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Quality upgrading and position in global value chains:

Firm-level evidence from the French agri-food industry

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Abstract

This paper analyzes how the quality of produced goods affects firms' position in global value chains (GVCs). Extending the theoretical framework of Chor et al. (2021), we find that quality upgrading increases the span of production stages performed by the firm: it imports more upstream (less transformed) intermediate products and exports more downstream (more highly processed) products. Expansion along GVCs through quality upgrading is accompanied by an increase in input purchases, assets, value added, and profits. These theoretical predictions are tested using 2000-2018 firm-level data on French agri-food industries (from French customs and the AMADEUS database). In line with recent work, we identify firms that participate in GVCs with those that jointly import and export, and measure firms' position in value chains through the level of transformation (*upstreamness*) of goods they use and produce. We use several ways to measure product quality at firm level, all inspired by the commonly accepted assumption that, at equal prices, higher quality products are sold in larger quantities. Our findings confirm the prediction that higher-quality firms use more upstream inputs produced by other firms to produce more transformed outputs, and perform a larger span of intermediate production stages in-house. We find limited empirical evidence in support of other predictions.

Keywords: international trade, global value chains, quality, firm strategies, agri-food industry.

JEL Codes: F12, F14, L15, L23, Q17.

1 Introduction

Product quality is the most important factor that drives firms to adapt their production processes and to align their products with consumer preferences in foreign markets. Lots of studies document the role of quality on trade performance across firms and countries (Verhoogen, 2008; Fajgelbaum et al., 2011; Baldwin and Harrigan, 2011; Crozet et al., 2012; Curzi and Olper, 2012; Crinò and Epifani, 2012; Aw-Roberts et al., 2020; Emlinger and Lamani, 2020). Conversely, the way quality allows firms to be successful in global value chains (GVCs) remains an unexplored issue even if GVCs have become an important part of international trade (Johnson and Noguera, 2012; Greenville et al., 2017; Beaujeu et al., 2018). This lack of interest is not surprising given the lack of direct measures of quality (Helpman, 2011) and the difficulty to measure participation in CVGs at firm level (Antràs, 2020).

In this paper, we: (i) study theoretically and empirically the effect of product quality on firms' position in GVCs, (ii) document the mechanisms that underlie this relationship, and (iii) analyze how firms' position in GVCs affects the main elements of their balance sheet (variable and fixed costs, value added, profits).

First, we build on the partial-equilibrium model of Chor et al. (2021), where heterogeneous firms maximize profits by choosing the processing level and quantity of goods they produce and of inputs they buy. We extend this framework by adding firms' decision on product quality. In this setting, the production of a good is segmented and entails a large number of production stages, performed in several countries. For simplicity, the production process is assumed linear. Each firm uses intermediate inputs purchased on the market and produced internally to obtain an output that is sold to final consumption or other firms that produce final consumption goods. Each firm decides the level of transformation of its output, the quality of output to produce, as well as which inputs to purchase on the market and which to produce in-house and in what amount. All these decisions determine the span of production stages performed by the firm, and characterize the firm's involvement in GVCs. We also let firms to endogenously choose the quality of their output, which adds another dimension of firm heterogeneity. In line with the literature on trade and quality, we assume that consumers are willing to pay higher prices for higher-quality goods, and that producing higher-quality goods is harder and costlier. The model predicts that quality upgrading pushes firms to integrate additional upstream and downstream stages. In other words, higher-quality firms use more upstream inputs purchased on the market to produce a more downstream (more transformed) output, with a larger span of intermediate production stages being performed in-house. Unsurprisingly, since productivity and quality enter firm revenues at equilibrium in the same way, we find that the main predictions of Chor et al. (2021) continue to hold in an environment where firms are differentiated by quality rather than productivity. The model also predicts that quality upgrading and more in-house production stages are associated with higher levels of input purchases, variable (labor) costs, fixed costs, generated value added, and profits.

Second, we match the US input-output table with French firm-level data to identify firms position in GVCs. There is a commonly accepted practice in the trade literature to evaluate the position of a good in the production process by its level of transformation. The literature usually measure the level of transformation of goods using classification tables, such as the Broad Economic Classification (BEC). This approach generally produces rough results that poorly reflect the level of transformation of traded goods because the same product may be an input for one industry and a final product for another.[1] An alternative solution adopted

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[1] Consider the example of tomato sauce, which can be used as a final consumption good by households, or as an intermediate good in the production of frozen pizza.

by recent works in the literature is to rely on input-output tables, exploring the links between all the sectors of an economy. This method is particularly attractive when industries are defined at a very narrow level because it assumes the same level of transformation for all the products within an industry. For France, we have highly disaggregated firm-level data, but a highly aggregated input-output table. To explore the richness of firm-level data, we use the US input-output, which comes at a much higher industry disaggregation level than the French table.[2] We use the input-output table to compute the *upstreamness* at industry-level following Fally (2012), Antràs et al. (2012), and Alfaro et al. (2019). We match results with French data on the product-level composition of firms' imports and exports to compute *upstreamness* indicators at firm-level.

Third, we empirically test the predictions of the theoretical model using firm-level data. An important step in our analysis is to identifying the goods purchased, produced, and sold by each firm. The lack of detailed data on firms' production at product and/or plant level determines us to rely on firm-level international trade data that comes at a vry narrow level of product disaggregation. Accordingly, we focus exclusively on firms that participate in GVCs, i.e. that jointly import and export. Similarly to Chor et al. (2021), we assume that firms' imports and exports reflect their purchases of inputs and sales of produced outputs, in terms of product composition. Firms can position themselves in the production process closer to production factors (more upstream) or to final consumption (more downstream). We analyze the position in GVCs of French agri-food firms over the period 2000-2018 and how it evolves with the quality of produced goods. For that, we combine firm-level data from French customs on foreign trade activity and from the AMADEUS database on firm characteristics. We use an approach similar to Khandelwal et al. (2013), built on the assumption that, at equal prices, higher quality products are sold in larger quantities, to measure the quality of firms' products at the firm-year-destination-product level. We then use the obtained results to compute a firm-level quality indicator with three alternative approaches. Our empirical analysis reveals that the number of production stages performed by French agri-food firms has slightly decreased over the 2000-2018 period. We find that quality upgrading determined French firms to import more upstream inputs and export more downstream goods, resulting in an expansion of production stages of GVCs performed on French soil, as predicted by the model. These findings are mainly corroborated when we control for reverse causality between quality and GVC position. We also confirm empirically that quality upgrading would induce the firm to operate on a bigger scale by using more inputs, increasing its value added and earning higher profits. In contrast, the pattern for the relationship between increased production steps and increased input use, value added, and profits is not robust in the regression analysis.

The approach adopted in this paper is closely related to the burgeoning literature that examined the positioning of firms in GVCs, productivity-heterogeneity and performance (Chor et al., 2021; Baldwin and Ito, 2021; Mahy et al., 2021). By addressing the issue of the role of quality heterogeneity in global production line, this paper also relates to the trade in

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[2] The French input-output tables use a very broad definition of industries: 37 industries for the entire economy, of which only two for the agriculture and food sectors. Differently, the US input-output table uses a much more detailed classification of industries (405 overall, of which 42 agri-food), and is therefore more adapted for our analysis. Previous works have shown that production processes do not vary significantly across countries. For instance, Antràs et al. (2012) show that using the input-output tables of another OECD country yields very similar results in terms of industries' level of *upstreamness* (Antràs et al., 2012). The industries in the US input-output table can not be directly matched with French firm-level data because of multiple two-way correspondences. We perform an important methodological work to build an input-output table at the level of French industries (NACE Rev. 2 level, 4-digit) from the original US input-output table and the correspondences between US and French industries, counting 604 industries of which 88 agri-food.

varying-quality products. The seminal productivity-heterogeneity framework (Melitz, 2003) has extended by incorporating heterogeneous quality across firms (Verhoogen, 2008; Fajgelbaum et al., 2011; Baldwin and Harrigan, 2011; Crozet et al., 2012; Curzi and Olper, 2012; Crinò and Epifani, 2012; Emlinger and Lamani, 2020). All these contributions have formed the basis of a new wave of theoretical and empirical vein that shows that vertical and horizontal quality differentiation of products enables firms to perform better in trade and use higher quality inputs. More broadly, our paper deals with a recent theoretical and empirical literature testing various aspects of the organization of GVCs at firm level (Antràs and Helpman, 2004; Conconi et al., 2012; Antràs and Chor, 2013; Del Prete and Rungi, 2017; Gaigné et al., 2018; Alfaro et al., 2019), and with the growing empirical literature on GVCs, that seeks to identify the different sources of value added embedded in trade flows (Hummels et al., 2001; Johnson and Noguera, 2012; Koopman et al., 2014; Borin and Mancini, 2019).

The remainder of the paper is organized as follows. In the next section, we present our theoretical framework, summarizing the key intuitions of firm behavior in GVCs, from which we build our key predictions. Section 3 presents the employed data, describes the computation of variables, and documents some descriptive statistics and stylized facts on firms' position in GVCs. Section 4 introduces the econometric strategy for testing the main theoretical predictions and presents the empirical results. Discussion and main conclusions are formulated in Section 5.

2 The model

In this section, we rely on the Chor et al. (2021) framework to develop a partial-equilibrium heterogeneous firm model of GVCs, in which quality valuation by consumers allows firms to adjust their participation in GVCs.

2.1 Consumers preferences and demand

Consider a variety of differentiated goods that include both final consumption and semi-finished products. Consumers value goods through a constant elasticity of substitution (CES) utility function:

$$\Upsilon = \left[\int_{\Omega_\upsilon} \left[\lambda(\upsilon) q(\upsilon)\right]^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{1}$$

where Ω_υ is the set of available products varieties υ, and $\varepsilon > 1$ is the elasticity of substitution between different varieties that is common for all firms in a given industry. We assume that consumers value quality: they obtain a higher utility from consuming the same quantity $q(\upsilon)$ of a variety with a higher perceived quality $\lambda(\upsilon)$. Accordingly, they have a higher willingness to pay for high quality products, which leads firms to charge higher prices for these goods. Given the CES form of consumer preferences and consumers' utility-maximizing behavior, the firm producing variety υ faces the following equilibrium (domestic and foreign) aggregate demand:

$$q(\upsilon) = A \left[\lambda(\upsilon)\right]^{\varepsilon-1} \left[p(\upsilon)\right]^{-\varepsilon}, \tag{2}$$

where $p(\upsilon)$ and $A > 0$ indicate the price of variety υ and its market size, respectively. Demand is decreasing in price and increasing in quality λ. Parameter λ captures both the perceived and intrinsic quality of variety υ.

2.2 Technology and profits

We assume a continuum of firms that produce differentiated goods and operate in a free and competitive market. Each firm produces one variety and chooses to produce the quantity that maximizes its profits. For the simplicity of exposition, we omit hereafter firm and industry indices. Similarly to Chor et al. (2021), we assume that the production of a final good in a given industry requires the completion of a continuum of production stages $u \in [1, \infty[$ that are sequentially integrated from a technological point of view. A higher u denotes a more upstream production stage, and $u = 1$ indicates the production of a final consumption good. Parameter u reflects the level of processing, *i.e.* the *upstreamness*, of the product in the value chain (Fally, 2012; Antràs et al., 2012; Antràs and Chor, 2013). Firms purchase on the market less processed intermediate inputs (up to upstreamness level U^M), and produce internally intermediate inputs corresponding to more downstream stages (up to upstreamness level U^X). The obtained output is sold to final consumption (if U^X is close to 1) or used as an input by other firms to produce final consumption goods. The production process (value chain) of a final product can be synthesized by the following scheme:

$$\underbrace{\infty \quad \rule{3cm}{0.4pt}}_{\substack{\text{inputs purchased}\\ \text{on the market}}} \quad U^M \quad \underbrace{\rule{4cm}{0.4pt}}_{\substack{\text{firm's in-house}\\ \text{production}}} \quad U^X \quad \underbrace{\rule{3cm}{0.4pt} \quad 1}_{\substack{\text{stages produced}\\ \text{by other firms}}}$$

A firm's participation to the value chain spells out as follows. Production stages $u \in [U^M, U^X]$ are produced by the firm. More upstream stages ($u > U^M$) and more downstream stages ($u < U^X$) are produced by other firms in the chain. The firm decides which inputs to purchase and which to produce internally by choosing the value of U^M and U^X. The output produced by the firm is a semi-finished good completed up to production stage U^X.

