MANUFACTURING FIRMS AS SERVICES PROVIDERS: WHAT THE BELGIAN DATA SHOW

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ABSTRACT

This paper investigates the role of firm and sector characteristics for servitisation of firms, i.e. the provision of services by manufacturing firms. First, it discusses theoretical arguments based on demand complementarity between a firm's goods and services, non-rivalry in the allocation of expertise between the production of goods and that of services and the degree of competition. Second, descriptive evidence highlights heterogeneity in service intensity between and within sectors, and a possible non-linear relationship between service intensity and firm efficiency. Third, an econometric assessment points to a U-shaped relationship between servitisation and firm productivity, depending on the sector of activity.

JEL classification: D24, D29, L11, L22, L23, L25.

Key words: Services, multi-product firms, firm behaviour, total factor productivity, panel data analysis, non-linear model.

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I. INTRODUCTION

In recent decades, services have acquired an increasingly important role in developed economies. This stands out clearly from macroeconomic figures such as GDP, employment or trade. In Belgium, on which this paper will base its empirical analysis, the share of manufacturing industries in GDP declined from 21% in 1995-1999 to 16% in the 2010-2014 period, while the share of services went up from 63% to 68% over the same period. Net job creation figures confirm this pattern, with 161.8 thousand job losses, one job in four, in the manufacturing sector between 1995 and 2014, and 849.1 thousand jobs created in the service sector, an increase of 30%. The growing share of the service sectors in aggregate GDP and employment – deindustrialisation – is accompanied by a process of servitisation at the individual manufacturing firm level. Servitisation refers to the provision of services by a company whose main or initial activity is to manufacture goods.

Typical examples of manufacturing companies that provide services to their customers are actually very widespread. This is common among car and aircraft manufacturers, or IT-related firms. Rolls-Royce offers “Power-by-the-Hour” contracts, i.e. packages of support services for aircraft engines. In 2017, Boeing predicted that the market for aeronautical services would be worth as much as $10 billion in the next ten years. Automobile manufacturers have provided services ranging from maintenance and repair to leasing and financing. Recently, the Volkswagen Group has announced to plan to invest €3.5 billion by 2025, making its cars digital devices on wheels. Information technology products have often been given added value thanks to the maintenance, training and tailor-made installation or customisation of the product. IBM, Dell or Hewlett-Packard now derive a large share of their revenue from services, where services include consulting, finance, training and so on. These few examples show there is a broad set of services that manufacturing firms supply, such as finance, insurance, consultancy, training, design and development, maintenance and support, installation and implementation, repair, retail and distribution, transport, leasing, etc.

The expansion of the servitisation phenomenon reveals a change in firms’ business model, organisation and mode of production. This challenges the way we consider important issues related to corporate decision-making, market competition or competitiveness, to list just a few. Indeed, firms compete not only on price or product quality but also by supplying related services. The implications of servitisation for firm production and organisation goes well beyond the field of multi-product firms, because it requires a more drastic move in terms of production technology. For example, offering financial services in addition to selling cars may involve establishing an entirely new unit, while adding cake products to a bakery factory’s range leads to more marginal adaptation of the production process. It may then imply bigger changes in terms of labour demand, investment or pricing decisions. The direction of the change is not clear-cut, as services may differ widely in nature; for example, providing financing services would probably involve highly skilled workers with a degree or experience in Economics or Finance, while providing delivery services would require a less skilled workforce but investment or leasing of vehicles.

Servitisation may affect the firm's performance in terms of profit, market power, survival, and so on. Engaging in servitisation is a risky investment, involving specific costs, as well as organisational and managerial challenges. The risks of failure are significant, and profits associated with services may not meet investors' expectations, may not compensate for those risks, or may be lower than the profits generated by producing goods alone. The question why do firms engage in servitisation in spite of this paradoxically lower-than-expected profits has been investigated mainly in the business literature (see Gebauer *et al*., 2005; Lee *et al*., 2016, among others). Several motives behind the idea of servitisation have been put forward. Broadening the range of firms' products and activities may be seen as a way to diversify revenue. Servitisation may result from existing complementarities between goods and services for some products. It also widens product differentiation; that proves to be especially relevant in mature industries where scope for cost competition has been exhausted. In addition, offering an integrated goods-services package improves the attractiveness of the product or the brand, and strengthens customer relationships. It may also be a defensive strategy for large mature companies to secure their market shares against competitors and potential entrants. Alternatively, it may be an offensive strategy for small firms to penetrate a market with new and more tailored-made products. Furthermore, it may become a necessary adjustment for laggard firms in industries where services provision has become standard, or firms experiencing adverse conditions or a downturn. In sum, servitisation may be an option for highly efficient companies that can afford the cost, financing and risks of developing a new service activity, but also for less efficient firms that use servitisation as a defensive strategy in order to remain active or grow.

The aim of this paper is to document and analyse the relationship between manufacturing firms' performance and servitisation. We first discuss theoretical economic mechanisms that motivate manufacturing firms to supply services. We consider a theoretical framework of monopolistic competition to analyse the relative role of demand factors, supply factors, product characteristics and market competition. More precisely, on the demand side, we extend Melitz and Ottaviano (2008) model of quadratic preferences for differentiated products to account for demand complementarity between goods consumption and services consumption, in the same spirit as Ariu *et al*. (2018). On the supply side, we draw on the online appendix in Breinlich *et al*. (2018), describing where firms decide on the allocation of (non-) rivalrous expertise between the production of goods and the provision of services.

The main conclusions of the theoretical analysis are twofold. First, servitisation varies with firms' efficiency, but the relationship may be complex and, in some cases, non-linear. For different motives, both high-performance and low-performance firms may find it optimal to develop services provision. Second, the shape of this relationship varies with product characteristics, production technology and market conditions. Indeed, the degree of complementarity between goods and services, the degree of goods and services differentiation, the extent of non-rivalry in technology, as well as market conditions – in particular, demand elasticity and the extent of competition – all affect the relationship between servitisation and firms' efficiency. The implications for an empirical assessment are that the relationship between servitisation and firms' characteristics is possibly non-linear and may well differ from one sector to another.

The paper goes on to give an empirical evaluation based on a unique dataset of total sales and goods sales for firms in the Belgian manufacturing sector over the period from 1997-2013. We focus our analysis on service intensity, defined as the share of a firm's sales attributable to services sales, the latter being measured as the difference between total sales and goods sales. We report a set of descriptive statistics that point to three main stylised facts: (1) there is substantial heterogeneity in service intensity, both between and within manufacturing sectors; (2) service intensity has increased over time in most manufacturing industries, although at a different pace according to the sector under consideration; (3) the relationship between firm efficiency and service intensity may be non-linear.

We then provide an econometric assessment of this relationship. We estimate a linear fixed-effects model for service intensity allowing for non-linear effects of firm-level efficiency, as measured by TFP. The specification controls for firm characteristics – age, size and average wage – and sector-level factors – the degree of competition, the mean service intensity, as well as time effects. For robustness, a Tobit model and a fractional Probit model are also considered. In line with our theoretical discussion, our results point to a U-shaped relationship between the fraction of services sold and firms' TFP performance. The curvature of this relationship varies across manufacturing sectors, however. In a set of manufacturing sectors, our results confirm that it is not only the most efficient firms that provide services, but less efficient firms may also turn to servitisation.

The rest of the paper is organised as follows. Section II gives a survey of the relevant literature. Section III develops our theoretical discussion. Section IV describes the data used in the empirical analysis and provides descriptive empirical evidence about servitisation. An econometric analysis of the relationship between servitisation and firm performance is provided in section V. Section VI concludes.

II – SURVEY OF THE LITERATURE

II.1 Theoretical insights on servitisation

Ariu *et al*. (2018) develop a model that extends and deviates from traditional models in two ways. First, it extends the usual demand for differentiated products model to one-way complementarity between goods and services, i.e. the use of the goods is a prerequisite for the use of the service. Providing services together with goods depends on the extent of complementarity between goods and services, as well as market conditions, and exporting services also depends on the firm's ability to pay the extra fixed cost entailed in exporting activity in general, and in exporting services in particular. Second, the model considers a framework of oligopolistic competition, where most theoretical trade models assume monopolistic competition. Together, these two features lead to the theoretical predictions that services provision boosts firm sales and market shares, and that higher sales result from both a greater quantity sold and higher prices charged. Furthermore, providing services while selling goods raises the perceived quality of the goods.

Focusing on the impact of trade liberalisation on service provision, Breinlich *et al*. (2018) discuss alternative theoretical features that would explain firm servitisation. In their online appendix model, they develop a model with differentiated products and firms operating under monopolistic competition. Firms produce both goods and services and decide on the allocation of their exogenously given expertise to the production of goods and services according to relative market conditions, the firm's total expertise level, the demand elasticity for goods and for services and, importantly, the degree of rivalry in the use of expertise. At one extreme of full rivalry, any extra use of expertise in the production of goods implies a reduction of the same amount of expertise allocated to the production of services; at the other extreme of non-rivalry the full amount of expertise can be used for both the production of goods and the production of services.

Lee *et al*. (2016) consider two alternative market outcomes when there is complementarity between goods consumption and services consumption. They compare firms' profits where goods and services are produced by two different types of firms – manufacturers produce goods and service firms produce services – or by a single firm – a servitised manufacturer that sells both services and goods. Demand for the goods depends on the price and quality of the goods as well as on the price and quality of services. Their analysis suggests that having goods and services provided by the same company is a better option (i) when the market for the combined goods-services package is large, (ii) the greater the complementarity between the use of goods and the consumption of services, (iii) the more the two options (goods and services produced by different firms versus goods and services produced by a single company) are substitutable, (iv) the higher the cost efficiency and improved quality of the servitised manufacturer.

Building on this literature, we put forward and discuss a model that includes both demand-side and supply-side features that can explain firm servitisation. On the demand side, the quadratic preference model for differentiated products is extended to account for complementarity between goods and services. On the supply side, we allow for non-rivalry in the allocation of expertise between goods production and services production.

