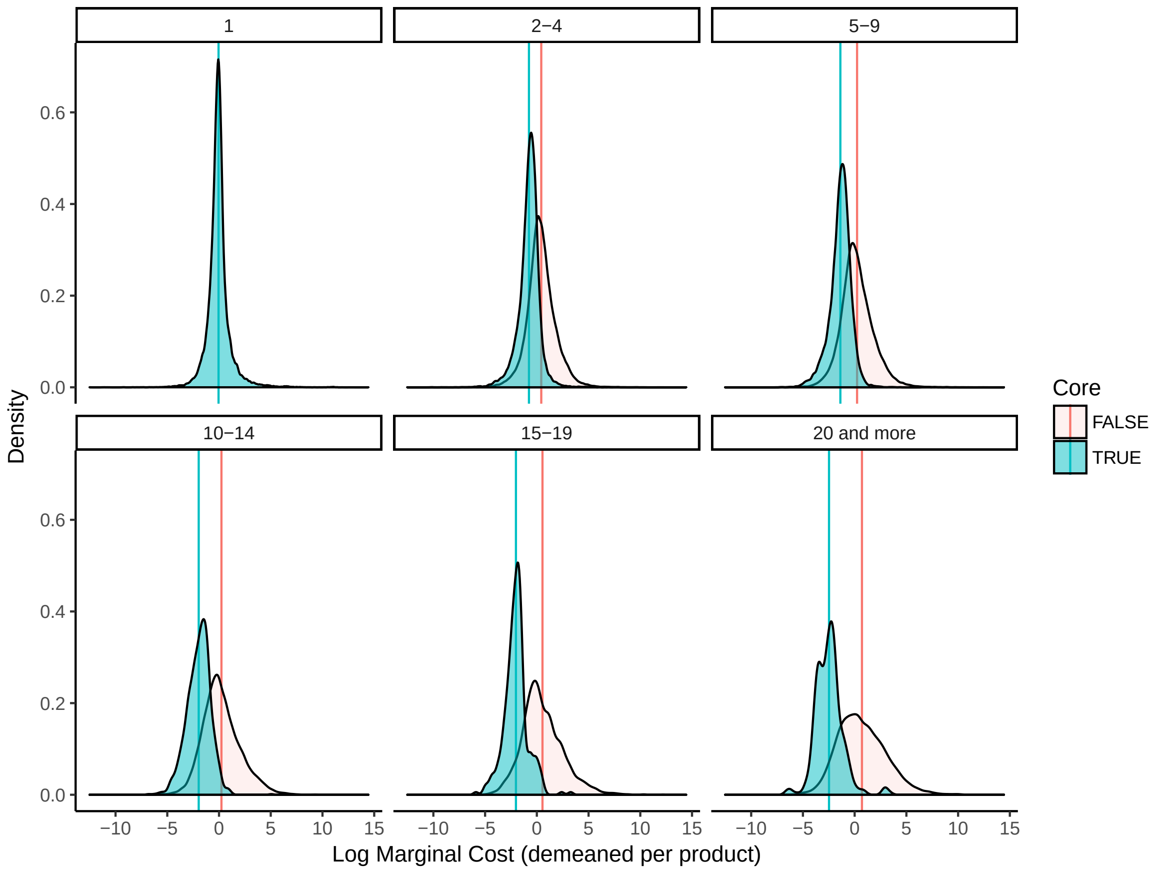


FIGURE D1. MARGINAL COSTS WITHIN MULTIPRODUCT FIRMS, BY PRODUCT PORTFOLIO SIZE

Note: The product with maximal sales value is the core product. Log marginal costs are demeaned by product.