We assume the same production technology as Chor et al. (2021):

$$q = \theta \left(\int_{U^X}^{U^M} x(u)^{\frac{\sigma-1}{\sigma}} du + q_M^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\rho\sigma}{\sigma-1}}. \tag{3}$$

The firm uses a quantity q_M of intermediate products completed up to stage U^M purchased at price p_M, and quantities $x(u)$ of internally produced inputs $u \in [U^M, U^X]$ to produce a quantity q of an output completed up to stage U^X, which it sells (to other firms or final consumers) at price p. Inputs are characterized by a constant elasticity of substitution $\sigma > 1$. Parameter θ reflects the productivity of the firm. Parameter $\rho \in (0, 1)$ captures the degree of decreasing returns to scale of the firm's output. Similarly to Chor et al. (2021), we assume that $\rho > \frac{\sigma-1}{\sigma}$, so that firms find it profitable to increase production in order to match a higher demand.

We extend this framework by decomposing firm productivity into two components: $\theta = \varphi\lambda^{-\gamma}$, with $0 \leq \gamma < 1$, as in Hallak and Sivadasan (2013). Productivity increases with firm's efficiency φ, and decreases with the quality of produced goods λ. This expression permits to integrate the common assumption that high quality products are more difficult to produce and require more [expensive] inputs.[3] Previous research has shown that more productive

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[3] Parameter γ is the elasticity of marginal cost with respect to quality. It reflects the industry-specific variable cost of quality.

firms produce and export higher quality goods (Johnson, 2012; Curzi and Olper, 2012; Curzi et al., 2015). The introduction of firm-specific efficiency (parameter φ) permits to reconcile this apparent contradiction. Then, firms' output rewrites as:

$$q = \varphi\lambda^{-\gamma}\left(\int_{U^X}^{U^M} x(u)^{\frac{\sigma-1}{\sigma}}du + q_M^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\rho\sigma}{\sigma-1}} \tag{4}$$

Firms take as given the price of purchased intermediate goods at different production stages. Each intermediate good completed up to stage u is traded in an open and competitive market at price $p(u)$. We assume that less transformed products, *i.e.* goods in more upstream production stages face a lower market price: $p'(u) < 0$. The cost of inputs produced in-house is specific to each firm. For each of these inputs $u \in [U^X, U^M]$, the firm incurs a variable cost $c(u)$ per unit of input $x(u)$, and a fixed cost $F(u)$ per time period if $x(u) > 0$. The former can be assimilated to labor costs; the latter refer to the acquisition and maintenance of fixed assets and equipment needed for the production process. Including quality in the model introduces a new type of fixed costs: costs related to quality, λ^α ($\alpha > 0$).[4] We assume that $c(u)$ and $F(u)$ are differentiable functions.

Firms sell their entire output on the market and maximize their profits:

$$\pi = pq - \left(p_M q_M + \int_{U^X}^{U^M}\left[c(u)x(u) + F(u)\right]du + \lambda^\alpha\right). \tag{5}$$

Overall profits are obtained by subtracting total production costs (the purchase of intermediate inputs, variable and fixed costs of inputs produced in-house, quality-specific fixed costs) from total revenues (total sales of the produced output at market price). Combining equations (2) and (4), one can express firm's total revenues as:

$$pq = A^{\frac{1}{\varepsilon}}\varphi^{\frac{\varepsilon-1}{\varepsilon}}\lambda^{\frac{(\varepsilon-1)(1-\gamma)}{\varepsilon}}\left(\int_{U^X}^{U^M} x(u)^{\frac{\sigma-1}{\sigma}}du + q_M^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\rho\sigma(\varepsilon-1)}{\varepsilon(\sigma-1)}}. \tag{6}$$

As in Chor et al. (2021), we disregard the origin and destination of products and focus on the global market. We assumed that at least a share of intermediate inputs and of firm's output is purchased, respectively sold, abroad. In section 3 we use data on French firms' imports and exports to proxy their purchases of intermediate inputs and sales of produced output.

The firm chooses the volume (q) and quality (λ) of its output, input quantities to purchase (q_M) and produce in-house ($x(u)$) and their corresponding level of processing (U^X and U^M) that maximize its profit π. We derive below the solution to this profit maximization problem. Note that U^X and U^M are processing cut-off levels that define the span of production stages performed by the firm. U^M is the processing threshold at which the firm is indifferent between producing the input in-house and purchasing it on the market. Inputs above this level ($u > U^M$) are more profitable to be purchased on the market; inputs bellow this level ($u < U^M$) are more profitable to be produced internally. In line with these definitions, producing purchased inputs in-house is not profitable for the firm. We translate this condition by imposing that $\frac{c(U^M)x(U^M)}{p_M q_M}$ and $\frac{F(U^M)}{p_M q_M}$ are sufficiently small. U^X is the processing threshold at which the firm makes no additional profits from integrating a more downstream stage.

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[4] Similarly to Sutton (2007), we assume that marginal costs increase with quality. Indeed, firms need to invest in new equipment, train workers, and adapt their production process before producing a single unit of a higher-quality product.

2.3 Firms' optimal choices

Before solving the firm's profit maximization problem, it is important to identify how a shift in product quality affects profits. On the one hand, quality upgrading increases consumers' willingness-to-pay for a product, leading to a higher demand with a positive effect on firm's revenues (*demand effect*). In our model, this effect is reflected by exponent $\frac{(\varepsilon-1)(1-\gamma)}{\varepsilon} > 0$ of quality parameter λ in equation (6), and is driven by the positive effect on price. On the other hand, producing higher quality is binding. It requires more inputs ($-\gamma < 0$ in equation (4)), higher fixed costs (λ^{α}), and an expansion of production stages performed by the firm (*cost effect*), which result in a higher marginal cost. Therefore, quality upgrading has an ambiguous overall effect on profits. The negative *cost effect* and the positive *demand effect* are always at work and remain at the core of firm's decisions in the profit-maximizing process. In the agri-food sector, we expect the *demand effect* to outweigh the *cost effect* of quality because of the growing concern about the attributes of food products, and the strong link between diet and health.

To increase the quality of its output, a firm needs to use a higher volume of all intermediate inputs, both those purchased on the market ($\frac{dq_M}{d\lambda} > 0$) and those produced in-house ($\frac{dx(u)}{d\lambda} > 0$, $\forall\ u \in [U^X, U^M]$). A higher quantity q_M of purchased upstream inputs determines the firm to integrate more upstream production stages, *i.e.* increase the processing threshold U^M ($\frac{dU^M}{d\lambda} > 0$). An increase in U^M generates two opposite effects on firm's total expenditure on upstream inputs purchased on the market ($p_M q_M$): it leads to a lower p_M (since $p'(u) < 0$), which at its turn yields a higher demand q_M for purchased inputs. The latter effect outweighs the former, and the firm's overall expenditure on upstream inputs increases ($\frac{d(p_M q_M)}{d\lambda} > 0$). At the same time, a higher volume of in-house produced inputs $x(u)$ induced by quality upgrading generates an increase in total variable and fixed costs associated with these inputs ($\frac{d(c(u)x(u))}{d\lambda} > 0$; $\frac{d(F(u)+\lambda^{\alpha})}{d\lambda} > 0$).

Quality upgrading permits the firm to charge a higher output price (because of the higher willingness-to-pay of consumers). However, it has an adverse selection effect as it determines some consumers to switch to lower quality (and price) goods. To limit this effect, the firm needs also to integrate some more downstream production stages, *i.e.* shift its processing threshold U^X closer to final consumption ($\frac{dU^X}{d\lambda} < 0$). By doing so, the firm reinforces the positive *demand effect* of quality upgrading (by charging a price close to the market price) and limits its negative *cost effect.*

Combining the effects on U^M and U^X, we conclude that quality upgrading determines the firm to extend the range of production stages performed in-house ($\frac{d(U^M-U^X)}{d\lambda} > 0$), both upstream and downstream (See Theory AppendixB for computation details). This result matches the empirical findings of Del Prete and Rungi (2017), according to which firms producing intermediate goods prefer to integrate production stages close to the ones that they already perform and with similar technological characteristics. Finally, the opposite demand and cost effects yield an ambiguous overall effect of quality upgrading on firm's profits. A similar line of reasoning permits to derive that quality upgrading generates an increase in firm's value added (defined as the sum of its profits and internal production costs).

These results can be summarized in the following proposition.

Proposition 1 *Quality upgrading yields:*

(i) an extension, both upstream and downstream, of production stages performed by the firm, as it chooses to purchase more upstream inputs and produce output goods closer to final demand:

$$\frac{dU^M}{d\lambda} > 0 \ ; \quad \frac{dU^X}{d\lambda} < 0 \quad ; \quad \frac{d(U^M-U^X)}{d\lambda} > 0$$

(ii) an increase in the volume of all inputs used by the firm:

$$\frac{dq_M}{d\lambda} > 0\ ;\ \frac{dx(u)}{d\lambda} > 0, \forall u \in [U^X, U^M]$$

(iii) an increase in firm's variable costs, fixed costs, expenditure on upstream inputs, value added, and an ambiguous effect on profits:

$$\frac{d(c(u)x(u))}{d\lambda} > 0;\ \frac{d(F(u)+\lambda^\alpha)}{d\lambda} > 0;\ \frac{d(p_M q_M)}{d\lambda} > 0;\ \frac{d(c(u)x(u)+F(u)+\lambda^\alpha+\pi)}{d\lambda} > 0;\ \frac{d\pi}{d\lambda} \lesseqgtr 0.$$

Note that the increase in the span of production stages performed by the firm $(U^M - U^X)$ generates an increase in total variable costs $\int_{U^X}^{U^M} c(u)x(u)du$ and total fixed costs $\int_{U^X}^{U^M} F(u)du + \lambda^\alpha$ due to an increase in the domain of the definite integral. This also leads to a positive effect on input purchases $p_M q_M$ because of a larger value of $(U^M - U^X)$ requires a higher U^M. Combining these effects with Proposition 1, indicates that a wider range of in-house production stages also increases the firm's value added and has an ambiguous effect on its profits. These results can be summarized as follows:

Proposition 2 *Under the product technology described above, an increase in the span of production stages performed by the firm generates an increase in firm's total variable costs, total fixed costs, expenditure on upstream inputs, total value added, and has an ambiguous effect on profits:*

$$\frac{d(c(u)x(u))}{d(U^M-U^X)} > 0;\ \frac{d(F(u)+\lambda^\alpha)}{d(U^M-U^X)} > 0;\ \frac{d(p_M q_M)}{d(U^M-U^X)} > 0;\ \frac{d(c(u)x(u)+F(u)+\lambda^\alpha+\pi)}{d(U^M-U^X)} > 0;\ \frac{d\pi}{d(U^M-U^X)} \lesseqgtr 0.$$

3 Data and descriptive statistics

3.1 Employed data and variables' construction

We use data from the AMADEUS database to identify French agri-food firms. This dataset records firms' main economic activity (NACE Rev.2 4-digit), and annual data on the number of employees, turnover, total assets, wage bill, value added, total purchases of raw materials and profits at firm level over the 2000-2018 period. Focusing the analysis on a single industry makes it possible to limit the effects of unobserved factors. However, the agri-food industry is far from being a homogeneous industry. It includes 32 NACE activity codes, all of which are present in the panel.

Our second source of data is French customs, which provide us annual data on the value in Euro and the quantity of firm's imports and exports by product (the 6-digit CPF classification) and partner, over 2000-2018. We exclude exports that do not reflect processing activities of agri-food firms, namely exports of live animals, hair, fur, and ivory, flowers, raw cereals, vegetal extracts, planting materials, food residues, and tobacco.

We match the two datasets using the unique identification (Siren) number of each firm, and aggregate trade data at the 4-digit NACE Rev.2 level using correspondences with CPF codes. In line with previous work (Baldwin and Yan, 2014; Antràs, 2020), we assume that participation to a GVC is reflected in the data by firms joint involvement in import and export activities. In the paper we focus only on firms that participate in GVCs, *i.e.* on firms that both import and export in a given year.

The position of industries and goods in global value chains. We compute the upstreamness index U_r of each industry r as a weighted average of the number of production stages distant from final demand for which it provides inputs. This approach developed by Fally (2012), Antràs et al. (2012) and Antràs and Chor (2013) is fully explained in Appendix A.1. To do so, we construct a highly disaggregated input-output table to identify the level of transformation of each industry. Since the French input-output table comes at a very high level of industry aggregation (37 industries of which only 2 agri-food), we use the U.S. input-output table that uses a much more narrow definition of industries (405, of which 42 agri-food), and correspondences between U.S. and French industry codes to build a highly disaggregated table (604 4-digit NACE Rev.2 industries, of which 88 agri-food) using the exact industry codes that identify French firms' main economic activity in our data. However, this brings an important challenge because of multiple correspondences in both directions between U.S. and French industry codes. We solve this problem by allocating equal weights to all correspondences within each pair industry codes (see Appendix A.2 fo more details).