II.2 Main results drawn from previous empirical analyses

On empirical evidence, recent microeconomic papers that describe the servitisation process are, for example, Bernard *et al.* (2017) and Crozet and Milet (2017a, 2017b). The former analyses the decline in manufacturing production in Denmark, focusing on firms that switch from manufacturing industries to service sectors. They consider and discuss the issue of services that are helpful to the production of goods or inherent to the firm’s functioning, such as HR services. By contrast, we focus on firms that are active in the manufacturing industry and sell services to their customers. Crozet and Milet (2017b) describe the servitisation process in France at the firm level. Their figures highlight substantial heterogeneity in the degree of servitisation, not only between different industries but also within industry; most firms sell few if any services, while some specialise in services provision. Four out of five firms report selling services, but only one-third of firms get at least 50% of their sales from services.

Turning to the relationship between servitisation and firms' characteristics, the literature has pointed to firm size and profit, to product complexity and innovation intensity, and to market competition factors. Crozet and Milet (2017b) report that servitised firms are larger, more productive and pay higher wages than non-servitised firms. Dachs *et al.*, (2014) investigate the determinants of servitisation for a set of firms in ten European countries. Their results highlight a U-shaped relationship between firm size and servitisation. Servitisation is also positively related to product complexity and firms' product innovation and is more present in innovation-intensive sectors. Analysing the effect of a change in the competitive environment, Breinlich *et al*. (2018) find that a reduction in import tariffs for goods leads to an increase in British manufacturing firms' service revenues and service revenue shares, and that the effect is more pronounced for firms with a higher initial R&D stock.

Through the lens of export performance, Ariu *et al.* (2018) assess the impact of selling both goods and services (being bi-exporters) to a given destination on goods export sales to that destination. Using detailed transaction export data for Belgian manufacturing firms, their results show that export sales are higher when services are exported to the same destination. Furthermore, this effect is attributable to an increase in both export volumes and export prices and shows up in a higher perceived quality of oods exported. Consistent with this finding, using survey information from German manufacturing SMEs, Aquilante and Vendrell-Herrero (2019) show that raising the share of services in firms' revenue is associated with higher export intensity.

Targeting more specifically the impact of servitisation on firm performance, Crozet and Milet (2017a) show that firms that start selling services see their profitability and total sales go up. Their results also highlight that the benefits of starting to sell services are greater for micro and small firms than for larger ones and vary across sectors. Kohtamäki *et al*. (2013) likewise find evidence supporting the view that offering services may foster firms' sales growth. They point to non-linear effects of services provision on firms' performance and the role of firms' network capabilities to reinforce the services provision effect. Suarez *et al.* (2013) find evidence of a U-shaped relationship between the share of services in firm revenues and firm profitability, and Fang *et al*. (2008) point up a U-shaped relationship between service intensity and firm's Tobin's Q.

III – AN ILLUSTRATIVE MODEL

This section discusses two theoretical ingredients that lead firms to optimally choose to provide services as well as goods. On the demand side, complementarity between the use of goods and the use of services can explain why manufacturers also sell services. This idea was used in Ariu *et al*. (2018) or Cusumano *et al*. (2015). On the supply side, the argument is based on the idea that firm expertise or know-how has the characteristics of a public good from the firm's point of view. Indeed, corporate production processes are increasingly based on assets such as the invention of new processes and/or products, and improvements in employee skills and brand image. These factors labelled as intangibles form a key component of firms' knowledge which is crucial to their productive performance (Marrocu *et al*., 2012; Bontempi and Mairesse, 2015). When firms produce both goods and services, it may not be possible to separate the knowledge embodied in the service from that embodied in the good, especially in the case of "adapting" services (Cusumano *et al.*, 2015). In this case, wider use of knowledge to produce a good may not reduce the knowledge available to produce a service. This idea has been used in Breinlich *et al*. (2018, online appendix).

We introduce these two features into a model of two monopolistic competition sectors – a goods sector and a services sector – differentiated products and firm heterogeneity in terms of expertise. On the demand side, we consider a continuum of identical consumers, with utility function separable and linear in the numeraire good. We extend the quadratic utility function used in Melitz and Ottaviano (2008) to complementarity between goods and services consumption. Preferences are defined over a continuum of differentiated varieties of goods and services indexed by *i*. The utility of a representative consumer *c* among *L* consumers in the economy is given by

$$\begin{aligned} U = \alpha \int_0^N q_i^c di - \frac{1}{2}\gamma_g \int_0^N \left(q_i^c\right)^2 di - \frac{1}{2}\left(\int_0^N q_i^c di\right)^2 \\ + \alpha \int_0^N y_i^c di - \frac{1}{2}\gamma_s \int_0^N \left(y_i^c\right)^2 di - \frac{1}{2}\left(\int_0^N y_i^c di\right)^2 + \theta \int_0^N q_i^c y_i^c di \end{aligned} \tag{1}$$

where *N* is the mass of consumed varieties, $\alpha, \gamma_g, \gamma_s \text{ and } \theta$ are positive parameters, q_i^c and y_i^c represent *c* individual consumption of goods variety and of services variety produced by the same firm *i*, respectively. Following Melitz and Ottaviano (2008), the parameters γ_g and γ_s express the specific consumer's preferences for goods and services. They express the degree of product differentiation between the varieties that increases with γ_g (or γ_s) as consumers give more weight to the distribution levels of consumption across varieties; when $\gamma_g = 0$ ($\gamma_s = 0$), the varieties are perfect substitutes and both markets are homogeneous. The parameter θ represents the degree of complementarity between the varieties of goods, and services produced by firm *i*. θ is defined over $\left]0, \min(\gamma_g, \gamma_s)\right[$, so that the model can take into account various degrees of complementarity. For example, Cusumano *et al.* (2015) assume that the degree of complementarity is lower for “smoothing” services – that just facilitate the purchases of goods by customers – than for “adapting” services that are able to expand the goods' functionality or help customers to develop new uses for the goods. In this paper, θ ranges from zero when the varieties of goods and services are independent for consumers to γ_g (γ_s) while the varieties are perfect complements for them (Vives, 1984).

On the production side, there is a continuum of firms that are heterogeneous in their level of productivity or expertise, T_i. They are multi-product in the sense that they produce a differentiated good and a differentiated service simultaneously. Following the Breinlich *et al*. (2018) online appendix model, firm *i*'s production function for goods and services is assumed to take the following form:

$$q_i = T_{ig} L_{ig} \tag{2a}$$

$$y_i = T_{is} L_{is} \tag{2b}$$

where T_{ig} and T_{is} represent the firm-specific productivity available for the production of goods and services respectively, and L_{ig} and L_{is} are the firm's labour inputs used to produce goods and services. The labour cost *w* is given and is the same across sectors. The values for firm-specific productivity T_{ig} and T_{is} are assumed to depend on expertise available in firm *i*. The total stock of expertise T_i $\left(T_i = T_{ig} + T_{is}\right)$ is assumed fixed within the firm and a CES function is used to model the degree of non-rivalry in knowledge across the production of goods and services:

$$T_i = \left(T_{ig}^t + T_{is}^t\right)^{\frac{1}{t}} \tag{3}$$

where $t \in (0, \infty)$. Firms allocate their expertise to the production of both goods and services in a way that is governed by the degree of non-rivalry in expertise, *t*. To illustrate this feature, we consider the two extreme cases of full versus zero rivalry. With full rivalry, i.e. for *t*=0, each unit of expertise can be used either for the production of goods, or the production of services. With non-rivalry, i.e. for high values of *t*, as $t \to \infty$, the total amount of firm expertise can serve both the production of goods and the production of services. Firm *i* maximises its profit by choosing optimal prices (p_i^g, p_i^s), and optimal amounts of knowledge allocated to the production of goods and services (T_{ig}, T_{is}), that will determine the relative production of goods and services.

To understand the relationship between firm expertise and service intensity, that is the share of services provision in a firm's total sales, we present the main results drawn from comparative statics. For high-performing firms, the relationship between service intensity and firm expertise is systematically positive. In other words, beyond a given efficiency threshold, service intensity monotonically increases with efficiency. However, for less-performing firms, the sign of the relationship is ambiguous, with the possibility of a negative sign. More precisely, in two cases discussed in Appendix A, services production declines as efficiency of low-performing firms rise. In both cases, low-performing firms provide both goods and services and survive thanks to weak competition on the goods market.

In the first case, low-performing firms are initially quite specialised in the production of services, because there is high demand complementarity between goods and services consumption, and because low rivalry in knowledge makes it easier to allocate additional expertise to goods production. Therefore, low-performing firms take advantage of a higher degree of expertise to reduce their services provision and rebalance production towards goods.

The second case is where low-performing firms initially allocate more expertise to the production of goods than to the production of services. Demand complementarity between both of them is relatively low and the production of goods is initially greater than the production of services, so that firms have little incentive to step up their production of services. In addition, there is rivalry in the allocation of expertise so that increasing services production would be costly in terms of goods production. Rather, firms tend to devote the rise in their initially low expertise stock to meet demand for their goods.

The two cases mentioned above arise under the condition that firms are low-performing. However, another condition must be fulfilled, namely that the production of services is not initially too low in comparison with the production of goods. When this condition is not met, firms have no incentive to reallocate their production from services to goods.

One empirical implication of this theoretical discussion is that the shape of the relationship between firm productivity and service intensity varies across sectors, according to demand parameters, production technology, and the degree of competition. It is likely to be increasing for high-performing firms but may turn U-shaped under some specific conditions. As indicated by the previous discussion, this can arise when the complementarity between goods and services and the degree of rivalry in knowledge are low or when both are high. Lacking reliable and convincing estimates of these parameters, these theoretical implications can hardly be verified empirically. By contrast, one can empirically test the fact that under some competition conditions the relationship between services production and efficiency can be negative for the left tail of the performance distribution. Indeed, when competition is weak between suppliers, the less performing firms can stay in the market; and these low-performers are engaged in servitisation like their better performing competitors. This last finding leads to the important empirically testable prediction that, in a low competition environment, firm performance is likely to be more dispersed, and that the relationship between firms' service intensity and productivity is more likely to be U-shaped rather than monotonic. In addition, this U-shaped relationship rests on the condition that the production of services by the low-performing firms is not too small in comparison with the production of goods. This is a second testable condition.

IV – DATA DESCRIPTION AND STYLISED FACTS ON SERVITISATION

The empirical analysis relies on firm-level data for Belgium over the period 1997-2013. It combines three data sources: the Survey of Industrial Production (Prodcom), VAT returns, and the Central Balance Sheet Office. This section describes the construction of our variables and present some stylised facts on firm servitisation.