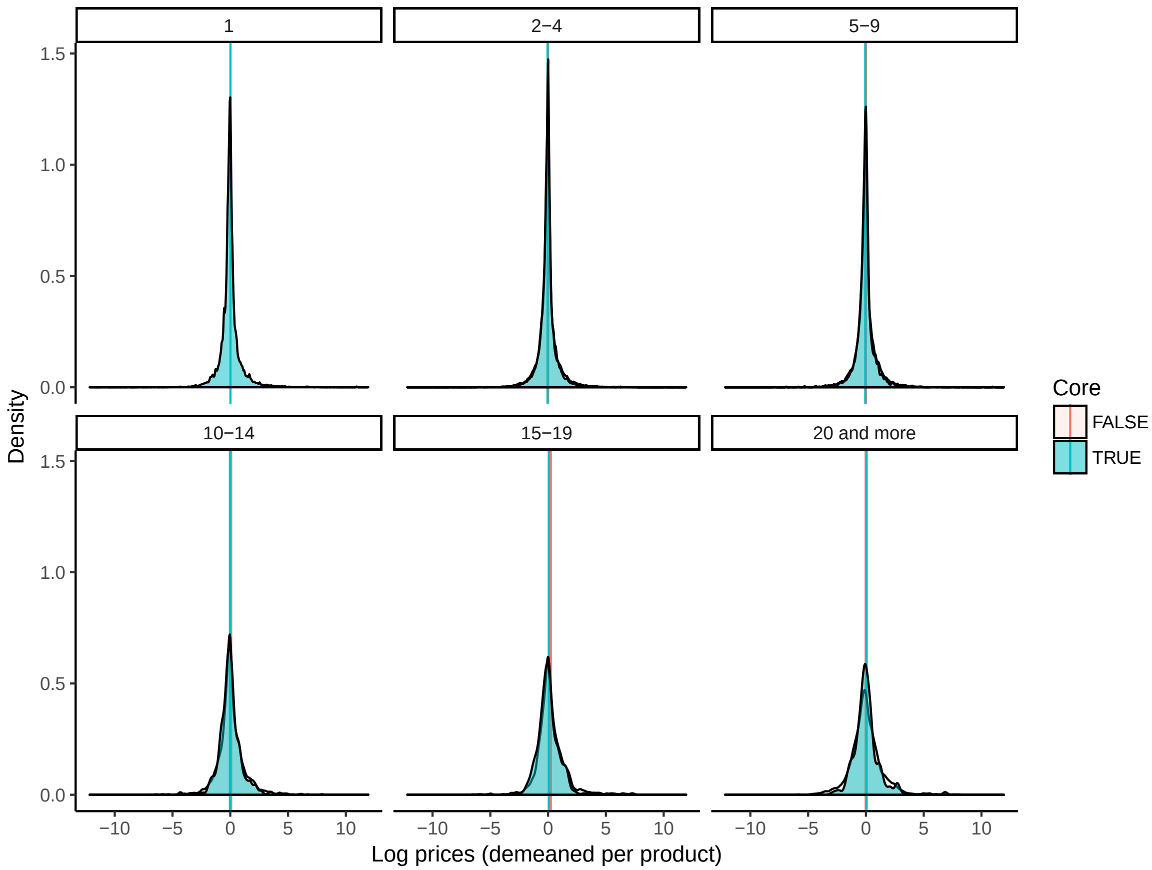


Figure D2. Prices within multiproduct firms, by product portfolio size

Note: The product with maximal sales value is the core product. Log prices are demeaned by product.

Table D2—Product age, markups and marginal costs. Selection or experience effect.