Table 1 reports some examples from the 604 NACE Rev.2 industries identified. Not surprisingly, among the most downstream industries are retail and services industries that are close to final demand. The most upstream industries tend to be related to the agricultural and farming activities which provide raw products that mainly used in the agri-food sector.

Table 2 shows some summary statistics of the upstreamness index, comparing the agri-food industry to the other industries.

Firm's position in global value chains. Following Chor et al. (2021), we consider that the level of transformation (processing) of goods used and produced by a firm indicates its position in the value chain.

Once the *upstreamness* indicators U_r are computed at industry level, we use the Chor et al. (2021) approach to compute this indicator at firm level. We assume that all products in a given industry share the same level of upstreamness. We compute the *upstreamness* of imports (U_{ft}^M) for each firm f as the weighted average *upstreamness* of industries to which belong the products imported by the firm. We use a similar approach to compute the *upstreamness* of exports (U_{ft}^X). The difference $U_{ft}^M - U_{ft}^X$ reflects the number of production stages in the global production line performed by the firm. We refer to it as the *GVC participation* of the firm. More specifically:

$$\begin{aligned} U_{ft}^M &= \sum_r^S \frac{M_{frt}}{M_{ft}} U_r \\ U_{ft}^X &= \sum_r^S \frac{X_{frt}}{X_{ft}} U_r \\ GVC_{ft} &= U_{ft}^M - U_{ft}^X = \sum_r^S \left(\frac{M_{frt}}{M_{ft}} - \frac{X_{frt}}{X_{ft}} \right) U_r \end{aligned} \tag{7}$$

where M_{frt} and X_{frt} are the value of imports, respectively exports, of firm f of products in industry r in period t. $M_{ft} = \sum_r^S M_{frt}$ and $X_{ft} = \sum_r^S X_{frt}$. Intuitively, the level of processing of sold (exported) products is higher than the level of processing of purchased (imported) products ($U_{ft}^X < U_{ft}^M$), as the sold products are closer to final consumption.

Estimation of firm's quality. Product quality is foremost a consumers' valuation of tangible (e.g. design, color, size) as well as intangible (e.g. reputation, brand name) characteristics of a good, while trade data only contains the classification in product categories. Thus, product quality is unobservable and difficult to estimate, and the quality for each firm-destination-product-period observation is usually inferred from observed data. In this article, we use the methodology developed

Table 1: Industry upstreamness (selection)

NACE industry	Upstreamness
Retail sale of fruit and vegetables in specialised stores	1.01
Retail sale of meat and meat products in specialised stores	1.01
Retail sale of fish, crustaceans and molluscs in specialised stores	1.01
Retail sale of bread, cakes, flour confectionery and sugar confectionery	1.01
Retail sale of beverages in specialised stores	1.01
Manufacture of rusks and biscuits; of preserved pastry goods and cakes	1.08
Manufacture of soft drinks; of mineral waters and other bottled waters	1.09
Manufacture of bread; manufacture of fresh pastry goods and cakes	1.10
Manufacture of macaroni, noodles, couscous and similar farinaceous products	1.15
Manufacture of beer	1.19
Manufacture of prepared meals and dishes	1.20
Manufacture of grain mill products	1.21
Restaurants and mobile food service activities	1.22
Manufacture of wine from grape	1.23
Growing of vegetables and melons, roots and tubers	1.28
Processing and preserving of poultry meat	1.31
Manufacture of condiments and seasonings	1.35
Production of meat and poultry meat products	1.37
Operation of dairies and cheese making	1.38
Manufacture of cocoa, chocolate and sugar confectionery	1.39
Manufacture of sugar	1.42
Processing and preserving of meat	1.44
Growing of perennial crops	1.46
Processing of tea and coffee	1.47
Manufacture of fruit and vegetable juice	1.47
Processing and preserving of fish, crustaceans and molluscs	1.60
Marine fishing	1.66
Freshwater fishing	1.69
Freshwater aquaculture	1.86
Sewerage	1.89
Growing of sugar cane	2.07
Marine aquaculture	2.10
Raising of swine/pigs	2.10
Raising of other animals	2.15
Raising of poultry	2.16
Manufacture of starches and starch products	2.16
Manufacture of oils and fats	2.72
Raising of dairy cattle	2.98
Manufacture of prepared feeds for farm animals	3.24
Raising of other cattle and buffaloes	3.30
Growing of rice	3.38
Growing of cereals (except rice), leguminous crops and oil seeds	3.45
Post-harvest crop activities	3.61
Seed processing for propagation	3.61

Notes: Computed by authors from the U.S. input-output table converted to NACE Rev.2 4-digit.

Table 2: Summary statistics of upstreamness index according to the type of industry

	Frequency	Min	Max	Mean	Std. dev.
Upstreamness - all industries	604	1.00	4.51	1.88	0.75
Upstreamness - agrifood	88	1.08	3.61	1.85	0.72

in Khandelwal et al. (2013), according to which, for a given price, a higher quantity of sales indicates a higher quality variety:

$$\ln q_{fjkt} + \varepsilon \ln p_{fjkt} = FE_{jkt} + e_{fjkt} \tag{8}$$

where FE_{jkt} are country-product-year fixed effects, which capture heterogeneity in destination-product-year triplets (consumer preferences, trade costs, markup, and market structure); q_{fjkt} is the quantity of product k exported by firm f to country j in year t; p_{fjkt} is the price (unit value) of product k exported by firm f to country j in year t and ε are the estimated trade elasticities at product level (HS 4- and 6-digit) from Fontagné et al. (2022). The quality measure is computed from residual e_{fjkt} after estimating (8) with OLS:

$$\widehat{Qual}_{fjkt} \equiv \ln \widehat{\lambda}_{fjkt} = \frac{\widehat{e}_{fjkt}}{\varepsilon - 1} \tag{9}$$

This approach permits to estimate the quality of available varieties within a specific destination-product-year. Results for the same firm are not directly comparable across destination-product-year triplets.

To obtain a firm-level quality measure, we adopt the following two-step procedure. First, we estimate equation (8) with firm-year fixed effects:

$$\ln q_{fjkt} + \varepsilon \ln p_{fjkt} = FE_{jkt} + FE_{ft} + e_{fjkt}. \tag{10}$$

Second, we transform terms $\widehat{FE}_{ft}$ by subtracting the mean and dividing by the standard error:

$$\widehat{Quality}_{ft} \equiv \frac{\widehat{FE}_{ft} - \bar{\widehat{FE}}_{ft}}{SE\left[\widehat{FE}_{ft}\right]}. \tag{11}$$

The obtained results correspond to the average standardized quality at firm-year level.

For robustness, we compute two additional firm-level quality measures. We transform terms $\widehat{Qual}_{fjkt}$ obtained from equation (9) by subtracting the mean and dividing by the standard error, and regress obtained results $\tilde{Qual}_{fjkt}$ on firm-year fixed effects. We use the estimated firm-year fixed effects as a first alternative quality measure at firm level. We compute export-weighted firm-level averages of transformed terms $\tilde{Qual}_{fjkt}$ and use them as a second alternative measure of firm-level quality. Both these measures are highly correlated with the measure used in the core of the paper (0.64 to 0.85), and produce similar results.

Table 3 summarizes the statistics of variables used in the empirical analysis for French agri-food firms.

3.2 Some stylised facts

Figure 1a reports the aggregate trends of import- and export- *upstreamness* over the 2000-2018 period in the French agri-food sector. This figure illustrates the weighted average level of import- and export- *upstreamness* of all firms, computed at sector-level:

$$U_t^M = \sum_f \frac{M_{ft}}{M_t} U_{ft}^M, \text{ and } U_t^X = \sum_f \frac{X_{ft}}{X_t} U_{ft}^X. \tag{12}$$

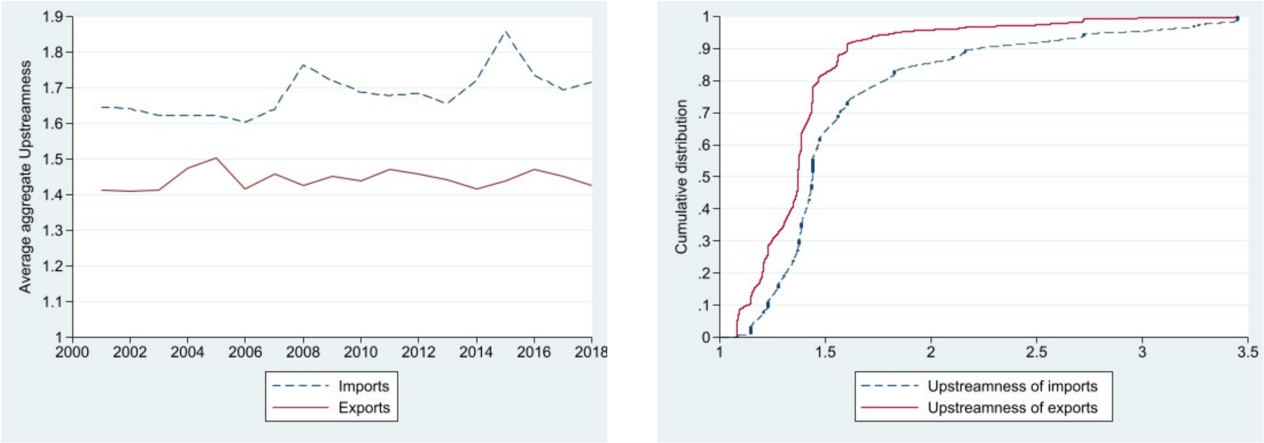
Table 3: Descriptive statistics: Firms in GVCs

	Frequency	Median	Mean	Standard deviation
ln Imports	18,459	6.2769	6.0077	2.5045
ln Exports	18,457	5.6744	5.4889	2.8211
Small firms (1 to 49 employees)	5,101	-	-	-
Middle-size firms (50 to 499 employees)	3,856	-	-	-
Large firms (500 employees or more)	831	-	-	-
ln Productivity	8,073	5.6914	5.7463	0.7660
ln Average wages (ln Total wages per worker)	8,053	3.6718	3.6927	0.3780
ln Assets intensity (ln Total assets per worker)	8,109	5.1111	5.1721	0.8602
ln Raw Inputs costs	11,277	9.1978	9.2678	1.7551
ln Wagebill	11,286	7.7236	7.8921	1.5146
ln Total Assets	11,439	9.1998	9.3446	1.6945
ln Profits	9,063	6.0403	6.0853	2.0138
ln Value Added	10,839	8.1194	8.2990	1.5330
ln Sales	11,350	9.8001	9.9231	1.6582
Import *upstreamness* (U_M)	18,459	1.4410	1.6431	0.5299
Export *upstreamness* (U_X)	18,457	1.3682	1.4201	0.3564
GVC participation ($U_M - U_X$)	18,457	0.0729	0.2230	0.5441
Quality	14,952	0.0010	0.0125	1.1563
Mean Quality	14,963	0.0129	0.0036	0.5742
Weighted Quality	17,969	0.4168	0.3728	0.8362

Notes: Quality measure is based on Khandelwal et al. (2013) methodology and are computed using price elasticities at the HS4 level from Fontagné et al. (2022), excluding re-exports and HS chapters that do not correspond to processing activities of agri-food firms (see section 3.1).

We use firms' imports and exports as weights. $M_t = \sum_f M_{ft}$ and $X_t = \sum_f X_{ft}$ are total sector-level imports and exports in year t.

Two observations emerge from the analysis of Figure 1. First, the imports of French agri-food firms are persistently more upstream than their exports. This reflects the fact that firms tend to import intermediate goods, less processed, which they use to produce goods with a higher level of transformation (Figure 1a). A similar pattern was shown by Chor et al. (2021) in the case



(a) Average import and export upstreamness

(b) Cumulative distribution of French firms

Figure 1: The *Upstreamness* of French agri-food firms

of China. Note that countries that mainly export primary goods and import final products may present different situations. Chor (2014) illustrates the examples of Brunei, Myanmar, Australia, and New Zealand, whose exports are more upstream (mainly concentrated in agriculture and primary products) than imports. Second, the cumulative distribution of the *upstreamness* of French agri-food firms displays a similar pattern (Figure 1b). The gap between the import and export curves reflect an average span of production stages performed by these firms.

Second, we observe a slight widening of the span of production stages performed by firms in Figure 1a. This means that the French agri-food sector can be considered as an important contributor to the domestic value added of French exports.