To construct a measure of servitisation, we use data from the Survey of Industrial Production and VAT returns. The first source reports the volume of industrial goods sold per NACE 8-digit product for each firm in the survey. It covers just over 4,000 firms per year, mostly in the manufacturing sector. We aggregate data at the firm level to obtain figures for firms' sales of goods. We supplement this information with data on total sales as reported by firms in their VAT returns. These give their turnover and consumption of intermediate inputs on a monthly or quarterly basis, depending on the firm's size, and the information is aggregated at the firm-year level. We control for the amount due to "processing on commission", also available in the Survey of Industrial Production dataset. We measure services as the difference between total sales and goods sales including processing on commission.[1] We focus our analysis on the firm service intensity, defined as the ratio of services sales to firm's total sales. To adjust for reporting errors, we exclude service intensity below -0.05 or above 1.05; and winsorize the remaining observations at the [0, 1] range.

Additional firm-level variables are based on VAT returns, for firms' sales and intermediate input consumption, and balance sheet data for the remaining variables, namely value added, employment, average wages and labour costs, investment and capital. For balance sheet data, we make a few small corrections concerning dates and years or an apparently erroneous number of months in the annual accounts.[2] After that, the annual account information was annualised[3] and missing values extrapolated. The sector of activity is determined according to the most commonly reported NACE codes available for each firm over the period, converted to the NACE-Rev2 classification where necessary. We construct the 2-digit NACE-Rev2 deflators on value added, investment and intermediate consumption based on published data in the national cccounts.

We construct a set of firm-level characteristics that are used as control variables in our estimations. Employment is defined as the average number of employees in full-time equivalents (FTEs) over the year. Size is the log of employment. The firm's average wage is given by its wage

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1 To be more precise, we focus on services sold to the firm's customers rather than on services that can be considered as inputs for the production of goods or related to the firm's management. We also consider services that the firm sells, whether they are produced in-house or outsourced (as may be the case where a delivery van is hired out to the buyer of furniture), exactly as we do for goods sold.

2 For example, when the year-end date was 2 January 2005, we changed the date to 31 December 2004. By doing so, we attributed the values reported in the annual accounts to the year 2004 instead of 2005.

3 Flows are adjusted by taking a weighted average of t and t+1 flows. Stocks are adjusted by adding the weighted change in stocks between the current year and next year to the current year stock. The procedure attributes a missing value when there is not enough information to reconstruct the entire year, for example when information about the first few months or the last few months of a given year is missing. This does not apply to the last year in which the firm is observed, or to flows in the first year that the firm is covered.

bill over the average number of employees expressed in full-time equivalents over the year. The firm's age is based on the official start-up date of the company.

To construct a measure of total factor productivity, production function coefficients are estimated according to the methodology of Ackerberg *et al*., (2015). We rely on data on firms' value added, capital stock at the beginning of the year and average number of employees in FT Es over the year. Investment in physical capital is used as the proxy variable in the control function. Production function coefficients are estimated at the level of broad macroeconomic sectors, to ensure a sufficiently large sample size for each sector.[4] Table B1 in Appendix B reports the estimated production function together with t-stat and number of observations by broad economic sector. Table B.2 in the Appendix reports descriptive statistics by broad sector of economic activity for the firm-level variables used to explain servitisation, namely log TFP, age, employment, and wage, as well as moments of their entire sample distribution. Table B.3 reports moments of the distribution of log TFP across sectors.

We also construct a set of sector-level variables at the 2-digit NACE Rev2 level. The yearly Herfindahl index is constructed on the basis of firms' sales as reported in the exhaustive sample of VAT returns. We also consider the average service intensity for the sector and for the year. This aims to capture imitation effects, whereby firms may follow their competitors' strategy in terms of servitisation.

In the analysis below, we focus on firms with at least 20 employees, active in the manufacturing sector over the period 1997-2013. More precisely, we consider firms classified under headings 10 to 33 in the NACE Rev2 classification. A firm is considered as active if it reports positive employment, total assets and nominal fixed tangible assets above €100. We exclude the coke and refined petroleum products sector and the repair and installation of machinery and equipment sector because the number of observations in these sectors is far too small. Our final sample includes 37,228 observations, covering 3,538 firms over the period 1997-2013.

To illustrate the servitisation phenomenon, the rest of this section derives a couple of stylised facts on service intensity. It focuses on heterogeneity of service intensity, the development of servitisation over time, and a preliminary illustration of the relationship between servitisation and firm efficiency.

III.1. Stylised fact 1: servitisation is heterogeneous across and within sectors

To give a preliminary idea of the data, note first that in our sample, on average 17 percent of aggregate sales of manufacturing firms were related to services provision in the period 1997-2013. Further, 87% of all firms were found to sell some services, a figure consistent with evidence for France from Crozet and Milet (2017b), showing that 83% of French manufacturing firms sold services. This clearly indicates that servitisation of the manufacturing sector is anything but

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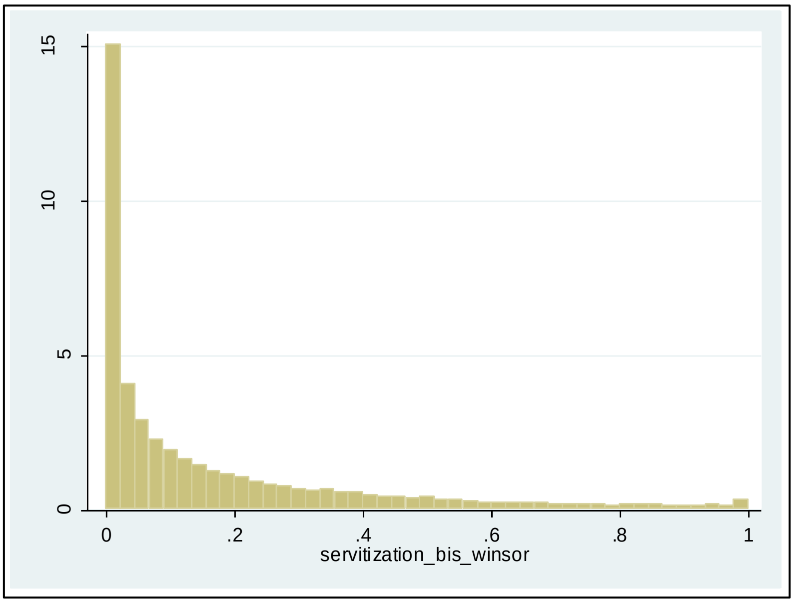
4 The sample used for the production function estimation is larger than that used to analyse servitisation because it does not need to be merged with the Survey on Industrial Production, which is used to measure firms' goods and services.

exceptional. However, there is substantial heterogeneity in that respect. As shown in Figure 1, the distribution of service intensity is very unequal. In our sample, many firms sell few services, or none at all. Indeed, in nearly half of the cases, services account for less than 5% of firm's sales. At the other end of the distribution, servitisation may become the primary source of a firm's revenues. In the last decile, it reaches 0.50, i.e. service intensity is above 50% in 10% of the cases.

Fig. 1. Histogram of the servitisation ratio for Belgian manufacturing firms, 1997-2013



Notes: Survey of Industrial Production and VAT returns, and Central Balance Sheet Office.
Sample of firms with 20 employees or more.

In fact, servitisation heterogeneity is prominent both across and within sectors of economic activity. As shown in Table 1, the service intensity varies across broad sectors defined as groups of NACE Rev2.0 sectors. Chemicals and pharmaceuticals industries have median service intensity around 20%. At the other extreme, the wood and metal sectors have median service intensity at around 3 percent. Furthermore, there is substantial heterogeneity within sectors as evidenced by the interquartile range, or the gap between the 5th and the 95th percentiles. And, the distribution of servitisation within sectors is far from normal, as indicated by skewness and kurtosis indicators.

TABLE 1

Service intensity by broad sector of economic activity

	# obs	mean	std	coef var	p5	p25	p50	p75	p95	skewness	kurtosis
Food, beverages and tobacco	5966	0.17	0.22	1,27	0.00	0.01	0.08	0.25	0.67	1.62	5.03
Textiles, wearing apparel and leather	3304	0.18	0.26	1,40	0.00	0.01	0.06	0.24	0.84	1.71	5.01
Wood, paper and printing	4044	0.11	0.18	1,68	0.00	0.00	0.03	0.12	0.54	2.45	8.89
Chemicals	2800	0.28	0.26	0,93	0.00	0.07	0.20	0.42	0.82	0.99	3.07
Pharmaceutical products	584	0.25	0.22	0,87	0.01	0.08	0.19	0.37	0.68	1.06	3.52
Rubber and plastics, and other non-metallic mineral products	5199	0.17	0.20	1,14	0.00	0.02	0.10	0.26	0.59	1.54	5.24
Metal	6466	0.14	0.23	1,67	0.00	0.00	0.03	0.15	0.70	2.18	7.16
Computer, electronic and optical products, electrical equipment	2285	0.21	0.26	1,26	0.00	0.01	0.09	0.32	0.81	1.43	4.13
Machinery and equipment	3258	0.19	0.25	1,27	0.00	0.01	0.09	0.29	0.79	1.60	4.90
Transport equipment	1348	0.17	0.21	1,22	0.00	0.02	0.10	0.24	0.65	1.92	6.77
Furniture; other manufacturing	1974	0.14	0.20	1,43	0.00	0.00	0.04	0.22	0.57	1.93	6.63
Total	37228	0.17	0.23	1,33	0.00	0.01	0.07	0.25	0.71	1.72	5.42

III.2. Stylised fact 2: servitisation has grown over time, at varying pace according to the sector

The importance of servitisation for firm's revenues has been growing over time. To illustrate this trend, Table 2 reports the average and median at different points in time, as well as the overall change over the 1997-2013 period. As indicated in the last line of the table, both average and median measures highlight an increase in service intensity of around 3 pp. over the last 15 years. This trend in servitisation has been more pronounced in some sectors than in others, as reflected in the average and median service intensity figures reported for each broad sector in Table 2. Computers and furniture experienced an increase in service intensity of 5 pp. over 1997-2013, while in the machinery equipment, transport equipment and chemicals sectors, service intensity has remained relatively flat.