	Within firm between products			Within firm-year between products			Within product-firm between years: Full sample			Within product-firm between years: Conditional on survival		
	Price	Marg. cost	Markup	Price	Marg. cost	Markup	Price	Marg. cost	Markup	Price	Marg. cost	Markup
1-year-old	−0.003	−0.188***	0.185***	−0.020	−0.346***	0.326***	0.013	−0.025	0.037	0.024	−0.065**	0.088***
	(0.011)	(0.022)	(0.022)	(0.026)	(0.044)	(0.046)	(0.016)	(0.024)	(0.024)	(0.019)	(0.030)	(0.030)
2-year-old	0.002	−0.317***	0.318***	0.026	−0.616***	0.641***	0.022	−0.034	0.054	0.029	−0.118**	0.146**
	(0.016)	(0.033)	(0.033)	(0.031)	(0.061)	(0.067)	(0.029)	(0.044)	(0.044)	(0.038)	(0.057)	(0.057)
3-year-old	−0.015	−0.453***	0.438***	−0.006	−0.818***	0.812***	0.021	−0.055	0.074	0.040	−0.175**	0.213**
	(0.021)	(0.044)	(0.046)	(0.036)	(0.077)	(0.086)	(0.042)	(0.064)	(0.063)	(0.055)	(0.083)	(0.084)
4-year-old	−0.035	−0.527***	0.492***	−0.025	−1.014***	0.989***	0.025	−0.025	0.047	0.051	−0.186	0.234**
	(0.028)	(0.062)	(0.063)	(0.047)	(0.096)	(0.109)	(0.056)	(0.092)	(0.087)	(0.073)	(0.117)	(0.116)
5-year-old	−0.039	−0.610***	0.570***	−0.062	−1.143***	1.080***	0.045	−0.021	0.062	0.081	−0.218	0.295**
	(0.033)	(0.068)	(0.073)	(0.057)	(0.118)	(0.134)	(0.068)	(0.104)	(0.104)	(0.091)	(0.139)	(0.140)
6-year-old	−0.067*	−0.658***	0.591***	−0.120	−1.259***	1.139***	0.051	−0.024	0.071	0.101	−0.263	0.360**
	(0.040)	(0.085)	(0.090)	(0.073)	(0.148)	(0.166)	(0.084)	(0.129)	(0.128)	(0.111)	(0.170)	(0.170)
Anteriority (unknown age) In sample since												
… last year	0.020	−0.771***	0.792***	0.005	−0.946***	0.951***	−0.025	−0.099	0.076	−0.044	0.040	−0.081
	(0.021)	(0.040)	(0.043)	(0.047)	(0.088)	(0.099)	(0.064)	(0.096)	(0.096)	(0.089)	(0.139)	(0.140)
… since 2 years	−0.042**	−0.884***	0.842***	−0.059*	−1.120***	1.062***	−0.068	−0.133*	0.067	−0.079	−0.027	−0.050
	(0.017)	(0.035)	(0.038)	(0.036)	(0.071)	(0.080)	(0.054)	(0.080)	(0.081)	(0.076)	(0.118)	(0.119)
… since 3 years	−0.045***	−0.968***	0.924***	−0.036	−1.309***	1.274***	−0.056	−0.125*	0.070	−0.060	−0.057	−0.002
	(0.015)	(0.035)	(0.036)	(0.033)	(0.073)	(0.080)	(0.046)	(0.068)	(0.068)	(0.065)	(0.100)	(0.100)
… since 4 years	−0.041***	−1.071***	1.030***	−0.039	−1.450***	1.411***	−0.031	−0.142**	0.111*	−0.028	−0.109	0.082
	(0.015)	(0.038)	(0.039)	(0.033)	(0.079)	(0.085)	(0.041)	(0.060)	(0.060)	(0.058)	(0.087)	(0.085)
… since 5 years	−0.060***	−1.162***	1.101***	−0.047	−1.595***	1.548***	−0.033	−0.150**	0.117**	−0.023	−0.154*	0.131*
	(0.018)	(0.045)	(0.045)	(0.036)	(0.089)	(0.096)	(0.040)	(0.059)	(0.058)	(0.055)	(0.082)	(0.078)
… since 6 years	−0.054**	−1.232***	1.177***	−0.045	−1.748***	1.702***	−0.013	−0.140**	0.126**	0.001	−0.181**	0.181**
	(0.022)	(0.053)	(0.055)	(0.041)	(0.096)	(0.106)	(0.044)	(0.064)	(0.063)	(0.059)	(0.085)	(0.080)
… since 7 years	−0.078***	−1.325***	1.247***	−0.125***	−1.890***	1.765***	−0.015	−0.138*	0.121*	0.012	−0.214**	0.224**
	(0.027)	(0.065)	(0.066)	(0.048)	(0.110)	(0.116)	(0.051)	(0.076)	(0.073)	(0.067)	(0.097)	(0.091)
Product-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No
Firm-year	No	No	No	Yes	Yes	Yes	No	No	No	No	No	No
Firm-Product	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Observations	287,620	287,180	287,180	287,620	287,180	287,180	287,620	287,180	287,180	271,397	270,970	270,970
R^2	0.947	0.864	0.398	0.970	0.900	0.481	0.972	0.958	0.847	0.974	0.959	0.845

Note: We can attribute to each product-firm-year observation either a product age within firm portfolio (because its entry within firm's portfolio was observed), or a sample age (only its entry in sample was observed jointly with the firm). The reference category is product age 0 (the product was introduced within the year). In case of reentry, a product-firm may have years with known age and with unknow age. Product dynamic sample: observations for which the firm is present both the next and the previous year are kept. Standard errors are clustered at the firm level. *p<0.1; **p<0.05; ***p<0.01