For a more accurate computation of the evolution of upstreamness, we regress the firm-level import- and export- upstreamness, as well as their difference (i.e. the position of firms in GVCs) on the full set of year dummies β_t, and firm fixed effects, FE_f:

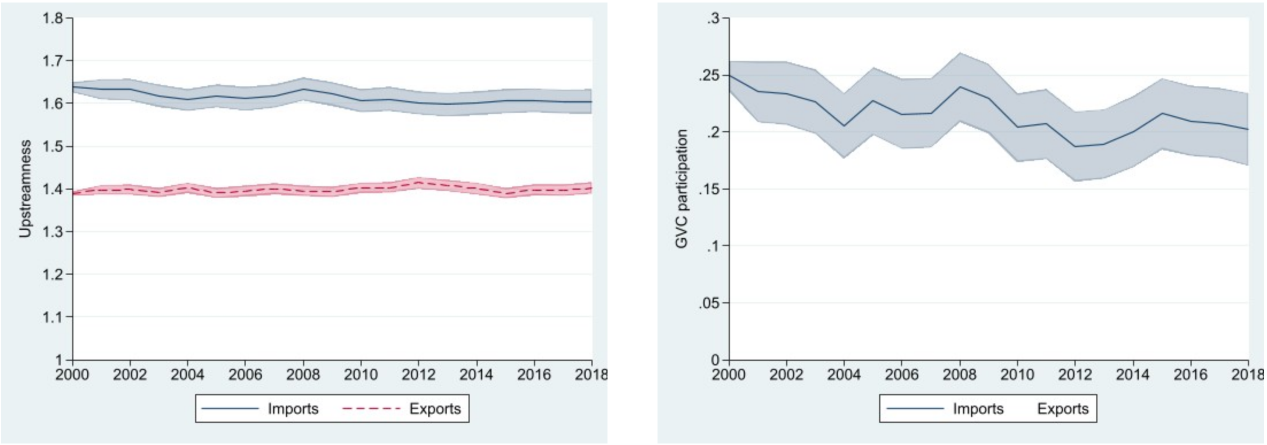
$$\begin{aligned} U_{ft}^{X/M} &= \beta_0 + \beta_{2000} + \beta_{2001} + \cdots + \beta_{2018} + FE_f + e_{ft}, \\ U_{ft}^{M} - U_{ft}^{X} &= \beta_0 + \beta_{2000} + \beta_{2001} + \cdots + \beta_{2018} + FE_f + e_{ft}. \end{aligned} \tag{13}$$

Figure 2 reports the average annual evolution of the upstreamness of French agri-food firms, i.e. terms $\beta_0 + \beta_t$ of the above estimations. Figure 2a depicts a slight decrease in the average upstreamness of imports and a relatively steady average upstreamness of exports over the past two decades. The narrowing gap between the two indicators is more noticeable in Figure 2b. This indicates a likely off-shoring of the French agri-food supply chain.

The shift-share decomposition of the evolution of aggregate upstreamness in the French agri-food sector permits to identify the contribution of changes in firm composition (at the extensive margin) and within firms (at the intensive margin):

$$\begin{aligned} \Delta U_t^M &= \sum_{f\in\Xi_t^M} \frac{M_{ft}}{M_t}\cdot U_{ft}^M - \sum_{f\in\Psi_t^M} \frac{M_{f,t-1}}{M_{t-1}}\cdot U_{f,t-1}^M + \sum_{f\in\Gamma_t^M} \frac{M_{f,t-1}}{M_{t-1}}\cdot \Delta U_{ft}^M + \sum_{f\in\Gamma_t^M} \Delta\frac{M_{ft}}{M_t}\cdot U_{ft}^M \\ \Delta U_t^X &= \underbrace{\underbrace{\sum_{f\in\Xi_t^X} \frac{X_{ft}}{X_t}\cdot U_{ft}^X}_{\text{starting firms}} - \underbrace{\sum_{f\in\Psi_t^X} \frac{X_{f,t-1}}{X_{t-1}}\cdot U_{f,t-1}^X}_{\text{stopping firms}}}_{\text{extensive margin}} + \underbrace{\underbrace{\sum_{f\in\Gamma_t^X} \frac{X_{f,t-1}}{X_{t-1}}\cdot \Delta U_{ft}^X}_{\Delta\text{upstreamness}} + \underbrace{\sum_{f\in\Gamma_t^X} \Delta\frac{X_{ft}}{X_t}\cdot U_{ft}^X}_{\Delta\text{mkt share}}}_{\text{intensive margin}} \end{aligned}$$

where Δ indicates annual change, Ξ_t is the set of firms that start exporting/importing, Ψ_t is the set of firms that stop to import/export, and Γ_t is the set of incumbent firms.



(a) Import and export upstreamness

(b) Position in GVC

Figure 2: The evolution of French agri-food firms' *Upstreamness*

Table 4: Decomposition of aggregate *upstreamness* trend over time

	Extensive margin			Intensive margin (incumbent)			Overall
	Starting firms	Stopping firms	Net effect	change in firm's upstreamness	change in firm's mkt share	Net effect	
ΔU_t^M	0.1329	-0.0336	0.0993	0.0064	0.0559	0.0623	0.1616
ΔU_t^X	0.1846	-0.1074	0.0772	-0.0032	0.1029	0.0998	0.1770
$\Delta U_t^M - \Delta U_t^X$	-0.0517	0.0738	0.0221	0.0096	-0.0470	-0.0374	-0.0154

Notes: Columns "Starting" and "Stopping" display the contribution of firms that start exporting/importing and, respectively, of firms that stop exporting/importing. The "Net" extensive margin column sums these two effects. The "Net" intensive margin column sums the effect of a change in firms' upstreamness and market shares. "Overall" columns show the overall effect on the two "Net" effects.

Table 4 shows the results of this decomposition. First, we see that the aggregate trend observed for U_t^M is confirmed by the overall increase during the period 2000-2018 (+0.1616). This increase is driven mainly by two forces: the net extensive margin (+0.0993), and the intensive margin induced by the increase in market share of firms with higher upstreamness (+0.0559). The former implies that new agri-food importers are sourcing more upstream products to France than exiting importers, while the latter denotes an increasing share of firms that import less processed inputs. A similar pattern is observed for exports.

4 Estimation strategy and results

According to proposition 1, firm's quality upgrading is associated with more upstream imports and more downstream exports, leading to the location of a wider segment of the supply chain within France. This is the central predictions of the model that we test empirically in this section. We also document the predictions about the increase in firms' input costs, assets, profits, and value added as firms perform more production stages.

4.1 Quality upgrading and firm's position in GVCs

Table 5 shows the results about the role of quality in the GVCs' position patterns of the firms. As shown in columns (4) to (6) and in line with the theoretical predictions, the coefficient of the variable $Quality_{ft}$ is significant and positive for imports *upstreamness*, negative for exports *upstreamness* and positive in the widening of the span of stages performed. These results show that quality upgrading allows firms to significantly expand its span of production stages within France. This means that an increase of 1% in the quality of the products of French agri-food firms may implied a change in the span of stages, $U_{ft}^M - U_{ft}^X$, of about 0.0002.[5]

We estimate regressions with ordinary least squares (OLS) to measure correlations (and not causal relationships). It is worth noting that we control for time-varying firm characteristics, $Controls_{ft}$, namely log productivity and size group - small (1 to 49 employees) - mid (50 to 499 employee) - large (500 employees or more). The coefficient of these variables are non-significant.[6] We

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[5] Given the level-log nature of the models, we obtain the change in units of production stages performed with respect to a one percent increase in quality measures by dividing the coefficient estimates of interest by 100.

[6] A surprising result is that the productivity has a non-significant role in the results. To ensure that our quality measure is not responsible for these results (due to colinearity between quality and productivity for instance), we also run the same regressions without the quality variable. Results are shown in columns (1) to (3). The non-significant role of the productivity is confirmed.

Table 5: Test of model predictions – Quality and firms' position in GVCs

	Imports upstreamness (U^M_{ft})	Exports upstreamness (U^X_{ft})	Position in GVCs (GVC_{ft})	Imports upstreamness (U^M_{ft})	Exports upstreamness (U^X_{ft})	Position in GVCs (GVC_{ft})
Quality				0.0171**	-0.0098*	0.0270***
				(0.0067)	(0.0052)	(0.0085)
ln Productivity	-0.0022	0.0107	-0.0129	-0.0031	0.0112	-0.0143
	(0.0194)	(0.0119)	(0.0219)	(0.0194)	(0.0119)	(0.0219)
Firm size						
small	reference	reference	reference	reference	reference	reference
medium	0.0507	0.0135	0.0371	0.0502	0.0138	0.0364
	(0.0340)	(0.0173)	(0.0378)	(0.0339)	(0.0174)	(0.0378)
large	0.0672	0.0329	0.0343	0.0691	0.0318	0.0374
	(0.0635)	(0.0249)	(0.0681)	(0.0636)	(0.0252)	(0.0687)
Fixed effects		firm, industry-year			firm, industry-year	
Observations	5,069	5,069	5,069	5,069	5,069	5,069
R^2	0.841	0.858	0.792	0.842	0.858	0.793

Notes: The sample comprises French agri-food firms of the fully matched sample over 2004-2017, which both export and import. Re-exports are excluded at firm-year-CN8 level in trade flows before computing import and export *upstreamness* and estimate the quality. Firms with main activity "Manufacture of prepared animal feeds" (1091 and 1092 in NACE Rev.2) are dropped from estimations. The quality is estimated using the Khandelwal et al (2013) methodology and the price elasticities at the HS4 level from Fontagné et al. (2022). We drop observations with the highest and the lowest 2% values of estimated quality. All regressions include firm and industry-year fixed effects. Standard errors clustered by firm in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

also control for permanent observed and unobserved firm-specific characteristics and sector-specific supply and demand shocks, by including firm fixed effects, FE_f and industry-by-year dummies FE_{rt}, where r denotes the NACE Rev.2 4-digit industry code which correspond to the firm f's primary activity. Doing so, we ensure that we compare changes within firms, by controlling for the potential omitted variable bias. Therefore, the coefficient of the variable $Quality_{ft}$ captures the variation within firms over time in supply chain position and firm's attributes relative to changes in quality.

4.2 Reverse causality between firm's quality and its position in GVCs

The previous OLS estimations may be subject to an endogeneity bias when the firm's decision to upgrade quality is not exogenous from the GVCs' position. In other words, a common set of determinants affects both the GVCs' position patterns and the quality upgrading.

The first possible source of endogeneity come from the fact that the types of inputs the firm used affect the firms' decision to control new stages in their production processes (Alfaro et al., 2019). It can be for instance a way to ensure the quality of its inputs. This control will affect the product quality (Verhoogen, 2008), both at the firm and industry level, and hence will bias our results. The simultaneity of these decisions may also bias our results, since both decisions are made within the same firm. The inclusion of firm and industry-year fixed effects in our estimations control for these biases.

The second endogeneity bias problem arises if the firm's position in GVCs drives the quality upgrading. This reverse causality may occur given that participation in GVCs allows firms to access to high quality inputs through import activities (Gaigné and Le Mener, 2014; Gibson and Graciano, 2011), to improve the quality of exported products, either through the use these inputs (Verhoogen, 2008) and/or through the mechanism of learning-by-exporting (Park et al., 2010). Since international trade stimulates incentives to upgrade the quality of existing products (Helpman, 2011), the intensity of participation in CVGs can thus affect the level of quality of the firms' products. To account for endogeneity, we use an instrumental variable approach to test mainly for reverse causality between quality upgrading and GVCs' position patterns. Following Chor et al. (2021), we construct our instrumental variable using information on a plausibly exogenous positive shocks to foreign demand which can boost firm total factor productivity (TFP), by raising firms' exports and thereby total sales. Our strategy is based on the positive relationship between TFP and quality.[7] Similar to Chor et al. (2021), we obtain the $Inst_{ft}$ variable, as a shift-share projected growth rate in foreign demand for firm f's products from year $t-1$ to t. Based on the CEPII BACI dataset, we take weighted-average of the year-on-year growth in rest-of-the-world export flows, by excluding France in origin and destination countries of exports, as follow:

$$Inst_{ft} = \ln\left(X_{f,t-1}\left(1 + \sum_{j \neq \text{France},k} \frac{X_{fjk,0}}{X_{f,0}} \cdot \frac{X_{\text{RoW},jkt} - X_{\text{RoW},jk,t-1}}{X_{\text{RoW},jk,t-1}}\right)\right) \tag{14}$$

$X_{\text{ROW},jkt}$ (respectively $X_{\text{ROW},jk,t-1}$) is the total exports emanating from the rest of the world by destination country j and HS 6-digit product k in year t (respectively $t-1$), $\frac{X_{fjk,0}}{X_{f,0}}$ is the share of country j and product k in firm f's export profile in the first year (indexed by 0) where the firm f is observed in the French customs data on foreign trade over 2000-2018, and serves as a weight to capture the degree of exposure of each firm f to export demand shocks from the rest-of-the-world at country-by-product level. This degree of exposure represents the firm-year level predicted growth rate of exports, which, combined with the firm's one-year lagged level exports, predicts its export volume in each year. Therefore, we adopt a predicted (log) level of firm f's exports in year t provided by equation (14) as our instrument. A sufficient condition for identification is that foreign demand shocks affect individual French agri-food firms' production staging decisions, only through its effect on firms' product quality.