TABLE 2

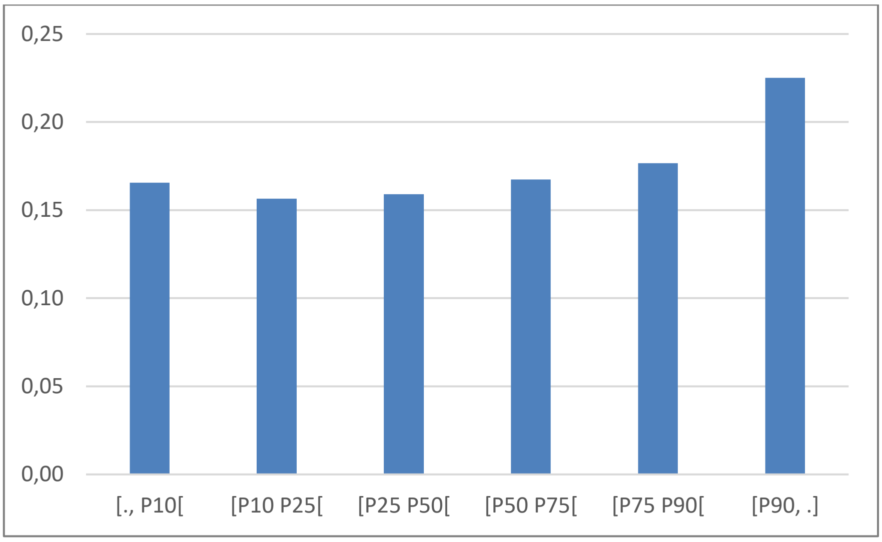
Median and average service intensity by broad sector over 1997-2013

	average service intensity			change over 2013-1997	median service intensity			change over 2013-1997
	1997	2005	2013		1997	2005	2013	
Food products, beverages and tobacco	0.17	0.17	0.20	*0.03*	0.07	0.07	0.12	*0.04*
Textiles, wearing apparel and leather	0.17	0.18	0.21	*0.04*	0.05	0.05	0.08	*0.03*
Wood and paper products, and printing	0.10	0.10	0.13	*0.03*	0.02	0.03	0.05	*0.03*
Chemicals	0.24	0.26	0.32	*0.07*	0.18	0.17	0.21	*0.03*
Pharmaceutical products	0.30	0.23	0.29	*-0.01*	0.27	0.22	0.27	*0.00*
Rubber and plastics products,	0.15	0.17	0.18	*0.03*	0.10	0.10	0.11	*0.02*
Metal	0.12	0.13	0.15	*0.04*	0.03	0.03	0.04	*0.01*
Computer, electronic and optical products and electrical equipment	0.17	0.22	0.23	*0.05*	0.07	0.10	0.13	*0.06*
Machinery and equipment	0.20	0.20	0.19	*-0.01*	0.10	0.09	0.09	*-0.01*
Transport equipment	0.17	0.17	0.17	*0.00*	0.09	0.11	0.11	*0.01*
Furniture; other manufacturing	0.13	0.13	0.17	*0.05*	0.03	0.04	0.09	*0.06*
Total	0.16	0.17	0.19	*0.03*	0.06	0.07	0.09	*0.03*

III.3. Stylised fact 3: the relationship between servitisation and firm efficiency may be non-linear, depending on the sector

To carry on with previous discussions and arguments on the fact that servitisation may result from very different motives that show up in different firm efficiency profiles, we now provide statistics on service industry according to firm efficiency. We relate service intensity to the position of firm TFP in the TFP distribution by sector and year. More precisely, Figure 2 reports average service intensity by TFP class, were TFP classes are defined according to the TFP decile or quartile defined by broad sector and year. This exploratory evidence suggests that the relationship between service intensity and TFP may be non-linear and rather U-shaped. Firms that lie at the bottom of their industry efficiency distribution have a slightly higher service intensity than those that have TFP closer to median values. Service intensity goes up as firm efficiency rises for efficiency values beyond the third quartile of the TFP distribution.

Fig. 2. Service intensity according to TFP class (defined by broad sector and year)



In addition, as shown in Table 3 below, the shape of the relationship between service intensity and TFP class varies across broad sectors. This is consistent with the theoretical discussion in section 2 that suggests the relationship varies with product characteristics, production technology and market characteristics.

TABLE 3

Average service intensity by sector according to TFP class

broad sector	[, P10[	[P10 P25[	[P25 P50[	[P50 P75[	[P75 P90[	[P90, ,]
Food products, beverages and tobacco	0.13	0.14	0.16	0.17	0.18	0.27
Textiles, wearing apparel and leather	0.22	0.17	0.16	0.18	0.17	0.25
Wood and paper products, and printing	0.12	0.13	0.09	0.08	0.12	0.16
Chemicals	0.24	0.23	0.26	0.30	0.30	0.33
Pharmaceutical products	0.26	0.15	0.25	0.27	0.30	0.26
Rubber and plastics products,	0.18	0.17	0.16	0.16	0.18	0.22
Metal	0.12	0.13	0.13	0.14	0.14	0.17
Computer, electronic and optical products and electrical equipments	0.19	0.16	0.21	0.19	0.25	0.26
Machinery and equipment	0.20	0.18	0.18	0.19	0.20	0.25
Transport equipment	0.18	0.20	0.18	0.18	0.15	0.17
Furniture; other manufacturing;	0.17	0.13	0.15	0.12	0.12	0.16

V – EMPIRICAL INVESTIGATION

In this section, we provide an econometric assessment of the relationship between servitisation, firm characteristics and sector-level determinants based on the data described in the previous section. This section presents the results of a linear fixed-effects model. A discussion on appropriate econometric estimation methods and robustness tests with respect to alternative empirical estimates can be found in Appendix C. Our specification allows for non-linear effects of firm-level variables and controls for time-varying sector characteristics, sector dummies and year effects. Standard errors are clustered at the firm level. Our specification is the following:

$$Serv_{it} = c + \alpha\, tfp_{it} + \beta\, tfp_{it}^2 + \gamma\, z_{it} + \phi\, Z_{st} + \delta_t + \delta_i + \varepsilon_{it} \qquad (4)$$

where z_{it} are firm-level control variables, firm age, age_{it}, firm size, $size_{it}$, and firm average wage, $wage_{it}$, Z_{st} are sector control variables, namely, the average service intensity, $\overline{servitization_{st}}$, and the Herfindahl index, $Herfindahl_{st}$. δ_t and δ_i are, respectively, firm- and year-effects. Note that sector effects are fully captured by the firm effects. As a robustness test, we include multiplicative sector-year effects instead of the average service intensity and Herfindahl index. We include square terms of log TFP to capture and test for non-linear effects of firm efficiency on servitisation.

The estimation results are presented in Table 4 below. Owing to the variable explained in our model, the firm service intensity is defined between 0 and 1 inclusive, we verify the percentage of observations where predicted values lie outside the [0, 1] interval. As shown in the last line of Table 4, this occurrence is very rare in most specifications.

Estimates confirm the existence of a non-linear relationship between servitisation and firms' productivity. As shown in column (1), both the level of log TFP and its square are significant at the conventional significance level. The signs of the coefficients point to a U-shaped relationship between firms' productivity and servitisation, with a turning point at 9.42. This implies that it is not only low-productivity firms that develop services provision, but high-productivity firms too. Concerning sector-level control variables, firm servitisation rises in sectors where servitisation is on the increase. This may reflect an imitation process or greater potential for bundling services and goods on account of the specificities or technical characteristics of the sector's products. The Herfindahl index is not significant, probably because of the small time-variation of this indicator.

The rest of the table considers alternative specifications to the baseline equation (4). Columns (2) to (4) include other firm-level variables as determinants of servitisation, which appears to be greater for younger and smaller firms. The average firm wage has a positive and significant relationship with servitisation. Column (5) brings all variables together in the model. The last column reports results with a full set of interactive sector-year effects.

TABLE 4

Fixed-effects linear probability model – LS estimation

	(1)	(2)	(3)	(4)	(5)	(6)
tfp_{it}	-0.132**	-0.130**	-0.120**	-0.133**	-0.124**	-0.140***
	(0.052)	(0.052)	(0.051)	(0.053)	(0.052)	(0.054)
tfp_{it}^2	0.007**	0.007**	0.006**	0.006**	0.006**	0.007**
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
age_{it}		-0.022**	-0.017*	-0.021**	-0.017*	
		(0.010)	(0.010)	(0.010)	(0.010)	
$size_{it}$			-0.030***		-0.028***	
			(0.008)		(0.008)	
$wage_{it}$				0.066***	0.062***	
				(0.014)	(0.014)	
$\overline{servitization_{st}}$	0.739***	0.741***	0.725***	0.734***	0.719***	
	(0.102)	(0.102)	(0.101)	(0.100)	(0.100)	
$Herfindahl_{st}$	0.086	0.078	0.082	0.071	0.075	
	(0.064)	(0.064)	(0.063)	(0.064)	(0.063)	
Constant	0.674***	0.722***	0.792***	0.107	0.207	0.614**
	(0.231)	(0.232)	(0.226)	(0.267)	(0.264)	(0.246)
year effects	Yes	Yes	Yes	Yes	Yes	
sector-year effects						Yes
Observations	36857	36857	36857	36853	36853	36857
R^2	0.775	0.775	0.776	0.776	0.776	0.772
% $\widehat{\text{serv}}_{it}$ outs [0, 1]	0.010	0.010	0.011	0.010	0.011	0.207

Notes: % $\widehat{\text{serv}}_{it}$ outs [0, 1] is the percentage of predicted values that lie outside the [0, 1] interval.

*** p<0.01, ** p<0.05, * p<0.1. All equations include firm fixed effects.

Our empirical results of a non-linear relationship between firms' performance and servitisation confirm the theoretical predictions whereby both low-performing and high-performing firms may engage in service provision. Another prediction from the theoretical discussion is that this relationship is shaped by a set of factors related to the economic environment (e.g. the degree of competition), product characteristics (the degree of product and service differentiation and the degree of demand complementarity between services and goods), or production technology characteristics (the degree of non-rivalry in efficiency allocation between goods and services). All these factors suggest that the relationship between firms' performance and servitisation is likely to vary across sectors.