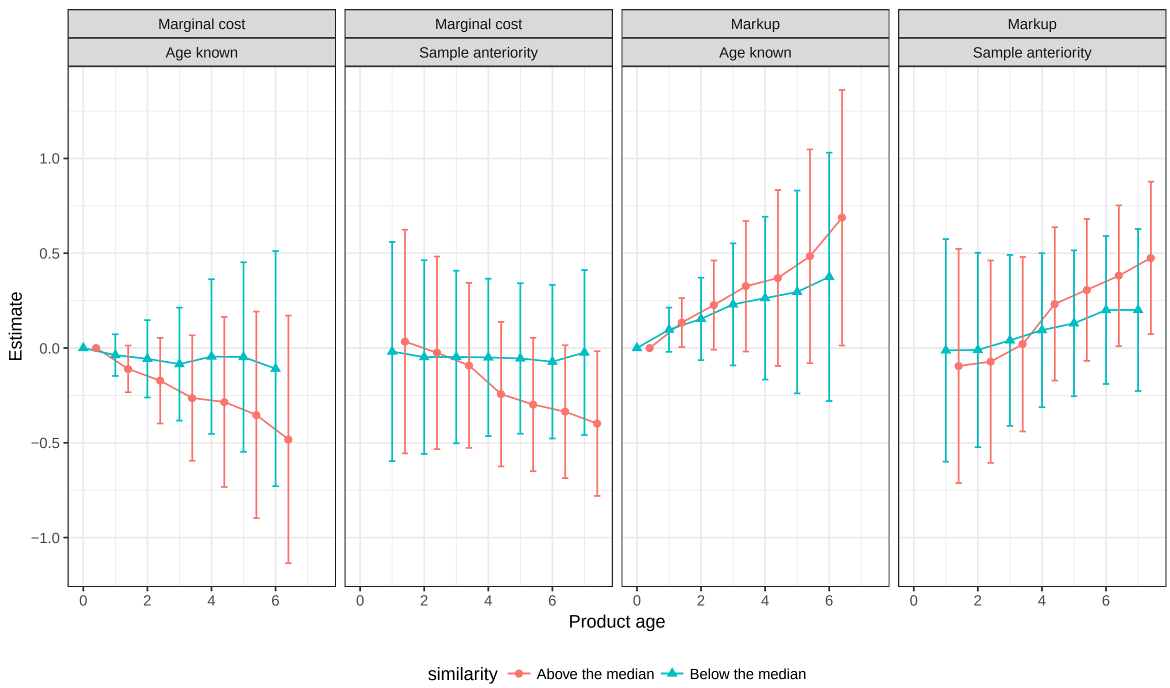


Figure D3. Experience effect - products close or distant from the core

Note: Estimates of equation (*). With firm-product fixed effects : $\nu_{fjt} = \nu_{fj}$. The sample is restricted to non-core products remaining in the firm portfolio the year after. the similarity measure is the coproduction similarity. Similarity median is computed on the restricted sample. Error bars correspond to the 5% confidence interval. All standard errors are clustered by firms. Estimates slightly offset for clarity purposes.