Table 6 reports the results. As expected, the first-stage in Column 1 indicate that a positive foreign demand shocks has a strong positive effect on the quality of products of the firms. Moreover, the high explanatory power of first-stage estimations confirms the validity of our instrument as a good predictor of the quality measures. Columns 2–4 show that controlling for endogeneity reinforces our previous findings that quality upgrading has a positive effect on imports *upstreamness*, a negative effect on exports *upstreamness* and a positive effect on the span of production stages. All the effects are significant.

4.3 The impact of firms' position in GVCs on its main balance sheet elements

Mechanically, the expansion along the global production chain is associated with increases in input costs, in total assets and in performance within firms, as our theoretical framework shows. The results are reported in Table 7. The five columns show that the relationship between firms' span of stages and input costs, total assets and their performance in terms of profits and value added is positive (even if not statistically significant) and in line with the theoretical predictions. Unexpectedly, the role of the span of stages on *Wagebill* is negative and non-significant. Table 8 deepens the analysis and distinguishes between the imports *upstreamness* and the exports *upstreamness*. The first column shows that a higher import *upstreamness* increases the purchases of raw inputs, as predicted by the model (see Section 2.3).

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[7] A raise in TFP can increase quality either through the learning-by-exporting mechanisms (Park et al., 2010) or by increasing firms' exports revenue that lead to more investments in firm'ss production technology

Table 6: Test of model predictions – Quality and firms' position in GVCs - IV estimates

	First stage	Second stage		
	Quality	U^M_{ft}	U^X_{ft}	GVC_{ft}
Instrument	0.0399***			
	(0.0097)			
Quality		0.1561*	-0.1529**	0.3091***
		(0.0808)	(0.0628)	(0.1010)
ln Productivity	0.0400	-0.0081	0.0201	-0.0282
	(0.0422)	(0.0216)	(0.0143)	(0.0248)
Firm size				
small	reference	reference	reference	reference
medium	-0.0058	0.0435	0.0161	0.0274
	(0.0709)	(0.0329)	(0.0182)	(0.0367)
large	-0.1658	0.0845	0.0083	0.0763
	(0.1363)	(0.0656)	(0.0270)	(0.0699)
Fixed effects	firm, industry-year	firm, industry-year		
Observations	4,856	4,856	4,856	4,856
R^2	0.723	0.848	0.862	0.801
F-stat	11.3938			
Endogeneity test		2.973*	5.726**	8.0703**
p-value		(0.0846)	(0.0167)	(0.0046)

Notes:

Notes: The sample comprises French agri-food firms of the fully matched sample over 2004-2017, which both export and import. Re-exports are excluded at firm-year-CN8 level in trade flows before computing import and export *upstreamness* and estimate the quality. Firms with main activity "Manufacture of prepared animal feeds" (1091 and 1092 in NACE Rev.2) are dropped from estimations. $Inst_{ft}$ stands for predicted exports. The quality is estimated using price elasticities at the HS4 level from Fontagné et al. (2022). All regressions include firm and industry-year fixed effects. Standard errors clustered by firm in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: The effect of firms' position in GVCs on costs, value added, and profits

	Raw Input Costs	Wagebill	Total Assets	Pofits	Value Added
Span of stages	0.0270	-0.0032	0.0023	0.0232	0.0097
	(0.0178)	(0.0143)	(0.0165)	(0.0461)	(0.0147)
Fixed effects	firm, industry-year				
Observations	7,359	7,359	7,359	7,359	7,359
R^2	0.966	0.983	0.985	0.847	0.981

Notes: The sample comprises French agri-food firms of the fully matched sample over 2004-2017, which both import and export. Re-exports are excluded at firm-year-CN8 level in trade flows before computing import and export *upstreamness*. Firms with main activity "Manufacture of prepared animal feeds" (1091 and 1092 in NACE Rev.2) are dropped from estimations. All regressions include firm and industry-year fixed effects. Standard errors clustered by firm in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

(Brandt et al., 2014).

Table 8: The effect of firms' position in GVCs on costs, value added, profits, decomposed

	Raw Input Costs	Wagebill	Total Assets	Pofits	Value Added
Import upstreamenss	0.0455*	-0.0029	-0.0059	0.0399	0.0137
	(0.0264)	(0.0191)	(0.0218)	(0.0586)	(0.0197)
Export upstreamenss	0.0126	0.0041	-0.0198	0.0126	-0.0010
	(0.0324)	(0.0203)	(0.0272)	(0.0743)	(0.0212)
Fixed effects	firm, industry-year				
Observations	7,359	7,359	7,359	7,359	7,359
R^2	0.966	0.983	0.985	0.847	0.981

Notes: The sample comprises French agri-food firms of the fully matched sample over 2004-2017, which both import and export. Re-exports are excluded at firm-year-CN8 level in trade flows before computing import and export *upstreamness*. Firms with main activity "Manufacture of prepared animal feeds" (1091 and 1092 in NACE Rev.2) are dropped from estimations. All regressions include firm and industry-year fixed effects. Standard errors clustered by firm in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5 Discussion and conclusion

Based on theoretical developments tested empirically using data on French agri-food firms, this article highlights to what extend product quality matters for a firm's position in GVCs. Our findings echo recent work by Chor et al. (2021) and Alfaro et al. (2019) in modeling and establishing new facts on how firms involve in the different stages of a production line and establish the boundaries in their participation. It appears in our work that the role of product quality is comparable to that of productivity in firms' key decision on which stages to perform in-house and which to outsource, and on how close to final demand should be their output. We show that quality upgrading pushes firms to integrate additional upstream and downstream stages. This implies using more upstream inputs produced by other firms to produce a more transformed output, a larger span of intermediate production stages being performed in-house. This could permits firms in the agri-food industry to increase their value added.

Quality upgrade increases firm's revenues due to the higher willingness-to-pay of consumers, but generates higher variable and fixed costs for the firm. To obtain the combined outcome of these opposite *demand* and *cost* effects, one needs to account for shifts in the boundaries of the production segment performed by the firm. In the case of French agrifood firms, we find that the *demand* effect outweighs the *cost* effect. Accordingly, producing higher quality outputs generates positive profits, which permits the firm to make new investments and expand its production chain. In the long term, this may reduce the firm's incentive to diversify its activities and to rely more on outsourcing and off-shoring, as shown by Cuervo-Cazurra and Pananond (2023).

Chor et al. (2021) show that when Chinese firms span more production stages at the domestic level, they increase total input costs, assets, profits and value added, and conclude that some of the additional production stages are performed in-house, and not only substituting foreign suppliers with domestic suppliers. We find that the relationship between the number of stages performed by French agri-food firms in GVCs and input costs, total assets and performance in terms of value added and profits are not robust. Our results could suggest that French agri-food firms fulfills all or most stages $u \in [U^X, U^M]$ via subcontracts or other arm's length contracts with other domestic suppliers. If this is the case, it will be difficult to explore these theoretical predictions in the data, even they remain valid, since we do not have information on firm transactions at the domestic level.

At this stage our theoretical predictions cannot be questioned and further analysis is needed to draw definitive conclusions.

With this overall picture in mind, we revisit the importance of firm characteristics in explaining their position in GVCs. A core element of our work is that firms' abilities to frame the range of internally performed production stages are unevenly distributed. Our findings offer an original understanding of the observed heterogeneity of firms' position in GVCs: it can stem from quality heterogeneity. This is a substantial contribution, but much remains to be done, in particular to empirically evaluate the potential gains associated with the intensity of participation in GVCs at firm or industry level, which we did not achieve in this paper.

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Appendices

A Variables' construction

A.1 Industry upstreamness

To measure the position of the different industries in the production line, we start by using the input-output table at 4-digit NACE Rev.2 level constructed in section A.2. Then we use methodology developed by Fally (2012), Antràs et al. (2012) and Antràs and Chor (2013) to compute the positioning of an industry in relation to final demand. This methodology starts from a basic gross output accounting identity. Assuming an economy with S ($S \geq 1$) industries, the total gross output of industry r is given by :

$$\begin{aligned} Y_r &= F_r + B_r = F_r + \sum_{s=1}^{S} d_{rs} Y_s \qquad \text{(A.1)} \\ &= F_r + \sum_{s=1}^{S} d_{rs} F_s + \sum_{s=1}^{S}\sum_{k=1}^{S} d_{rk} d_{ks} F_s + \sum_{s=1}^{S}\sum_{k=1}^{S}\sum_{l=1}^{S} d_{rl} d_{lk} d_{ks} F_s + ... \end{aligned}$$

where F_r (respectively $B - r$) is the value of industry r used for final consumption (respectively as an intermediate input), $d_r s$ is the value of the output of industry r needed to produce one unit of the output of industry s, i.e. the *direct requirements* coefficient. From the second row of equation , the gross output vector Y is obtained in matrix form as:

$$\begin{aligned} Y &= F + B \cdot F + B^2 \cdot F + \dots \qquad \text{(A.2)} \\ &= [I - B]^{-1} \cdot F \end{aligned}$$

where B is the matrix of direct requirements coefficients of dimension ×, I is the identity matrix, $B^m F(m>0)$ is the vector of the value of the total gross output used for final consumption, after $m+1$ production stages. Equation (A.2) expresses the classical Leontief inverse matrix formula that generates the gross output Y needed to produce the vector of final uses F. Y is equal to the sum of an infinite number of terms, which can be approximated by the matrix $[I - B]^{-1} F$, and Y_r is the $r-th$ term of Y. Each term on the right-hand side of the second row of equation indicates the number of production stages through which the output of industry r passes before it is absorbed as final consumption. Expression can thus be interpreted as the sum of the value of industry r's output used directly (F_r) and indirectly $\left(\sum_{s=1}^{S} d_{rs} F_s + \sum_{s=1}^{S}\sum_{k=1}^{S} d_{rk} d_{ks} F_s + \sum_{s=1}^{S}\sum_{k=1}^{S}\sum_{l=1}^{S} d_{rl} d_{lk} d_{ks} F_s + \dots\right)$ to produce the country's final consumption. From this point of view, a production stage is counted each time a good is absorbed as final consumption or used as an intermediate input. In an economy where $S \geq 1$, industry s's *upstreamness* is computed as:

$$U_r = 1 \cdot \frac{F_r}{Y_r} + 2 \cdot \frac{\sum_{s=1}^{S} d_{rs} F_s}{Y_r} + 3 \cdot \frac{\sum_{s=1}^{S}\sum_{k=1}^{S} d_{rk} d_{ks} F_s}{Yr} + 4 \cdot \frac{\sum_{s=1}^{S}\sum_{k=1}^{S}\sum_{l=1}^{S} d_{rl} d_{lk} d_{ks} F_s}{Y_r} + \dots \qquad \text{(A.3)}$$

U_r is the weighted average of the number of stages from final demand (consumption or investment) at which r enters as an input in production processes. The weights correspond to 1 for the part of r's output that goes to final consumption, 2 for the part of r's output used in another industry before being absorbed as final consumption and so on. The weights in expression (A.3) permit the definition of the importance of industry r's share in the total output of r at each production stage. In matrix form, we obtain the following expression:

$$F + 2 \cdot B \cdot F + 3 \cdot B^2 \cdot F + 4 \cdot B^3 \cdot F + \dots = [I - B]^{-2} \cdot F. \qquad \text{(A.4)}$$

The right-hand side term of equation (A.4) is the final consumption vector F pre-multiplied by the square of the Leontief inverse matrix $\left([I-B]^{-2}\right)$. The numerator of each right-hand side term in equation (A.3) is the $r-th$ element of the right-hand side expression in equation (A.4). Antràs et al. (2012) and Antràs and Chor (2013) construct the *upstreamness* indicator of the industry r by taking the ratio of the $r-th$ element of the column vector $[I-B]^{-2}F$ to the $r-th$ element of the column vector $[I-B]^{-1}F$. Fally (2012) proposes an alternative measure of *upstreamness* by assuming that an industry r that sells a disproportionate share of its output to another industry s located further upstream is itself located relatively further upstream. He sets up the following recurrence equation:

$$U_r = 1 + \sum_{s=1}^{S} \frac{d_{rs} \cdot Y_s}{Y_r} U_s \tag{A.5}$$

where $\frac{d_{rs} \cdot Y_s}{Y_r}$ is the total share of industry r's output purchased by industry s. Industry r is thus considered as belonging to a higher "upstream stage" than the weighted sum of industries s that use the products of industry r as intermediate inputs. Fally (2012) and Antràs et al. (2012) show that the measure of *upstreamness* expressed by equation (A.3) is the unique solution of expression (10). Using matrix algebra, they establish the following equivalence between these different measures of *upstreamness*:

$$U_r = [I - \Delta]^{-1} \mathbf{1} \tag{A.6}$$

where Δ is a matrix whose term (r,s) is equal to $\frac{d_{rs} \cdot Y_s}{Y_r}$ and $\mathbf{1}$ is a unit column vector.