We therefore estimate the above model by broad sector of economic activity. However, due to the small size of the sample, most of the estimated parameters are insignificant. We exclude broad sectors for which there are less than 1,500 observations, and the sector composed of sectors 19, 20, 21 which is too heterogeneous to be considered as a single sector in regard to servitisation.[5] Table 5 below reports estimates for model (1) where the only firm-level variable is log TFP. The point estimates highlight differences in the relationship between servitisation and log TFP across sectors. The results indicate that it is U-shaped in three manufacturing sectors, namely food, beverages and tobacco; textiles, wearing apparel and leather; and wood, paper and printing. In the other five manufacturing sectors, the linear and quadratic effects of log TFP on the service intensity are not significant. This confirms that the U-shaped relationship is not systematic across sectors. Of course, the lack of precision in the estimates may be due to the limited number of observations available in some sectors, as is the case with furniture; other manufacturing.

TABLE 5

Fixed-effects linear probability model by broad sector

	tfp_{it}		tfp_{it}^2		obs.	R^2	%obs outs [0,1]
Food, beverages and tobacco	-0.172*	(0.103)	0.010*	(0.006)	5747	0.79	0.010
Textiles, wearing apparel and leather	-0.454*	(0.237)	0.026*	(0.014)	3272	0.79	0.010
Wood, paper and printing	-0.641**	(0.273)	0.034**	(0.015)	4012	0.76	0.009
Rubber and plastics, and other non-metallic mineral products	-0.053	(0.092)	0.002	(0.006)	5139	0.73	0.012
Metal	-0.134	(0.121)	0.006	(0.007)	6402	0.79	0.010
Computers, electronic and optical products, electrical equipment	0.104	(0.208)	-0.007	(0.011)	2261	0.77	0.011
Machinery and equipment	-0.102	(0.214)	0.004	(0.012)	3239	0.77	0.007
Furniture. other manufacturing	-0.511	(0.355)	0.030	(0.023)	1962	0.74	0.006

Notes: Robust (clustered by VAT) standard errors in brackets. All regressions include firm and year effects. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Figure 3 illustrates the results by reporting the average predicted service intensity for a range of values of log TFP in the three manufacturing sectors where the U-shaped relationship is identified. Further, to give an idea of the extent of non-linearity in the observed sample, the bold line represents values that lie within the [P1-P99] range of the TFP distribution for the corresponding broad sector. The chart indicates some differences between the three manufacturing sectors. In the wood, paper and printing sector, very low-performing firms tend to opt for servitisation with a higher intensity than those in the food, beverages and tobacco and in textiles, wearing apparel and leather sectors. In addition, the turning point of the U-shaped relationship differs according to the sectors. It is lower in the food, beverages and tobacco sector than in textiles, wearing apparel and leather and in the wood, paper and printing sector.

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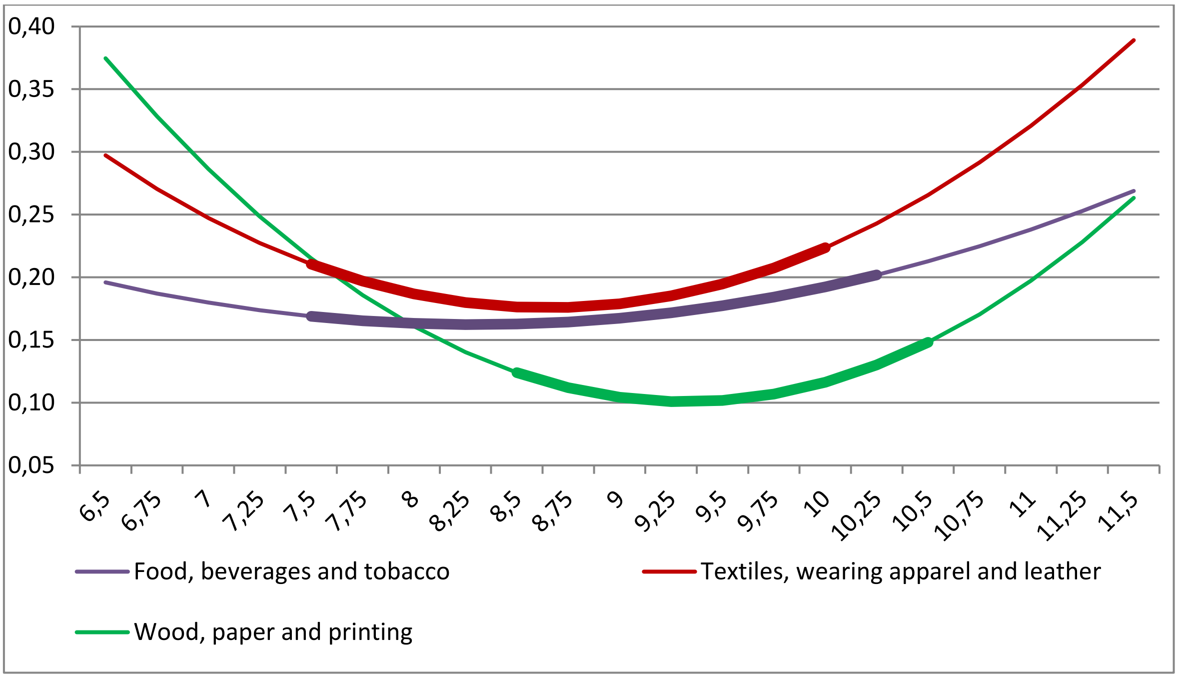
5 It includes sectors as heterogeneous as coke and refined petroleum products, chemicals and pharmaceutical products.

Fig. 3. Average predicted service intensity for alternative values of TFP



In order to understand the estimated differences across sectors, it should be remembered that the theoretical conditions that lead to a U-shaped relationship between servitisation and efficiency are a low competitive environment where both low-performing and high-performing firms coexist, and where both low- and high-performing firms obtain a relatively large proportion of their revenues from services compared to medium-performing firms. The figures reported in Table 1 and Table B.2. in Appendix do actually suggest that in the food, textiles, wood and furniture sectors, either the coefficient of variation for TFP or that for service intensity or both of them are higher than average.

VI – CONCLUSION

Over recent decades, manufacturing firms have been increasingly offering services to customers along with goods. In some cases, firms that traditionally sold almost nothing but goods now obtain most of their turnover from services. There are several possible reasons why firms provide the customer services themselves, rather than letting other companies do it. Since developing a new activity – the provision of services – involves both costs and risks, one might suspect that only the more efficient firms can afford it. However, less efficient firms may also use it as a defensive strategy, to differentiate their product and sustain market shares, or new firms may use it as an offensive strategy to penetrate a new market.

To gain a deeper understanding of these mechanisms, this paper discusses economic mechanisms based on a theoretical framework that contains the following ingredients: the demand for differentiated goods and services is complementary, and firms decide on the allocation of rivalrous expertise between goods production and services provision. Furthermore, expertise is unevenly distributed across firms that operate under monopolistic competition. Together, these ingredients imply that the extent of servitisation depends on firm characteristics, product characteristics and market conditions. In particular, the relationship between firm efficiency and servitisation may be non-linear. Further, the relationship varies across products and sectors.

Thanks to a unique dataset that reports firm-level information on sales and goods sales, we analyse a measure of service intensity for Belgian manufacturing companies. Three stylised facts emerge from this: (1) there is substantial heterogeneity in the share of firm sales attributable to services provision, both between and within sectors of economic activity; (2) service intensity has been growing over time, albeit at different paces across sectors; (3) the relationship between firm efficiency and service intensity may be non-linear, although the shape of this relationship varies across sectors. To investigate this last issue more closely, we estimate a linear fixed-effects model, and find evidence a U-shaped relationship between service intensity and firms' TFP, the curvature of which varies by sector.

The implication of our paper is that evidence that a firm undertakes servitisation actually gives no information on the current state of its performance. This opens the way for future research into many dimensions of servitisation. First, our findings call for a deeper understanding of the motives behind servitisation, in particular whether this reflects an offensive strategy of new entrants, a defensive strategy of incumbent leaders, or a follower strategy of firms that would otherwise be out of the market. Second, it is very likely that the impact of servitisation on firm outcomes will vary according to the underlying motive behind servitisation. This may rationalise empirical evidence that services provision has complex implications for firm decisions. Third, another interesting aspect of servitisation that would merit further analysis concerns the type of service provided. For example, identifying whether or not services are skill-intensive or innovation-intensive is likely to have an impact on a firm’s decisions about workforce composition, pricing, investment, and so on. A deeper analysis on this issue calls for new and more detailed data.

REFERENCES

Ackerberg, D.A., Caves, K., Frazer, G. (2015), 'Identification Properties of Recent Production Function Estimators', *Econometrica*, 83, pp. 2411–2451.

Aquilante T., Vendrell-Herrero, F. (2019), 'Bundling and exporting: evidence from German SMEs', Bank of England Staff Working Paper No. 781.

Ariu, A., Mayneris, F., Parenti, M. (2018), 'One Way to the Top: How Services Boost the Demand for Goods', CEPR Discussion Paper 12918.

Bernard, A.B., Smeets, V., Warzynski, F. (2017), 'Rethinking Deindustrialization', *Economic Policy*, 32, pp. 5–38.

Bontempi, M.E., Mairesse, J. (2015), 'Intangible capital and productivity at the firm level: a panel data assessment', *Economics of Innovation and New Technology* , 24, pp. 22–51.

Breinlich, H., Soderbery, A., Wright, G.C. (2018), 'From selling goods to selling services: firm responses to trade liberalization', *American Economic Journal: Economic Policy*, 10, pp. 79-108.

Crozet, M., Milet, E. (2017a), 'Should everybody be in services? The effect of servitisation on manufacturing firm performance', *Journal of Economics and Management Strategy*, 26, pp. 820-841.

Crozet, M., Milet, E (2017b), 'The servitisation of French manufacturing firms'. In *The Factory-Free Economy: Outsourcing, Servitisation and the Future of Industry*, L. Fontagné and A. Harrisson (eds.), Oxford University Press.

Cusumano, M.A., Kahl, S.J., Suarez, F.F. (2015), 'Services, industry evolution, and the competitive strategies of product firms', *Strategic Management Journal*, 36, pp. 559–575.

Dachs, B., Biege, S., Borowiecki, M., Lay, G., Jäger, A., Schartinger, D. (2014), 'Servitisation of European manufacturing: evidence from a large scale database', *The Service Industry Journal*, 34, pp. 5–23.

Fang, E., Palmatier, R. Steenkamp, J.-B. (2008), 'Effect of Service Transition Strategies on Firm Value'. *Journal of Marketing*, 72, pp. 1-14.