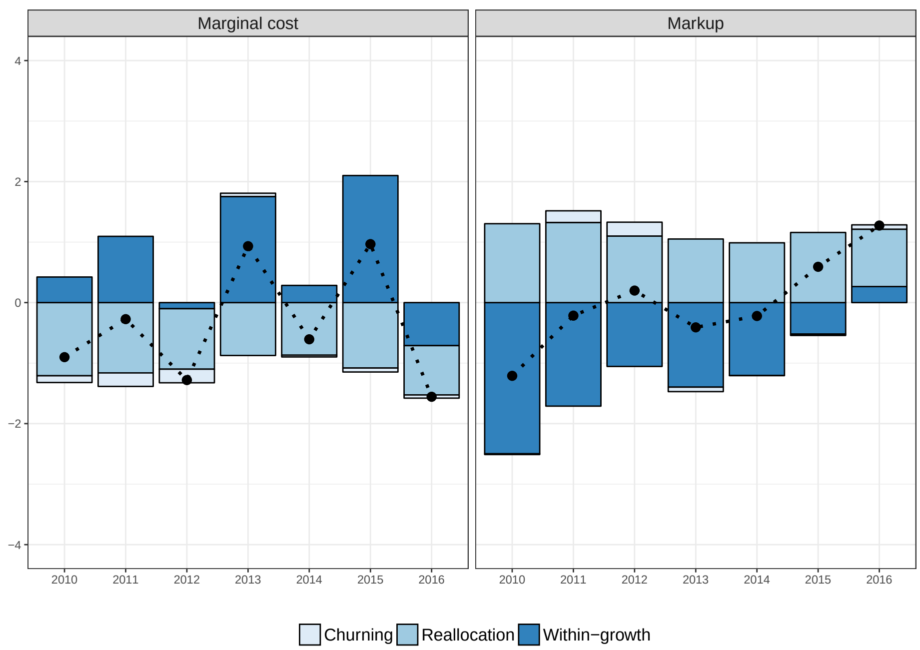


Figure D4. Firm-level markups and marginal costs growth decomposition by year

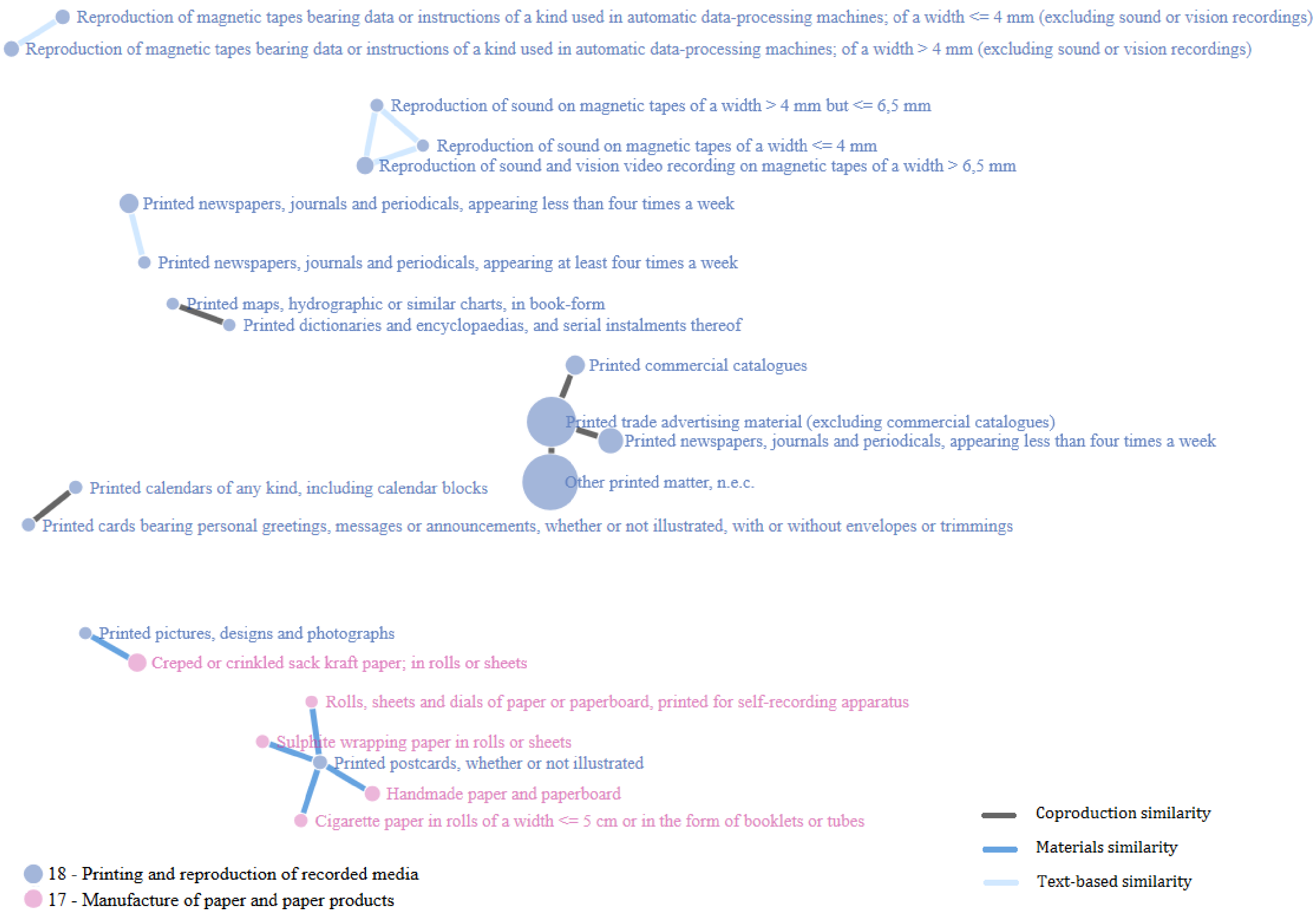


Figure D5. Five closest links between products for each similarity measure, for products in the Printing and reproduction of recorded media industry