In general, $U_r \geq 1$. A higher value of the *upstreamness* indicates that the industry is at a higher upstream stage in the production line. An *upstreamness* equal to 1 means that the entire output of industry r is directly used as final consumption in the sense of Fally (2012) and Antràs et al. (2012).[8]

We compute the *upstreamness* of each 4-digit NACE Rev.2 industry r in the input-output table constructed in section A.2, obtaining first:

$$d_{rs} = \frac{b_{rs}}{Y_s} \implies d_{rs} \cdot Y_s = b_{rs} \implies \frac{d_{rs} \cdot Y_s}{Y_r} = \frac{b_{rs}}{Y_s}$$

A.2 Input-output table

The measurement of the level of processing of products traded by firms relies on the information provided by the input-output table. The availability of these tables at detailed levels for each country remains an important challenge in carrying out this work. Moreover, our interest in the agri-food sector further complicates this task insofar as the European input-output tables are established at high levels of aggregation. In France, for example, the input-output tables provided by the OECD Structural Analysis database (OECD STAN) include only thirty industries, and only one concerns the agri-food industry. To overcome this issue, we use as a starting point the US input-output table, developed by the Bureau of Economic Analysis (BEA), which is available online, in open access.[9] More specifically, we rely on the most recent Use Table after redefinition at producer prices for 2012.

The US input-output table has the advantage to include information on production linkages between industries at a high level of disaggregation. It includes 405 industries (identified by individual 6-digit I-O codes) of which 42 are in the agri-food sector. It is important to take into account all the industries in the economy because the production of agri-food goods involves the use of inputs, raw materials and intermediate products from other sectors (for example, packaging). However, using the U.S. input-output table for an application on French data presents significant classification and matching challenges. We have developed a methodology to convert the U.S. input-output table to the 4-digit NACE Rev.2 codes level, reported for French firms.

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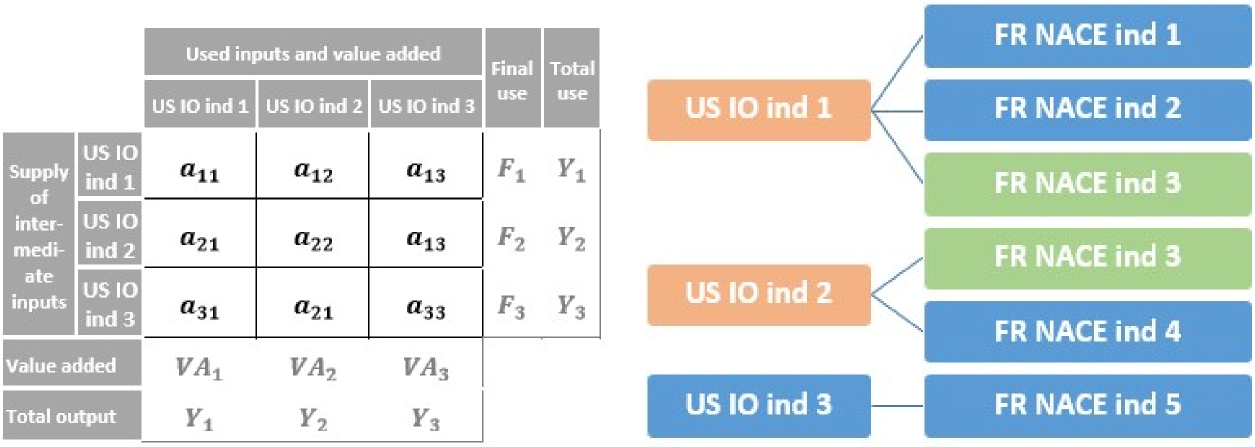
[8] In the specific case of the *upstreamness* indicator developed by Alfaro et al. (2019), a value of 1 indicates that industry r is used entirely in the production of products of the same or other industries through a single production stage.

[9] `https://www.bea.gov/industry/input-output-accounts-data`.



(a) US input-output table (b) Multiple industry correspondences

Figure A.1: US input-output table structure and correspondences with NACE Rev.2

The entries a_{ij} in Figure A.1.a report the value of intermediate goods of industry i used in the production of goods of industry j. In addition, there is a column (F_i) that reports the value of products i that goes into aggregate final uses, such as final consumption, investment, changes in inventories and net exports.

The main challenge in using the U.S. I-O table on French data is that there is not a one-to-one correspondence between the U.S. IO and the NACE Rev.2 industries. Note that the U.S. IO codes are specific to the 2012 North American Industry Classification System (NAICS) structure. An U.S. IO code can correspond to one or more NAICS codes. The NAICS codes in turn have different levels of aggregation, from 2 digits (most aggregated level) to 6 digits (least aggregated level). We have mapped the U.S. IO codes to NACE Rev.2 codes using the links between the U.S. IO codes and the NAICS 2012 codes and the correspondence table between NAICS 2012 and NACE Rev.2 provided by Eurostat.[10] However, there are several concerns with this mapping. As shown by Figure A.1.b, a 6-digit IO code may correspond to several 4-digit NACE Rev.2 codes. Similarly, a 4-digit NACE Rev.2 code may be associated with several 6-digit U.S. IO codes. Out of the the 1,547 U.S. IO-NACE Rev.2 code combinations, only 31 industries, (and 2 in the agri-food sector), had a one-to-one correspondence. In these circumstances, we chose to divide each a_{ij} entry in the U.S. I-O table equally among all (r, s) combinations of NACE Rev.2 codes to which the (i, j) entry corresponds (Figure A.2.a). We then simply take the sum of the (r, s) entries that are identical to obtain the entries b_{rs} of the new input-output table at NACE Rev.2 level. We end up with the table in Figure A.2.b.

For example, in Figure A.1.b the U.S. IO1, respectively IO2 codes correspond to 3, respectively 2 NACE codes and the NACE3 code corresponds to 2 I-O codes. Thus, in order to convert the structure of the U.S. I-O table from the level of U.S. IO codes (Figure A.1.a) to the level of NACE Rev.2 codes (Figure A.2.b), we formally have performed the following transformations:

$$b_{rs} = \sum_{i,j} \frac{a_{ij}}{n_i \times n_j}, \text{with } (i \supseteq r \text{ or } i \subseteq r) \text{ and } (j \supseteq s \text{ or } j \subseteq s)\,. \tag{A.7}$$

where n_i, respectively n_j represent the number of different NACE Rev.2 codes associated with input i (in rows in Figure A.1.a), respectively, output j (in columns in Figure A.1.a). This transformation makes it possible to remain as close as possible to the structure of the initial U.S. I-O table, i.e. at the level of U.S. IO codes. This permits us to build a highly detailed input-output table for 604 4-digit NACE Rev.2 industries, of which 88 agri-food. Once this transformation has been carried out, we only need to compute the *upstreamness* indicator for the 4-digit NACE Rev.2 industries.

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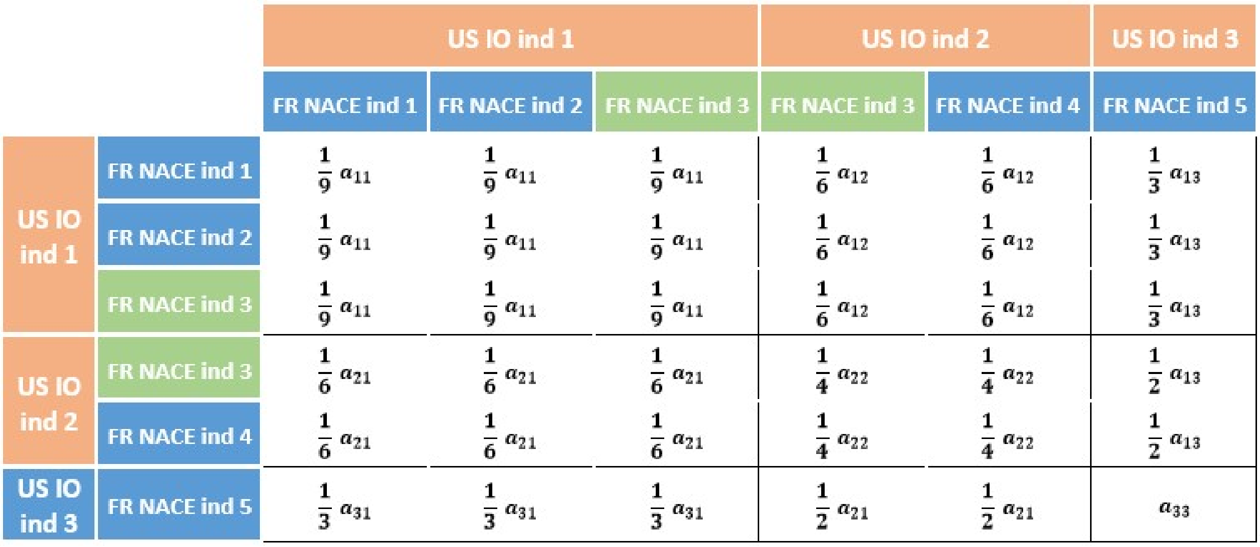
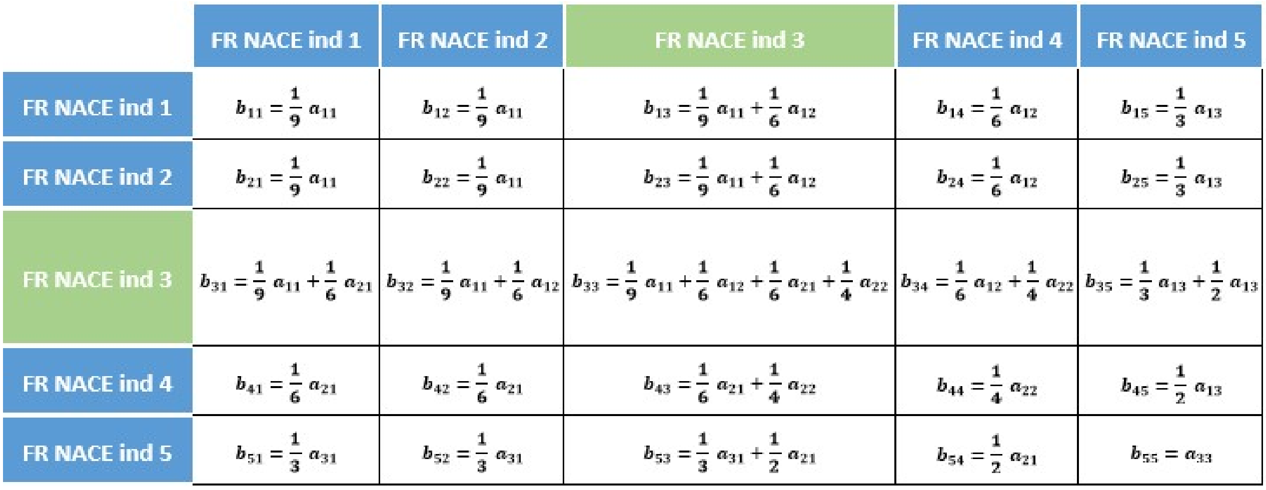
[10] `http://ec.europa.eu/eurostat/ramon/documents/NACE_REV2-US_NAICS_2012.zip`..