Gebauer, H., Fleisch, E., Friedli, T. (2005), 'Overcoming the Service Paradox in Manufacturing Companies', *European Management Journal*, 23, pp. 14–26.

Gouriéroux, C., Monfort, A., Trognon, C. (1984), 'Pseudo Maximum Likelihood Methods: Theory', *Econometrica*, 52, pp. 681-700.

Greene, W. *Econometric Analysis*, 7th edition, Pearson; 2011.

Honoré, B.E. (1992), 'Trimmed LAD and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects', *Econometrica*, 60, pp. 533-565.

Kohtamäki, M., Partanen, J., Parida, V., Wincent, J. (2013), 'Non-linear relationship between industrial service offering and sales growth: the moderating role of network capabilities', *Industrial Marketing Management*, 42, pp. 1374-1385.

Lee, S., Yoo, S., Kim, D. (2016), 'When is servitisation a profitable competitive strategy?', *International Journal of Production Economics*, 173, pp. 43–53.

Marrocu, E., Paci, R., Pontis, M. (2012), 'Intangible capital and firms' productivity', *Industrial and Corporate Change*, 21, pp. 377–402.

Melitz, M.J., Ottaviano, G.I.P. (2008), 'Market Size, Trade, and Productivity', *Review of Economic Studies*, 75, pp. 295–316.

Papke, L.E., Wooldridge, J.M. (1996), 'Econometrics methods for fractional response variables with an application to 401 (K) plan participation rates', *Journal of Applied Econometrics*, 11, pp. 619-632.

Papke, L.E., Wooldridge, J.M. (2008), 'Panel data methods for fractional response variables with an application to test pass rates', *Journal of Econometrics*, 145, pp. 121–133.

Ramalho, E.A., Ramalho, J.S. (2017), 'Moment-based estimation of nonlinear regression models with boundary outcomes and endogeneity, with applications to nonnegative and fractional responses', *Econometric Reviews*, 36, pp. 397-420.

Ramalho, E.A., Ramalho, J.S., Coelho, L. (2018), 'Exponential Regression of Fractional-Response Fixed-Effects Models with an Application to Firm Capital Structure', *Journal of Econometric Methods*, 7, pp. 1-18.

Suarez, F., Cusumano, M., Kahl, S. (2013), 'Services and the business model of product firms: an empirical analysis of the software industry', *Management Science*, 59, pp. 420-435.

Vives, X. (1984), 'Duopoly Information Equilibrium: Cournot and Bertrand', *Journal of Economic Theory*, 34, pp. 71-94.

Wooldridge, J.M. (2010) *Econometric Analysis of Cross Section and Panel Data*, 2nd edition, MIT Press.

APPENDIX A – DERIVATION OF THE THEORETICAL MODEL

We consider an economy with two monopolistic competition sectors. The supply side of the model draws on the Breinlich *et al*. (2018) online appendix model. In the manufacturing and services sectors, there is a continuum of firms that produce a differentiated good and a differentiated service simultaneously. Firms are heterogeneous in their level of productivity and can allocate some specific knowledge across goods and services production processes according to the degree of non-rivalry in respect of the specific knowledge. On the demand side, there is a continuum of consumers of the same type with a utility function separable and linear in the numeraire good. We extend the quadratic utility function as used in Melitz and Ottaviano (2008) to complementarity between goods consumption and services consumption.

Demand

We consider a continuum of consumers of the same type, with utility function separable and linear in the numeraire good.[6] Preferences are defined over a continuum of differentiated varieties of goods and services indexed by *i*. The utility of a representative consumer *c* for *L* consumers in the economy is given by

$$U = \alpha\int_0^N q_i^c di - \frac{1}{2}\gamma_g\int_0^N \left(q_i^c\right)^2 di - \frac{1}{2}\left(\int_0^N q_i^c di\right)^2 + \alpha\int_0^N y_i^c di - \frac{1}{2}\gamma_s\int_0^N \left(y_i^c\right)^2 di - \frac{1}{2}\left(\int_0^N y_i^c di\right)^2 + \theta\int_0^N q_i^c y_i^c di$$

(a.1)

where *N* is the mass of consumed varieties[7], $\alpha, \gamma_g, \gamma_s$ and θ are positive parameters, q_i^c and y_i^c represent *c*'s individual consumption levels of goods variety *i* and of services variety *i* (produced by the same firm *i*), respectively. The parameters γ_g and γ_s express the specific consumer's preferences for goods and services and index the degree of product differentiation between the varieties. θ captures the degree of complementarity between variety *i* of goods and variety *i* of services.

The opposite demand by the representative consumer *c* for the variety of good and for the variety of service produced by firm *i* can be written as follows:

$$p_i^g = \alpha - \gamma_g q_i^c - Q^c + \theta y_i^c \qquad \text{(a.2)}$$

[6] Under these assumptions, there are no income effects on the monopolistic competition sectors and we can perform a partial equilibrium analysis.

[7] To simplify the model, we assume an identical mass for goods varieties and services varieties. We assume also that all varieties are consumed.

$$p_i^s = \alpha - \gamma_s y_i^c - Y^c + \theta q_i^c \qquad \text{(a.3)}$$

By assuming that consumers are uniformly distributed across the range of varieties, equation (a.2) and equation (a.3) can be inverted to yield the linear market demand for goods and services varieties *i*

$$q_i = L\left(a - bp_i^g - cp_i^s + d\bar{P}^g + e\bar{P}^s\right) \qquad \text{(a.4)}$$

$$y_i = L\left(a' - cp_i^g - b'\, p_i^s + e\bar{P}^g + d\,'\bar{P}^s\right) \qquad \text{(a.5)}$$

where

$$a \equiv \frac{\alpha}{(\gamma_g\gamma_s - \theta^2)}\left(\gamma_s + \theta - \frac{(\gamma_g+\theta)(\gamma_s+\theta)+\gamma_s^2+\theta\gamma_g}{(\gamma_g+N)((\gamma_s+N)-\theta^2}\right),$$

$$a' \equiv \frac{\alpha}{(\gamma_g\gamma_s - \theta^2)}\left(\gamma_g + \theta - \frac{(\gamma_g+\theta)(\gamma_s+\theta)+\gamma_g^2+\theta\gamma_s}{(\gamma_g+N)((\gamma_s+N)-\theta^2}\right), \qquad b \equiv \frac{\gamma_s}{(\gamma_g\gamma_s-\theta^2)}, \qquad b' \equiv \frac{\gamma_g}{(\gamma_g\gamma_s-\theta^2)},$$

$$c \equiv \frac{\theta}{(\gamma_g\gamma_s-\theta^2)}, \qquad d \equiv \frac{\gamma_s(\gamma_s+N)+\theta^2}{(\gamma_g\gamma_s-\theta^2)\left((\gamma_g+N)((\gamma_s+N)-\theta^2\right)},$$

$$d\,' \equiv \frac{\gamma_g(\gamma_g+N)+\theta^2}{(\gamma_g\gamma_s-\theta^2)\left((\gamma_g+N)((\gamma_s+N)-\theta^2\right)}, \qquad e \equiv \frac{\theta(\gamma_g+\gamma_s+N)}{(\gamma_g\gamma_s-\theta^2)\left((\gamma_g+N)((\gamma_s+N)-\theta^2\right)},$$

L represents a continuum of consumers, $\bar{P}^g = (1/N)\int_0^N p_i^g di$ and $\bar{P}^s = (1/N)\int_0^N p_i^s di$ are the average prices of goods and services, respectively that are taken as exogenous by firm *i*. The parameters *a* and *a'* are both positive if the mass of the consumed variety is sufficiently large ($N \geq 1$) and if the degree of differentiation exceeds the degree of complementarity ($\min(\gamma_g, \gamma_s) > \theta$) or in other words if goods and services cannot be perfect complements. Note that when these two conditions are fulfilled, the other parameters of the demand functions are positive.

Production

Firm *i*'s production functions for goods and services are assumed to take the following form:

$$q_i = T_{ig} L_{ig} \qquad \text{(a.6)}$$

$$y_i = T_{is} L_{is} \qquad \text{(a.7)}$$

where T_{ig} and T_{is} are firm-specific productivity terms and the firm's labour inputs used to produce goods and services are L_{ig} and L_{is}. The labour cost *w* is given and is the same across sectors.

Following Breinlich *et al*. (2018), the stock of knowledge is assumed to be fixed within the firm and a CES function is used to model the degree of non-rivalry in knowledge across the production of goods and services,

$$T_i = \left(T_{ig}^t + T_{is}^t\right)^{\frac{1}{t}} \tag{a.8}$$

where $t \in (0, \infty)$ represents the degree of non-rivalry. For high values of *t*, knowledge can be considered as non-rivalrous. In other words, when $t \to \infty$, the firm can use the full amount of T_i simultaneously in both production processes.

Firm *i* maximises its profit by choosing the optimal prices (p_i^g, p_i^s), and the optimal amounts of knowledge to allocate to the production of goods and services (T_{ig}, T_{is}). The objective function can be expressed as follows:

$$\max_{p_i^g, p_i^s, T_{ig}, T_{is}} p_i^g L\left(a - bp_i^g - cp_i^s + d\bar{P}^g + e\bar{P}^s\right) + p_i^s L\left(a' - b' p_i^g - cp_i^s + e\bar{P}^g + d'\bar{P}^s\right) - w\left(L_{ig} + L_{is}\right)$$
$$s.t. \quad T_i = \left(T_{ig}^t + T_{is}^t\right)^{\frac{1}{t}} \quad q_i = T_{ig} L_{ig} \quad y_i = T_{is} L_{is} \tag{a.9}$$

From the first-order conditions, we can get the optimal selling prices of goods and services given by,

$$p_{ig} = \frac{\left(\gamma_g \gamma_s - \theta^2\right)}{2}\left(\left(ab' - a'c\right) + \left(b'd - ce\right)\bar{P}^g + \left(b'e - cd'\right)\bar{P}^s + \frac{w}{\left(\gamma_g \gamma_s - \theta^2\right)T_{ig}}\right) \tag{a.10}$$

$$p_{is} = \frac{\left(\gamma_g \gamma_s - \theta^2\right)}{2}\left(\left(a'b - ac\right) + \left(be - cd\right)\bar{P}^g + \left(bd' - ce\right)\bar{P}^s + \frac{w}{\left(\gamma_g \gamma_s - \theta^2\right)T_{is}}\right) \tag{a.11}$$

From the first-order conditions on T_{ig} and T_{is}, the rule for the optimal allocation of knowledge between goods production and services production is given by:

$$\frac{T_{is}}{T_{ig}} = \left(\frac{y_i}{q_i}\right)^{\frac{1}{1+t}} \tag{a.12}$$

where $q_i = \frac{L}{2}\left(a + d\bar{P}^g + e\bar{P}^s - \frac{bw}{T_{ig}} - \frac{cw}{T_{is}}\right)$ and $y_i = \frac{L}{2}\left(a' + e\bar{P}^g + d'\bar{P}^s - \frac{cw}{T_{ig}} - \frac{b'w}{T_{is}}\right)$

that represents the optimal quantities of goods and services sold by the firm. Note that the amount of knowledge in goods and the amount of knowledge in services both have a positive effect on the quantities of goods and services sold. But as the goods and services are not perfect complements ($\gamma_g > \theta$ and $\gamma_s > \theta$), the impact of T_{ig} on q_i is greater than the effect of T_{is}.The same result holds for y_i with T_{is} now having a larger impact.