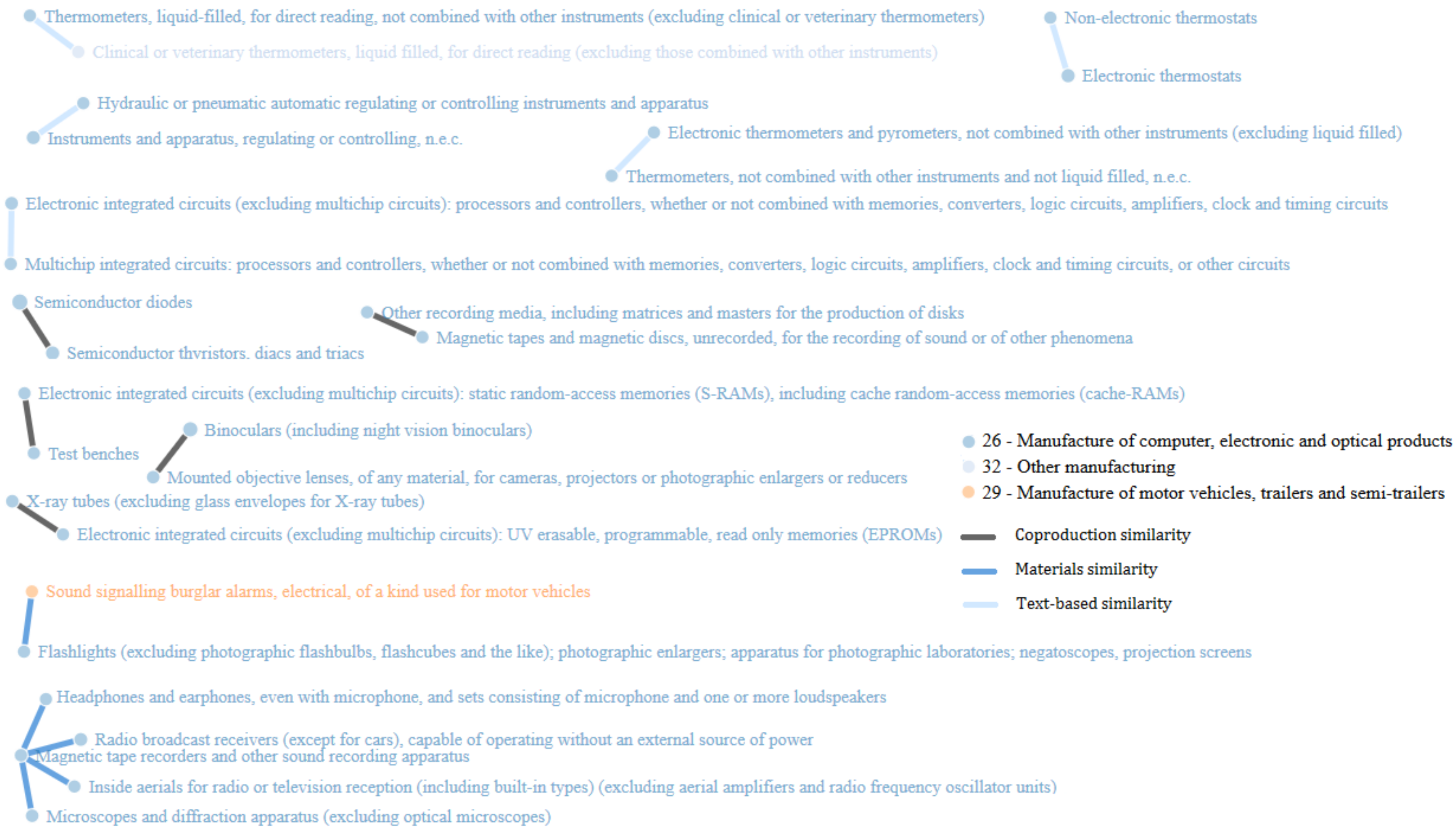


Figure D6. Five closest links between products for each similarity measure, for products in the Manufacture of computer, electronic and optical products industry

Figure D7. Five closest links between products for each similarity measure, for products in the Manufacture of motor vehicles, trailers and semi-trailers industry

Figure D8. Five closest links between products for each similarity measure, for products in the Other manufacturing industry

Response to demand shocks

International competition, if increased by demand shocks, is likely to alter firm's product profitability and to encourage them to restructure their production. Using French custom data, Mayer et al. (2014) and Mayer et al. (2016), observe that foreign demand shocks lead firms to skew their export sales toward their best performing products. A positive demand shock in a foreign market with free entry implies an increased competition (more varieties) and lowers the efficiency threshold at which firms find production profitable. Hence, inefficient firms exit the market and firms may drop their highest marginal cost products. Even if firms keep their product range fixed, they respond to a positive demand shock by producing relatively more of their most efficient product (their core competency), and relatively less of their relatively higher cost products, leading to an increase in skewness of sales. In turn, the reallocation of sales toward best performing products leads a reallocation of production factors towards those products and leads to firm level productivity increase. Mayer et al. (2016) show that, for this result to hold, demand must become more inelastic when consumption increases.[41] When the market size increases, the number of operating firms (and the number of varieties) increases, and the per-capita consumption of each variety decreases by substitution with new varieties, making demand more elastic, and leading to a tougher competition, lower market prices and lower markups. However, Ushchev (2017) argue that a market size increase may not always lead to a reduction of a firm's product mix, if there exists sufficient scale-scope economics, i.e. that firms with a wide product range (technically closer varieties) are more efficient. The extent of these scale-scope economies are hard to measure with usual economic datasets and are likely to widely differ across industries.

We use insights from Mayer et al. (2016) to build foreign demand shocks. We use the world trade database BACI provided by CEPII Gaulier and Zignago (2010), containing information on quantity and sales of products export and import, broken down by destination. We also use very detailed information on french firm exports from 2009 to 2016 with custom data provided by the national direction of foreign trade statistics to determine foreign destination-products exports.[42] We build two product-specific demand shocks:

$$\gamma_{fjt} = \sum_{d \in B_{fjt}} w_{fjd,t-1} \tilde{\Delta} M_{djt}$$

$$\Gamma_{fjt} = \sum_{d \in B_{fjt}} w_{fjd,t-1} \Delta GDP_{dt}$$

Where B_{fjt} is the set of destination for which firm f reports positive sales of product j in both $t-1$ and t; $w_{fjd,t-1}$ is the weight at $t-1$ of firm f sales of product j to destination d in all its exports of j in destinations in B_{fjt}, and $\tilde{\Delta} M_{djt}$ is the variation of imports of product j into destination d from all countries except France, in other words, exogenous import demand

[41] Property known as Marshall Second Law of Demand, or increasing Love for Variety Zhelobodko et al. (2012)

[42] Our analysis is limited to 2016 because of data availability. Products are defined as envelopes of PRDFRA-NC8-HS6 classification

for product j in d. ΔGDP_{dt} is GDP growth of country d.[43] These two demand shocks are quite data restrictive since they use only information on countries and product which are relatively stable. However, we consider that this restriction is useful in order to build demand shocks on regular transactions (product destination), which may be more representative of the firms' business reality.