		US IO ind 1			US IO ind 2		US IO ind 3
		FR NACE ind 1	FR NACE ind 2	FR NACE ind 3	FR NACE ind 3	FR NACE ind 4	FR NACE ind 5
US IO ind 1	FR NACE ind 1	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{6}a_{12}$	$\frac{1}{6}a_{12}$	$\frac{1}{3}a_{13}$
	FR NACE ind 2	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{6}a_{12}$	$\frac{1}{6}a_{12}$	$\frac{1}{3}a_{13}$
	FR NACE ind 3	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{6}a_{12}$	$\frac{1}{6}a_{12}$	$\frac{1}{3}a_{13}$
US IO ind 2	FR NACE ind 3	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{4}a_{22}$	$\frac{1}{4}a_{22}$	$\frac{1}{2}a_{13}$
	FR NACE ind 4	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{4}a_{22}$	$\frac{1}{4}a_{22}$	$\frac{1}{2}a_{13}$
US IO ind 3	FR NACE ind 5	$\frac{1}{3}a_{31}$	$\frac{1}{3}a_{31}$	$\frac{1}{3}a_{31}$	$\frac{1}{2}a_{21}$	$\frac{1}{2}a_{21}$	a_{33}

(a) Equal weights for all correspondences within each pair of industry codes



	FR NACE ind 1	FR NACE ind 2	FR NACE ind 3	FR NACE ind 4	FR NACE ind 5
FR NACE ind 1	$b_{11}=\frac{1}{9}a_{11}$	$b_{12}=\frac{1}{9}a_{11}$	$b_{13}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}$	$b_{14}=\frac{1}{6}a_{12}$	$b_{15}=\frac{1}{3}a_{13}$
FR NACE ind 2	$b_{21}=\frac{1}{9}a_{11}$	$b_{22}=\frac{1}{9}a_{11}$	$b_{23}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}$	$b_{24}=\frac{1}{6}a_{12}$	$b_{25}=\frac{1}{3}a_{13}$
FR NACE ind 3	$b_{31}=\frac{1}{9}a_{11}+\frac{1}{6}a_{21}$	$b_{32}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}$	$b_{33}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}+\frac{1}{6}a_{21}+\frac{1}{4}a_{22}$	$b_{34}=\frac{1}{6}a_{12}+\frac{1}{4}a_{22}$	$b_{35}=\frac{1}{3}a_{13}+\frac{1}{2}a_{13}$
FR NACE ind 4	$b_{41}=\frac{1}{6}a_{21}$	$b_{42}=\frac{1}{6}a_{21}$	$b_{43}=\frac{1}{6}a_{21}+\frac{1}{4}a_{22}$	$b_{44}=\frac{1}{4}a_{22}$	$b_{45}=\frac{1}{2}a_{13}$
FR NACE ind 5	$b_{51}=\frac{1}{3}a_{31}$	$b_{52}=\frac{1}{3}a_{31}$	$b_{53}=\frac{1}{3}a_{31}+\frac{1}{2}a_{21}$	$b_{54}=\frac{1}{2}a_{21}$	$b_{55}=a_{33}$

(b) Group weights across NACE industries

Figure A.2: Convert the US I-O table to the NACE Rev.2 4-digit level

We check the stability of the *upstreamness* measure of industries between U.S. and France in order to test the relevance of using the U.S. table on French data. To do so, we use French input-output data from several sources: the OECD STAN database and the INSEE input-output table. Note that the OECD STAN database include 34 industries and the INSEE input-output contain 15 industries. Given the high level of aggregation of these two tables, we aggregate the input-output table constructed above, so as to have respectively the 34 industries present in the OECD STAN database - Aggregate NACE (34 industries) - and the 15 industries present in the INSEE table - Aggregate NACE (15 industries) . After that, we check how *upstreamness* computed from the French table in the STAN database, respectively in the INSEE database, compares with the Aggregate NACE (34 industries), respectively Aggregate NACE (15 industries). To verify the consistency of industry *upstreamness* across industries in different input-output table, we conduct a Spearman rank correlation test.

Table 2 reports the Spearman rank correlation. We are particularly interested in the correlation between *upstreamness* from the pairs Aggregate NACE (34 industries) and OECD STAN database which are 0.65; Aggregate NACE (15 industries) and INSEE table which are 0.68. It useful to note that the rank correlation is always large and significantly different from zero at a p-value of 0.01.

Table A.1: Spearman (Pearson) correlation

	Aggregate NACE (34 industries)	Aggregate NACE (15 industries)	OECD STAN database (34 industries)	INSEE table (15 industries)
Aggregate NACE (34 industries)	1			
Aggregate NACE (15 industries)	-	1		
OECD STAN database (34 industries)	0.65 (0.66)	-	1	
INSEE table (15 industries)	-	0.68 (0.67)	-	1

Notes: Pearson correlation in brackets. Authors' own calculations based on U.S. input-output table converted to the 4-digit NACE Rev.2 level, French original input-output tables from OECD STAN database and INSEE.

The cross-industry variation of the *upstreamness* measure between French original input-output tables (OECD STAN database and INSEE table) and our constructed NACE level input-output table from U.S. table is largely consistent with the range of values reported by Fally (2012) for a subset of EU countries (Czech Republic, Luxembourg, Germany, Spain, *etc.*). In sum, this evidence gives us great confidence that the industry measures are stable across U.S. and France, at least at the higher level of aggregation, and confirm the relevance of using the U.S. table on French data.

B Theory Appendix

Proof of Proposition 1.
We start by determining the sales price for each type and variety of goods produced by the firm, $p(U^X)$, from the demand function (2), and then its total revenue $p(U^X)q$, by using the expression from (4).

$$q = A\lambda^{\varepsilon-1}\left[p(U^X)\right]^{-\varepsilon} \tag{B.1}$$

From (B.1), we have:

$$p(U^X) = A^{\frac{1}{\varepsilon}}\lambda^{\frac{\varepsilon-1}{\varepsilon}}q^{-\frac{1}{\varepsilon}} \tag{B.2}$$

By using q from the expression (4) in the main text, full expression of profit gives:

$$\begin{aligned}\pi = {} & A^{\frac{1}{\varepsilon}}\varphi^{\frac{\varepsilon-1}{\varepsilon}}\lambda^{\frac{(\varepsilon-1)(1-\gamma)}{\varepsilon}}\left(\int_{U^X}^{U^M} x(u)^{\frac{\sigma-1}{\sigma}}du + q_M^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\rho\sigma(\varepsilon-1}{\varepsilon(\sigma-1)}} \\ & -\left(p(U^M)q_M + \int_{U^X}^{U^M}\left[c(u)x(u)+F(u)\right]du + \lambda^\alpha\right)\end{aligned} \tag{B.3}$$

The CPO for profit maximisation give:

$$\frac{(\varepsilon-1)(1-\gamma)}{\alpha\varepsilon}p(U^X)q = \lambda^\alpha \tag{B.4}$$

$$\frac{\rho(\varepsilon-1)}{\varepsilon}q_M^{-\frac{1}{\sigma}}p(U^X)q^{\frac{\rho\sigma-(\sigma-1)}{\rho\sigma}}\lambda^{-\gamma\frac{(\sigma-1)}{\rho\sigma}}\varphi^{\frac{(\sigma-1)}{\rho\sigma}} = P(U^M) \tag{B.5}$$

$$\frac{\rho(\varepsilon-1)}{\varepsilon}x(u)^{-\frac{1}{\sigma}}p(U^X)q^{\frac{\rho\sigma-(\sigma-1)}{\rho\sigma}}\lambda^{-\gamma\frac{(\sigma-1)}{\rho\sigma}}\varphi^{\frac{(\sigma-1)}{\rho\sigma}} = c(u) \tag{B.6}$$

$$-\frac{\rho\sigma(\varepsilon-1)}{\varepsilon(\sigma-1)}x(U^X)^{\frac{\sigma-1}{\sigma}}p(U^X)q^{\frac{\rho\sigma-(\sigma-1)}{\rho\sigma}}\lambda^{-\gamma\frac{(\sigma-1)}{\rho\sigma}}\varphi^{\frac{(\sigma-1)}{\rho\sigma}} + c(U^X)x(U^X) + F(U^X) = 0 \tag{B.7}$$

$$\frac{\rho\sigma(\varepsilon-1)}{\varepsilon(\sigma-1)}x(U^M)^{\frac{\sigma-1}{\sigma}}p(U^X)q^{\frac{\rho\sigma-(\sigma-1)}{\rho\sigma}}\lambda^{-\gamma\frac{(\sigma-1)}{\rho\sigma}}\varphi^{\frac{(\sigma-1)}{\rho\sigma}} - p'(U^M)q_M - c(U^M)x(U^M) - F(U^M) = 0 \tag{B.8}$$

We totally differentiate the system of equations (B.4) to (B.8) in order to understand how the firm's choice over the span of production stages is affected by λ. Equations (B.4) to (B.6) give:

$$\alpha\frac{d\lambda}{\lambda} = \frac{p\prime(U^X)}{p(U^X)}dU^X + \frac{dq}{q} \tag{B.9}$$

$$-\frac{1}{\sigma}\frac{dq_M}{q_M} + \frac{p\prime(U^X)}{p(U^X)}dU^X + \frac{\rho\sigma-(\sigma-1)}{\rho\sigma}\frac{dq}{q} - \gamma^{\frac{(\sigma-1)}{\rho\sigma}}\frac{d\lambda}{\lambda} + \frac{(\sigma-1)}{\rho\sigma}\frac{d\varphi}{\varphi} = \frac{p\prime(U^M)}{p(U^M)}dU^M \tag{B.10}$$

$$-\frac{1}{\sigma}\frac{dx(u)}{x(u)} + \frac{p\prime(U^X)}{p(U^X)}dU^X + \frac{\rho\sigma-(\sigma-1)}{\rho\sigma}\frac{dq}{q} - \gamma^{\frac{(\sigma-1)}{\rho\sigma}}\frac{d\lambda}{\lambda} + \frac{(\sigma-1)}{\rho\sigma}\frac{d\varphi}{\varphi} = 0 \tag{B.11}$$

From (B.10) and (B.11), we have:

$$\frac{dx(u)}{x(u)} = \frac{dq_M}{q_M} + \sigma\frac{p\prime(U^M)}{p(U^M)}dU^M \tag{B.12}$$

Then, we totally differentiate q from (4) in the main text:

$$\frac{dq}{q} = \frac{d\varphi}{\varphi} - \gamma\frac{d\lambda}{\lambda} + \frac{\rho\sigma}{\sigma-1}\frac{x(U^M)^{\frac{\sigma-1}{\sigma}}dU^M - x(U^X)^{\frac{\sigma-1}{\sigma}}dU^X + \int_{U^X}^{U^M}\frac{\sigma-1}{\sigma}x(u)^{\frac{\sigma-1}{\sigma}}\frac{dx(u)}{x(u)}du + \frac{\sigma-1}{\sigma}q_M^{\frac{\sigma-1}{\sigma}}\frac{dq_M}{q_M}}{\left(q\varphi^{-1}\lambda^{\gamma}\right)^{\frac{\rho-1)}{\rho\sigma}}} \tag{B.13}$$

Note that from CPO (B.6), we have:

$$\frac{\rho\sigma\,(\varepsilon-1)}{\varepsilon(\sigma-1)}\frac{1}{\left(q\varphi^{-1}\lambda^{\gamma}\right)^{\frac{\rho-1)}{\rho\sigma}}}x(u)^{\frac{\sigma-1}{\sigma}} = \frac{\sigma}{\sigma-1}\frac{c(u)x(u)}{p(U^X)q} \tag{B.14}$$

for all $u \in [U^X, U^M]$

It should be noted that, derivative $P(U^X)$ with respect to U^X, from (B.2) gives:

$$p\prime(U^X) = -\frac{\rho\sigma}{\varepsilon(\sigma-1)}p(U^X)\left(q^{-1}\varphi\lambda^{-\gamma}\right)^{\frac{\rho-1}{\rho\sigma}}x(U^X)^{\frac{\sigma-1}{\sigma}} \tag{B.15}$$

By replacing (B.14) and (B.15) in the CPO (B.7) and (B.8), we have:

$$p\prime(U^X)q = -\frac{1}{\varepsilon-1}\left[c(U^X)x(U^X) + F(U^X)\right] \tag{B.16}$$

$$F(U^X) = \frac{1}{\sigma-1}c(U^X)x(U^X) \tag{B.17}$$

$$p\prime(U^M)q_M = \frac{1}{\sigma-1}c(U^M)x(U^M) - F(U^M) \tag{B.18}$$

Using the (B.5), (B.12), (B.14) and (B.18), we can simplify $\frac{dq}{q}$ to obtain:

$$\frac{dq}{q} = \frac{d\varphi}{\varphi} - \gamma\frac{d\lambda}{\lambda} + \sigma\frac{dq_M}{q_M} - \frac{\varepsilon\sigma}{(\varepsilon-1)(\sigma-1)}\frac{c(U^X)x(U^X)}{p(U^X)q}dU^X + \sigma\left[\frac{\varepsilon}{\varepsilon-1}\frac{F(U^M)}{p(U^X)q} + \rho\frac{p\prime(U^M)}{p(U^M)}\right]dU^M \tag{B.19}$$

Now we totally differentiate the CPO (B.8):

$$\begin{aligned}&\frac{\sigma-1}{\sigma}\frac{dx(U^M)}{x(U^M)} + \frac{p'(U^X)}{p(U^X)}dU^X + \frac{\sigma-1}{\varepsilon\sigma}\frac{d\varphi}{\varphi} - \gamma\frac{\sigma-1}{\varepsilon\sigma}\frac{d\lambda}{\lambda} + \frac{\rho\sigma-(\sigma-1)}{\rho\sigma}\frac{dq}{q}\\ =&\frac{p'(U^M)q_M\frac{dq_M}{q_M} + c(U^M)x(U^M)\frac{dx(U^M)}{x(U^M)} + \left[p''(U^M)q_M + c'(U^M)x(U^M) + F'(U^M)\right]dU^M}{p^{'}(U^M)q_M - c(U^M)x(U^M) - F(U^M)}\end{aligned} \tag{B.20}$$

Using (B.11), we can derive the left-hand side of (B.20), which exactly equal to $\frac{dx(U^M)}{x(U^M)}$. By replacing the expression of $\frac{dx(U^M)}{x(U^M)}$ from (B.12) on both sides of (B.20), we obtain:

$$\frac{dq_M}{q_M} = \frac{1}{F(U^M)}\left[\Phi^M - \frac{\sigma}{\sigma-1}c(U^M)x(U^M)\frac{p\prime(U^M)}{p(U^M)}\right]dU^M \tag{B.21}$$

where $\Phi^M = \left[p''(U^M)q_M + c\prime(U^M)x(U^M) + F\prime(U^M)\right]$.