Comparative statics

We focus on how the firm allocates its knowledge to the production of services according to its total amount of knowledge. The total differential of expression (a.12) with respect to T_{is} and T_i enables us to determine what happens to servitisation at the equilibrium when the exogenous amount of knowledge in the firm changes. Hence, we have:

$$\frac{\mathrm{d}T_{is}}{\mathrm{d}T_i} = \left(\frac{T_{is}}{T_i}\right)^{1-t}\left(\frac{T_{ig}A}{T_{is}B + T_{ig}A}\right) \qquad \text{(a.13)}$$

where

$$A = \left(\frac{cwL}{2T_{ig}}\left(\left(\frac{T_{is}}{T_{ig}}\right)^{1+t}\frac{b}{c} - 1\right) - (1+t)y_i\right) \text{ and } B = \left(\frac{cwL}{2T_{is}}\left(\left(\frac{T_{ig}}{T_{is}}\right)^{1+t}\frac{b'}{c} - 1\right) - (1+t)q_i\right).$$

When $\frac{\mathrm{d}T_{is}}{\mathrm{d}T_i} > 0,$ an increase in the productive performance of the firm raises its service provision. Expression A corresponds to the total differential of T_{ig} on both sides of (a.12). Rewriting *A* as $A = \frac{1}{(T_{ig})^{1+t}}\left(\frac{Lwb}{2T_{ig}}(T_{is})^{1+t} - \frac{Lwc}{2T_{ig}}(T_{ig})^{1+t}\right) - (1+t)y_i$, the left-hand term in *A* is the difference between the direct effect of T_{ig} on the quantity of goods sold weighted by $\left(T_{is}\right)^{1+t}$, and the indirect effect of T_{ig} on the quantity of services supplied weighted by $\left(T_{ig}\right)^{1+t}$. Note that the indirect effect exists because the goods and services are complementary, and that the indirect effect is lower than the direct effect. Therefore, one can have $A > 0$ as long as T_{ig} is not too large compared to T_{is}. By contrast, when T_{ig} is much larger than T_{is}, the weighted indirect effect can exceed the weighted direct effect and the result can be $A < 0$. The same reasoning applies for *B*.

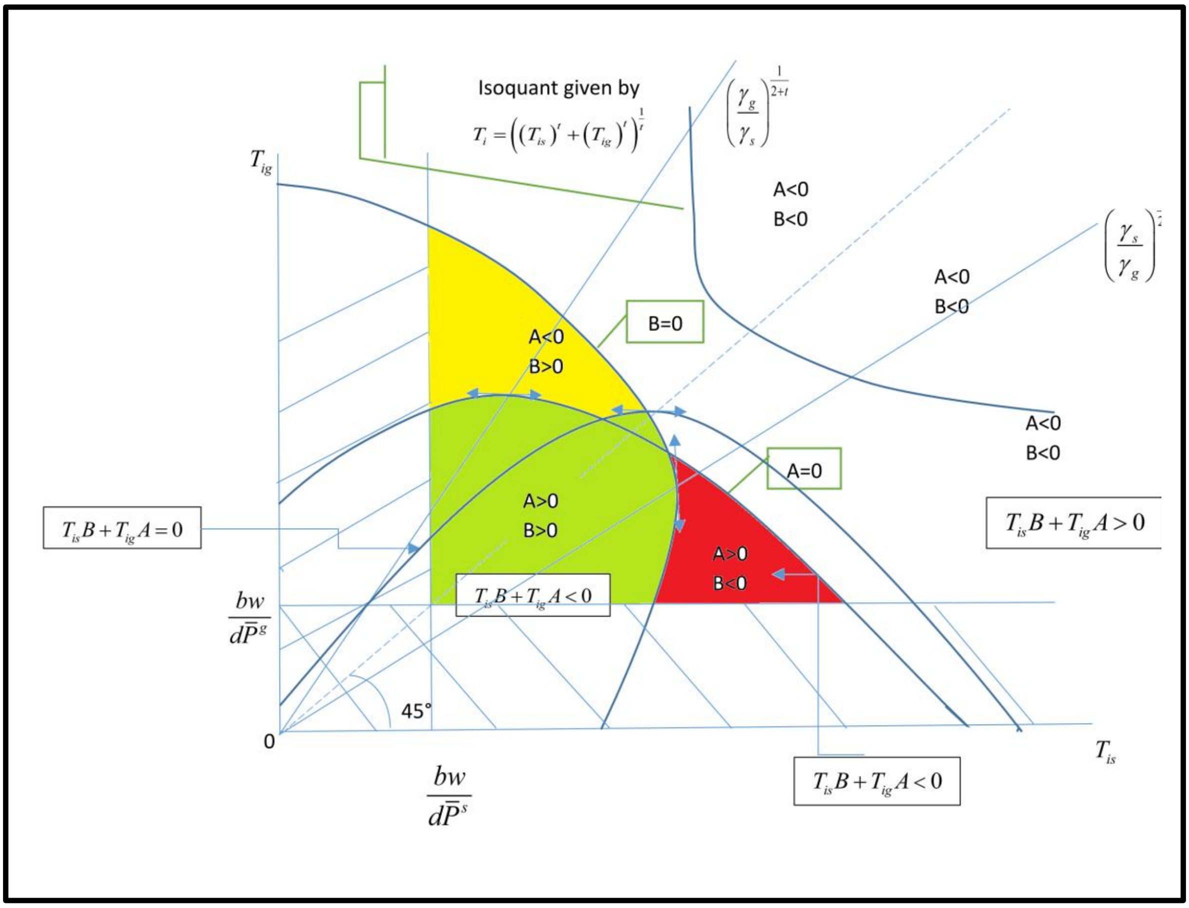
However, the effect of T_i on servitisation is not so clear-cut and depends in the first instance on the signs for *A* and *B*. Fortunately, Figure A.1 allows us to present more comprehensive findings drawn from our model. The lines $T_{ig} > bw/d\bar{P}^g$ and $T_{is} > b'w/d'\bar{P}^s$ delimit the area of values of T_{is} and T_{ig} so that both goods and services are produced. The curves *A=0* and *B=0* delimit the areas where both *A* and *B* are positive, where *A<0* and *B>0*, where *A>0* and *B<0*, and where both *A* and *B* are negative. Finally, the condition $T_{is}B + T_{ig}A = 0$ is also reported to present in which cases the less-performing firms reduce their service provision when they raise productive performance ($\mathrm{d}T_{is}/\mathrm{d}T_i < 0,$). Lastly, it should be noted that highly efficient firms are in the upper right area of Figure A.1, where both T_{is} and T_{ig} are themselves high, and less efficient firms are represented in the coloured areas.

First, it should be noted that a positive productivity shock always leads more efficient firms to intensify their servitisation. Second, two factors explain why less efficient firms may engage in servitisation like the efficient firms: weak competition and high demand complementarity. To understand the role of the first factor, we need to consider the opposite case with strong market competition. For low market prices, $\bar{P}^g$ and $\bar{P}^s$ the less efficient firms are on the fringe, outside both markets (in the area delimited by $T_{ig} > bw/d\bar{P}^g$ and $T_{is} > b'w/d'\bar{P}^s$) and servitisation is not a strategy that these firms can use to stay in the market. The relevance of demand complementarity follows from the fact that it generates a "bonus" for consumers if they buy goods and services from the same firm, and the higher θ , the larger this bonus. Therefore, a high degree of complementarity allows the less productive firms to be present in both markets and to benefit from servitisation.

Last, in two mutually exclusive cases, namely $T_{is}B + T_{ig}A > 0$ with *A*<0 and *B*>0 or if $T_{is}B + T_{ig}A < 0$ with *A*>0 and *B*<0, a negative productivity shock (a decrease in T_i) leads the less performing firms to step up their servitisation (an increase in T_{is}). The first case is verified if knowledge is allocated more to services provision ($T_{is} > T_{ig}$) to fulfil *A*<0 and *B*>0. Two additional conditions have to be satisfied in order to verify $T_{is}B + T_{ig}A > 0$: knowledge is not too rivalrous (t rather close to 0) and the demand complementarity is relatively weak. In the second case, knowledge is allocated more in goods provision ($T_{ig} > T_{is}$), knowledge is not rivalrous and demand complementarity is more pronounced. Both cases share the same condition that the production of goods is not too large in comparison to the production of services to allow for the allocation of additional knowledge to the production of goods rather than to the production of services. In Figure A.1, the first case corresponds to the yellow area, the second to the red area. The green area is the case where a positive shock in knowledge leads the lower-performing firms to increase their service provision as in the white area for the efficient firms.

To sum up, our model indicates that (i) the more efficient firms may find it optimal to use a servitisation strategy; (ii) when goods and services cannot be easily bundled or when competition on the services market is fierce, less efficient firms may prefer not to engage in services provision; but (iii) less efficient firms can boost their services provision when hit by a negative productivity shock in some cases. All in all, a U-shaped relationship between servitisation and firms' performance may exist but is not systematic.

Figure A.1: Degree of servitisation and firms' performance



APPENDIX B: PRODUCTION FUNCTION COEFFICIENTS ESTIMATION

TABLE B1.