We also use firm-specific demand shocks, one is product-oriented and one is destination-oriented:

$$\zeta_{ft} = \sum_{j \in J_{ft}} \widetilde{w}_{fj,t-1} \tilde{\Delta} M_{jt}$$

$$\xi_{ft} = \sum_{d \in D_{ft}} \widetilde{\widetilde{w}}_{fd,t-1} \Delta GDP_{dt}$$

Where J_{ft} is the set of product exported by the firm in both t and $t-1$, $\widetilde{w}_{fj,t}$ is the weights of f sales of product j in total sales of products in J_{ft}, $\tilde{\Delta} M_{jt}$ is world import variation from all countries except France. D_{ft} is the set of destinations of firm f exports in t and $t-1$, $\widetilde{\widetilde{w}}_{fd,t}$ is the weight of exports of f into d in all exports into destinations in D_{ft}. We argue that these demand shocks are exogenous, since the firm-product specific shocks γ_{fjt} excludes imports from France, thus from specific factors that could affect both French firms exports and pricing behaviour. These shocks are also exogenous because they rely only on the past structure of firms' products and destinations portfolios, as well on aggregate variations not susceptible to be influenced by French firms production, export and pricing decisions.

We first check that exports and production respond to these demand shocks. Table E1 reports OLS results for both product-level exports and production variations in response to product-specific demand shocks. Demand shock Γ_{fjt}, which represents the GDP growth of product-destination clients of firm f is always highly significant. The demand shock γ_{fjt}, built with destination-product imports excluding imports from France is significant, except for export growth with product-year fixed effects. The firm-specific demand shocks are also consistently correlated with firm total export and production.

Exporters respond to foreign demand shocks by producing and exporting more. Our estimates suggest a significant impact of both global demand for products and foreign clients GDP growth on total production and export. Table 12 presents markups, marginal costs and prices reactions to demand shocks. When the demand shock originates from product-specific increased imported demand, jointly with an increases in export and production, we observe a decrease in prices. Independent of firms' export rate, marginal costs decrease. For firms with a high export rate ($> 30\%$ export rates), markups increase and marginal costs decrease. This heterogeneity in pass-through has already been pointed out in the literature in diverse forms, for instance in Garcia-Marin and Voigtländer (2019) (established exporters pass-through of marginal costs' decrease is limited by markups, which is not observed for new exporters) or Amiti et al. (2018) (large firms pass-through of marginal costs' decrease is only half of that

[43] GDP growth in volume, obtained with the world bank database

TABLE E1—EXPORT AND PRODUCTION RESPONSES TO DEMAND SHOCKS AT PRODUCT AND FIRM LEVEL

	Dependent variable at product-level:			
	ΔExport$_{fjt}$		ΔProduction$_{fjt}$	
γ_{fjt}	0.033**	-0.002	0.041***	0.018*
	(0.016)	(0.021)	(0.008)	(0.010)
Γ_{fjt}	0.802***	0.772***	0.430***	0.501***
	(0.243)	(0.272)	(0.119)	(0.132)
Fixed effects	Industry-Year	Product-Year	Industry-Year	Product-Year
Observations	65,157	65,157	66,314	66,314
R^2	0.002	0.165	0.004	0.198

	Dependent variable at firm-level:	
	ΔExport$_{ft}$	ΔProduction$_{ft}$
ζ_{ft}	0.311***	0.198***
	(0.053)	(0.018)
ξ_{ft}	0.917***	0.160**
	(0.317)	(0.080)
Fixed effects	Industry-Year	Industry-Year
Observations	40,736	63,776
R^2	0.003	0.009

Note: *p<0.1; **p<0.05; ***p<0.01
Standard errors are clustered at the firm level

of small firms). When the shock originates from destination GDPs, we find a decrease in marginal costs as well.

Table E2—markup, marginal cost and price response of a demand shock

	Full sample			Firms with export rate $\geq 30\%$		
	$\Delta\mu_{fjt}$	Δmc_{fjt}	Δp_{fjt}	$\Delta\mu_{fjt}$	Δmc_{fjt}	Δp_{fjt}
γ_{fjt}	0.013	-0.036***	-0.027***	0.042**	-0.059***	-0.029**
	(0.012)	(0.014)	(0.010)	(0.019)	(0.020)	(0.015)
Γ_{fjt}	0.340*	-0.491***	-0.060	0.283	-0.673**	-0.101
	(0.176)	(0.187)	(0.123)	(0.278)	(0.307)	(0.191)
Obs	72,914	72,906	73,660	38,922	38,922	39,379
R^2	0.003	0.007	0.009	0.005	0.011	0.011