Using the expression from (B.12) and (B.18) in (B.21), we obtain:

$$\frac{dx(U^M)}{x(U^M)} = \frac{1}{F(U^M)}\left[\Phi^M - \sigma\frac{(p\prime(U^M))^2q_M}{p(U^M)}\right]dU^M \tag{B.22}$$

By replacing the expression of $\frac{p\prime(U^X)}{p(U^X)}dU^X$ from (B.9) and the expression of $\frac{dq}{q}$ from (B.19) in (B.10) and simplify it, one can obtain:

$$\alpha\frac{d\lambda}{\lambda} = B\cdot dU^X + C\cdot dU^M, \tag{B.23}$$

where

$$B \equiv -\frac{\varepsilon}{\rho(\varepsilon-1)}\frac{c(U^X)x(U^X)}{p(U^X)q} \tag{B.24}$$

$$C \equiv \frac{1}{x(U^M)}\frac{dx(U^M)}{dU^M} + \frac{\varepsilon(\sigma-1)}{\rho(\varepsilon-1)}\frac{F(U^M)}{p(U^X)q} \tag{B.25}$$

Then, we totally differentiate the CPO (B.7):

$$\begin{aligned}\frac{\sigma-1}{\sigma}\frac{dx(U^X)}{x(U^X)} + \frac{p'(U^X)}{p(U^X)}dU^X + \frac{\sigma-1}{\varepsilon\sigma}\frac{d\varphi}{\varphi} - \gamma\frac{\sigma-1}{\varepsilon\sigma}\frac{d\lambda}{\lambda} + \frac{\rho\sigma-(\sigma-1)}{\rho\sigma}\frac{dq}{q} \\ = \frac{c(U^X)x(U^X)\frac{dx(U^X)}{x(U^X)} + [c'(U^X)x(U^X)+F'(U^X)]dU^X}{c(U^X)x(U^X)-F(U^X)}\end{aligned} \tag{B.26}$$

By replacing (B.8) and (B.13) in the left hand side of the expression (B.26) and simplifying it, one could obtain:

$$\alpha\frac{d\lambda}{\lambda} = D \cdot dU^X + E \cdot dU^M, \tag{B.27}$$

where

$$D \equiv -\frac{1}{(\varepsilon-1)}\left[\frac{\varepsilon}{\rho}\frac{c(U^X)x(U^X)}{p(U^X)q} + \frac{c'(U^X)x(U^X)+F'(U^X)}{p'(U^X)q}\right] \tag{B.28}$$

$$E \equiv \left[1 + \frac{1}{\varepsilon-1}\frac{F(U^X)}{p'(U^X)q})\frac{1}{x(U^M)}\right]\frac{dx(U^M)}{dU^M} + \frac{\varepsilon(\sigma-1)}{\rho(\varepsilon-1)}\frac{F(U^M)}{p(U^X)q} \tag{B.29}$$

Solving (B.23) and (B.27) simultaneously yields:

$$\frac{\lambda}{\alpha}\frac{dU^M}{d\lambda} = \frac{B-D}{B \cdot E - C \cdot D} \tag{B.30}$$

$$\frac{\lambda}{\alpha}\frac{dU^X}{d\lambda} = \frac{E-C}{B \cdot E - C \cdot D} \tag{B.31}$$

with:

$$B - D = \frac{1}{(\varepsilon-1)}\frac{c'(U^X)x(U^X)+F'(U^X)}{p'(U^X)q} \tag{B.32}$$

$$E - C = \frac{1}{(\varepsilon-1)}\frac{F(U^X)}{p'(U^X)q}\frac{1}{x(U^M)}\frac{dx(U^M)}{dU^M} \tag{B.33}$$

$$\begin{aligned}BE - CD = \left[\frac{c'(U^X)x(U^X)+F'(U^X)}{p'(U^X)q} - \frac{\varepsilon}{\rho(\sigma-1)(\varepsilon-1)^2}\frac{c(U^X)x(U^X)}{p(U^X)q}\frac{c(U^X)x(U^X)}{p'(U^X)q}\right]\frac{1}{x(U^M)}\frac{dx(U^M)}{dU^M} \\ + \left[\frac{\varepsilon(\sigma-1)}{\rho(\varepsilon-1)}\frac{F(U^M)}{p(U^X)q}\right]\left[\frac{c'(U^X)x(U^X)+F'(U^X)}{p'(U^X)q}\right]\end{aligned} \tag{B.34}$$

Since $\frac{\lambda}{\alpha}$ is positive, then the sign of $\frac{dU^M}{d\lambda}$ and $\frac{dU^X}{d\lambda}$ corresponds to the sign of $\frac{B-D}{B \cdot E - C \cdot D}$ and $\frac{E-C}{B \cdot E - C \cdot D}$, respectively. To determine the signs of $B - D$, $E - C$ and $B \cdot E - C \cdot D$, we refer to the second-order necessary conditions for U^X and U^M. The second-derivative of the profit function with respect to U^X and with respect to U^M both need to be negative when evaluated at the local turning point in order to ascertain that we have a local maximum. Differentiating the left-hand side of (B.7) with respect to U^X and the left-hand side of (B.8) with respect to U^M, and using (B.14), one can show that these second-order necessary conditions reduce to:

$$\frac{c\prime(U^X)x(U^X)+F\prime(U^X)}{p\prime(U^X)q} > \frac{\sigma}{\sigma-1}\frac{c(U^X)x(U^X)}{p(U^X)q} - \frac{\varepsilon\sigma(\rho\sigma-\sigma+1)}{\rho(\sigma-1)^2(\varepsilon-1)}\frac{c(U^X)x(U^X)}{p(U^X)q}\frac{c(U^X)x(U^X)}{p'(U^X)q}$$

and:

$$\Phi^M > \frac{\varepsilon\sigma(\rho\sigma-\sigma+1)}{\rho(\sigma-1)^2(\varepsilon-1)}\frac{c(U^M)^2x(U^M)^2}{p(U^X)q}.$$

Given that $p'(u) < 0$, this implies: Φ^M, $\frac{c\prime(U^X)x(U^X)+F\prime(U^X)}{p\prime(U^X)q} > 0$ if and only if $\rho > \frac{\sigma-1}{\sigma}$.

Examining (B.32), with the sufficient condition that $\rho > \frac{\sigma-1}{\sigma}$, we have $B-D > 0$. Next, consider (B.33). Notice from (B.18) and (B.22) that:

$$\frac{1}{x(U^M)}\frac{dx(U^M)}{dU^M} = \frac{p(U^M)q_M}{F(U^M)}\left[\frac{\Phi^M}{p(U^M)q_M} - \sigma\left(\frac{\frac{1}{\sigma-1}c(U^M)x(U^M)-F(U^M)}{p(U^M)q_M}\right)^2\right] \tag{B.35}$$

If $\frac{c(U^M)x(U^M)}{p(U^M)q_M}$ and $\frac{F(U^M)}{p(U^M)q_M}$ are sufficiently small, at least relative to $\frac{\Phi^M}{p(U^M)q_M}$, then it would follow that $\frac{1}{x(U^M)}\frac{dx(U^M)}{dU^M} > 0$. So, given that $p'(U^M) < 0$ in the denominator of the right-hand side of (B.33), it follows that $E - C < 0$.

Turning to (B.34), under the assumptions that $\frac{c(U^M)x(U^M)}{p(U^M)q_M}$ and $\frac{F(U^M)}{p(U^M)q_M}$ are sufficiently small, and that $p'(U^X) < 0$, which imply that Φ^M, $\frac{c\prime(U^X)x(U^X)+F\prime(U^X)}{p\prime(U^X)q} > 0$, it follows that the sign of the entire expression of equation (B.34) is positive ($B \cdot E - C \cdot D > 0$).

With $B \cdot E - C \cdot D > 0$, $B - D > 0$ and $E - C < 0$, (B.30) and (B.31) imply that $\frac{dU^M}{d\lambda} > 0$, $\frac{dU^X}{d\lambda} < 0$ and $\frac{(dU^M-U^X)}{d\lambda} > 0$. Moreover, given that $\frac{1}{x(U^M)}\frac{dx(U^M)}{dU^M} > 0$, we have $\frac{dx(u)}{d\lambda} > 0$, and since $\Phi^M > 0$, one can deduce from (B.21) that $\frac{dq_M}{d\lambda} > 0$.

Dividing (B.12) by $d\lambda$ yields:

$$\frac{1}{x(u)}\frac{dx(u)}{d\lambda} = \frac{1}{q_M}\frac{dq_M}{d\lambda} + \sigma\frac{p\prime(U^M)}{p(U^M)}\frac{dU^M}{d\lambda} \tag{B.36}$$

which represent how the firm's payments for upstream intermediate inputs changes. Recall that $p'(U^M) < 0$ and $\sigma > 1$, and that $\frac{dx(u)}{d\lambda} > 0$ implies $\frac{1}{x(u)}\frac{dx(u)}{d\lambda} > 0$. Consequently, on can easily show that the demand effect, $\frac{1}{q_M}\frac{dq_M}{d\lambda}$, dominates the lower prices of the upstream intermediates inputs, $\sigma\frac{p\prime(U^M)}{p(U^M)}\frac{dU^M}{d\lambda}$, when (U^M) following the quality upgrading.

Relaxing the assumption that $\frac{c(U^M)x(U^M)}{p(U^M)q_M}$ and/or $\frac{F(U^M)}{p(U^M)q_M}$ are sufficiently small relative to $\frac{\Phi^M}{p(U^M)q_M}$ implies that $\frac{1}{x(U^M)}\frac{dx(U^M)}{dU^M} < 0$. It is very unlikely that this situation arises, since it is technically difficult to imagine a decrease in the quantities $x(u)$ of stages inputs, while the cut-off stage U^M increases. Indeed, the increase in the cut-off stageU^M due to quality upgrading must result in a purchase of a higher quantity q_M of upstream intermediate inputs, and will require more quantities $x(u)$ of stage inputs.

Proof of Proposition 2.
As discussed in the paper, the change in the profit following an upgrade in quality depends on the relative weight of two opposite effects, which can offset one another, but a positive change is expected even if it may be small. Obviously, when properties (i) and (ii) are met, quality upgrading leads to an increase in U^M and a decrease in U^X, *i.e.* the firm expands its span of production stages, $U^M - U^X$. Under the condition that the firm performs all or most stages $u \in \left[U^X, U^M\right]$ in-house, the firm's total fixed costs $\left(\int_{U^X}^{U^M} F(u)du + \lambda^\alpha\right)$ would increase because λ increases and the same fixed

costs are incurred for a wider span of production stages. Notice that we also have higher quantity $x(u)$ and consequently the firm's total variable costs $\left(\int_{U^X}^{U^M} c(u)x(u)du\right)$ would also increase. As mentioned earlier, since q_M increases and dominates the effect of the decrease in $p(U^M)$, the total expenditure on upstream inputs $\left(p(U^M)q_M\right)$ increases. Last, as the profit also increases because of an increase in λ, the firm produces a higher value added $(c(u)x(u) + F(u) + \lambda^{\alpha} + \pi)$.