Estimates of production function per broad sector by the Ackerberg-Caves-Frazer method (1997-2013 period)

Broad sector (NACE rev 2)	ln k_{it}	ln l_{it}	# obs.
Food, beverages and tobacco (10, 11, 12)	0.203 (22.53)	0.752 (84.46)	44138
Textiles, wearing apparel and leather (13, 14, 15)	0.225 (38.73)	0.686 (94.60)	18737
Wood, paper and printing (16, 17, 18)	0.173 (39.27)	0.736 (162.93)	36125
Coke, chemicals and pharmaceutical products (19, 20, 21)	0.242 (28.83)	0.813 (84.20)	8613
Rubber, plastic and other non-metallic mineral products (22, 23)	0.215 (21.24)	0.740 (70.13)	23591
Basic metals and fabricated metal products (24, 25)	0.170 (59.58)	0.740 (237.80)	48114
Computers, electronic, optical products and electrical Eequipment (26, 27)	0.167 (16.49)	0.825 (59.69)	11643
Machinery and equipment n.e.c. (28)	0.212 (0.79)	0.740 (2.69)	15193
Transport equipment (29, 30)	0.185 (21.92)	0.830 (81.96)	5022
Furniture and other manufacturing (31, 32)	0.356 (1.06)	0.608 (1.97)	12520
Repair and installation of machinery and equipment (33)	0.182 (36.64)	0.787 (117.50)	8014

Notes: t student statistics in brackets. Physical investment is used as a proxy and the capital stock is measured at the beginning of year. Data source: annual accounts of firms and VAT reports

TABLE B.2

Descriptive statistics on firm-level determinants of servitisation

broad sector	TFP	TFP	age (# years)	employment (# persons)	average wage
	sector average	coefficient of variation	sector average	sector average	sector average
Food, beverages and tobacco	9,03	0,058	29	140	28564
Textiles, wearing apparel and leather	8,84	0,055	29	120	21146
Wood, paper and printing	9,50	0,044	28	109	29327
Chemicals	8,70	0,050	31	255	43393
Pharmaceutical products	8,38	0,062	39	490	36945
Rubber and plastics, and other non-metallic mineral products	8,90	0,054	28	133	30098
Basics Metals and Fabricated Metal Products	9,53	0,042	26	149	28456
Computer, electronic and optical products and electrical equipment	9,57	0,050	26	238	33612
Machinery and equipment n.e.c.	9,41	0,044	30	178	31615
Transport equipment	9,13	0,047	24	430	29713
Furniture; other manufacturing	7,64	0,054	27	76	23575
Repair and installation of machinery and equipment	9,64	0,040	15	85	36652
Mean	9,10	0,050	28	166	29821
Std	0,65		18	422	10573
p1	7,23		2	22	12358
p25	8,75		15	38	22958
p50	9,16		24	62	27892
p75	9,52		37	135	34361
p99	10,43		88	1987	66335

TABLE B.3.

TFP distribution by broad sector of economic activity in the estimation sample

log Total Factor Productivity	mean	std	p1	p25	p50	p75	p99
Food, beverages and tobacco	9,03	0,53	7,56	8,74	9,01	9,33	10,31
Textiles, wearing apparel and leather	8,84	0,48	7,42	8,58	8,85	9,13	9,98
Wood, paper and printing	9,50	0,42	8,45	9,26	9,49	9,73	10,57
Chemicals and Pharmaceutical products	8,70	0,43	7,47	8,45	8,71	8,96	9,75
Rubber and plastics, and other non-metallic mineral products	8,38	0,52	7,15	8,06	8,31	8,57	9,95
Basics Metals and Fabricated Metal Products	8,90	0,48	7,70	8,67	8,90	9,14	9,97
Computer, electronic and optical products and electrical equipment	9,53	0,40	8,47	9,31	9,51	9,74	10,55
Machinery and equipment n.e.c.	9,57	0,48	8,34	9,29	9,59	9,88	10,61
Transport equipment	9,41	0,42	8,52	9,13	9,37	9,67	10,54
Furniture; other manufacturing	9,13	0,43	7,91	8,92	9,16	9,39	10,14
Repair and installation of machinery and equipment	7,64	0,41	6,72	7,39	7,63	7,87	8,72

APPENDIX C : ROBUSTNESS ANALYSIS. ALTERNATIVE ESTIMATION.

In Section IV, we use a linear fixed-effects model to estimate the relationship between service intensity, firm and sector characteristics. However, a linear probability model may be ill-suited to model a continuous variable defined between 0 and 1 inclusive, because it allows the predicted value to lie outside the [0, 1] range. Furthermore, it suffers from the same defects as when applied to dichotomous variables.

This Appendix discuss alternative econometric models that account for the fact that the dependent variable is a ratio defined over [. 1], and compares results from our linear fixed-effects model with those obtained with alternative models. More precisely, we consider a fractional Probit model and a Tobit type I model.

There are several convergent estimation methods for models[8] in which the explained variable is a fractional variable defined on the interval [0.1]. We follow the method proposed by Papke and Wooldridge (1996) and generalised to panel data by Papke and Wooldridge (2008). It makes it possible to relax the hypothesis on the density function of the perturbations posed by the two-limit Tobit Type I model, namely $u|x \sim N(0, \sigma^2)$. The methods rely on the idea that we can specify a model for E($y|\boldsymbol{x}$) in a way that ensures predicted values of y are in (0.1). Papke and Wooldridge (1996), following Gouriéroux *et al.* (1984), suggest estimating this model by a Quasi Maximum Likelihood Estimator (QMLE). This estimator is called a QMLE fractional logit or probit regression, depending upon the law used. The method also enables us to reconsider the hypothesis of strict exogeneity of *x* by using the Chamberlain-Mundlak device (see Papke and Wooldridge, 2008). In addition, it allows us to deal with heteroscedasticity, which is crucial to obtain unbiased and convergent estimators in a logit-Probit model, contrary to the linear model (see Greene, 2011, and Wooldridge, 2010). In order to estimate a fractional response model with an unbalanced panel framework, the conditional variance should actually be allowed to vary with the nature of the unbalanced character of the sample. We therefore estimate a fractional Probit model with multiplicative heteroscedasticity, controlling for endogeneity with respect to unobserved individual characteristics.

We also consider a two-limit Tobit type I model. Such a model can be used in the context of corner-solution models in which we observe a service intensity between 0 and 1. But in this case, a rate of 0 or 1 is an economic decision, i.e. the result of a firm's profit maximisation and not the result of a truncation process due to failure to observe the latent variable (see Wooldridge, 2010). By setting, $\alpha_1 = 0$ and $\alpha_2 = 1$, we can model the latent variable $y^* = X\beta + u$ with $u|x \sim N(0,\sigma^2)$. y^* is the latent variable and so we define the observed service intensity as:

$y = 0$ if $y^* <= 0$

[8] Ramalho and Ramalho (2017) and Ramalho *et al*. (2018) discuss some alternative estimators for fractional response models with panel data. However, the suggested estimators can be applied only when y is defined on the interval]0,1] or [0,1[but not on [0,1]. Using a Poisson model is not a solution either because it models y >=0 and not 0<= y <=1.

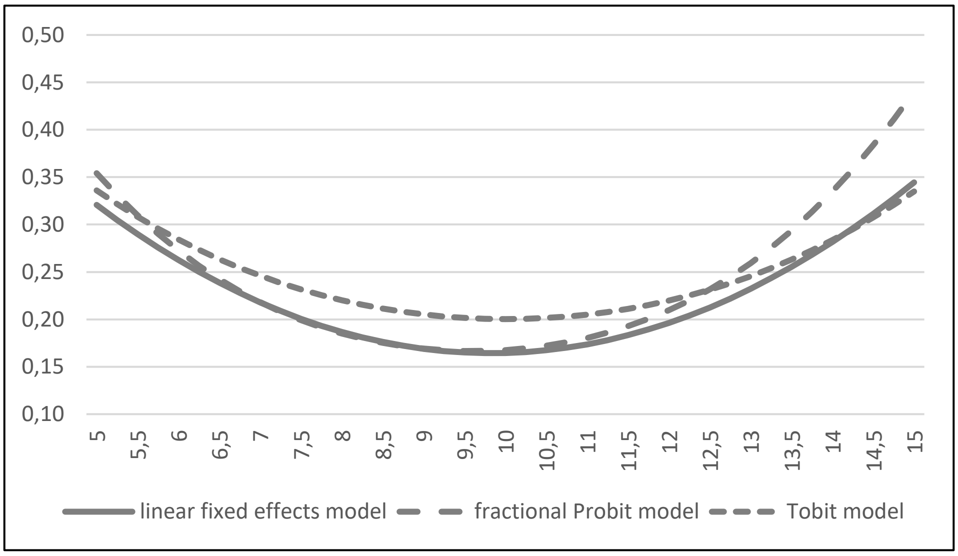
y = y* if 0 < y* < 1

y = 1 if y* >= 1

In fact, *y** has no real economic interpretation. The service intensity cannot be lower than 0% or greater than 100% (even in a latent interpretation). The model only restricts *y*, the variable of interest, to fall between 0 and 1. It can be estimated in a convergent and asymptotically efficient way by maximum likelihood. This specification, besides being well adapted to the case of a variable fractional response, offers several other advantages. First, the random effects two-limit Tobit type I model is well-suited to the case of panel data (and hence to the unobserved heterogeneity of firms).[9] Second, it enables us to question the hypothesis of strict exogeneity of the covariates by using the framework of the correlated random effects Tobit model, which adapts the Chamberlain-Mundlak method used for Probit models with random effects on panel data (see Wooldridge, 2010). However, this method may be non-convergent in the event of heteroscedasticity of disturbances (see Wooldridge, 2010).

The specification of the Fractional Probit and Tobit type I models includes the same set of firm-level variables and sector controls as in our base equation (4), year effects but no firm fixed effects. In order to illustrate how these alternative models compare with our estimates of the linear fixed effect model, Figure C.1 below reports the average predicted values of service intensity for alternative values of TFP, for the model wioth log TFP and its square term as the only firm characteristics.

Fig. C.1. Comparison between average predicted service intensity estimated according to alternative econometric models



9 The fixed-effects two-limit Tobit Type I suffers from the incidental parameters problem and its estimation may be biased and inconsistent (for more details, see Honoré, 1992).