Note: *p<0.1; **p<0.05; ***p<0.01
All estimation include industry-year fixed effects
Standard errors are clustered at the firm level

The OLS estimates show a significant correlation, which we interpret as causal, between demand shocks and marginal cost variations, for both demand shocks. For intensive exporters, the demand shock γ_{fjt} implies a decrease in marginal cost, which is shared between a price decrease and an increase in markup. The negative effect of demand shock on marginal cost might be puzzling, since marginal costs are usually increasing in quantities for a given production technology. The first explanation could be a productivity gain by an increase in the intensive margin of exporting. For the extensive margin, De Loecker (2013) show that firms entering export markets experience productivity gains. Here, marginal cost is directly inversely proportional to firm-level productivity.[44] Garcia-Marin and Voigtländer (2019) shows that when a product which was sold domestically begins to be exported, it is directly its marginal cost which decreases, both at export entry and the following years. Besides productivity gains, another explanation may be relative to our level of aggregation which does not precisely identify products. If firms actually produce several varieties within the product definition we use, demand shocks for a product may encourage firms to reallocate production toward more efficient product varieties, those with the lowest marginal cost, as argued by Mayer et al. (2014), implying a decrease in marginal cost, by a composition effect. However, in our case, the demand shocks can not be interpreted as an increase in the toughness of competition, as markups, if anything, increase.

Firms can also respond to demand shock by reorganizing their product portfolio. In Table E3, we estimate the effects of firm-specific demand shocks on firm aggregate markup and marginal cost variations, as well with the three decomposition terms of Equation 2, namely,

[44]The latter correlates positively with demand shocks, although with weak significance.

the turnover effect (adding and dropping products), the within effect (product specific growth at constant sales shares) and the reallocation effect (sales shares reallocation). The sample is restricted to firms that are multiproducts in $t-1$ or in t as otherwise turnover and reallocation effects do not contribute.

Table E3 confirm the results of Table E2. Demand shocks imply lower marginal costs and higher markups costs, including at the firm level. However, we find that product portfolio effect, namely churning and reallocation do not react to demand shocks. This effect is particularly strong for intensive exporter firms, since nearly all the effect of demand on both markups and marginal cost is driven by markup and marginal cost growth within continuing products, at given weights. Firm-level aggregate markups and marginal costs are more responsive to the product oriented demand shock ζ_{ft}, i.e. weighted average of global demand for products in firms portfolio, than the client (destination) oriented shock ξ_{ft}. We find no evidence of (both domestic and export market) sales reallocation toward best performing products, either in the sense of markups or marginal costs, following a firm-level demand shocks. Although the method is different, this is at odds with what is observed by Mayer et al. (2016) in the export market (an increased skewness of sales) following the same kind of demand shocks.

Table E3—Demand shock effect on firm markup growth decomposition - full multiproduct sample

		Total	Churning	Within	Reallocation
Full sample		$\Delta\mu_{ft}$			
		Total	Churning	Within	Reallocation
	ζ_{ft}	0.400***	0.037	0.312***	0.053
		(0.083)	(0.041)	(0.079)	(0.038)
	ξ_{ft}	0.031	0.041	0.267	-0.276
		(0.295)	(0.127)	(0.308)	(0.173)
	Obs	21,745	21,745	21,755	21,755
	R^2	0.014	0.015	0.010	0.009
		Δmc_{ft}			
		Total	Churning	Within	Reallocation
	ζ_{ft}	-0.330***	-0.091	-0.126	-0.118
		(0.116)	(0.078)	(0.090)	(0.072)
	ξ_{ft}	-0.679	0.089	-0.791**	-0.018
		(0.455)	(0.292)	(0.349)	(0.295)
	Obs	21,745	21,745	21,755	21,755
	R^2	0.030	0.035	0.011	0.016
Firms with export rate ≥ 30%		$\Delta\mu_{ft}$			
		Total	Churning	Within	Reallocation
	ζ_{ft}	0.452***	0.027	0.402***	0.029
		(0.141)	(0.077)	(0.131)	(0.065)
	ξ_{ft}	-0.356	-0.241	0.415	-0.531
		(0.611)	(0.263)	(0.627)	(0.363)
	Obs	8,842	8,842	8,844	8,844
	R^2	0.019	0.023	0.016	0.013
		Δmc_{ft}			
		Total	Churning	Within	Reallocation
	ζ_{ft}	-0.528***	-0.076	-0.412***	-0.057
		(0.192)	(0.145)	(0.144)	(0.135)
	ξ_{ft}	-0.934	0.308	-1.097	-0.139
		(0.950)	(0.577)	(0.734)	(0.602)
	Obs	8,842	8,842	8,844	8,844
	R^2	0.032	0.038	0.015	0.016

Note: *p<0.1; **p<0.05; ***p<0.01
OLS include year-industry fixed effects
Standard errors clustered at the firm level

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