

Global supply chains, firm scope and vertical integration: evidence from China

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Abstract

This article investigates how firms organize supply chains within and across countries. Utilizing highly disaggregate customs trade statistics for Chinese processing exports, I develop a novel strategy for measuring the position of cities on the value chain. By linking variation in value chain position over time and across cities, to changes in the share of exports that are foreign owned, I assess the role of sequential production in determining optimal vertical integration and firm scope along the global supply chain. I provide evidence that the supply chain position of intermediates and the degree of substitutability across sequential stages of production provide incentives for firms to own intermediate good suppliers, consistent with the theoretical predictions of Antràs and Chor (2013, *Econometrica*, 81: 2127–2204). Additionally, I find evidence that the value added to gross output ratio depends critically on supply chain position—value added increases as firms move down the supply chain, toward final production—which is consistent with Fally and Hillberry (2015, Working Paper 21520, NBER).

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1. Introduction

The falling cost and complexity of transporting information, goods and people has played an important role in the rise of global production sharing and the increased importance of supply chain trade (trade linked through production networks).¹ One of the first examples of large-scale unbundling of the supply chain began in the 1980s with the Maquiladora program, which created ‘twin plants’ on either side of the U.S. and Mexican border. This program saw enormous growth throughout the 1980s, expanding employment by 20% per year from 1982 through 1989 (Feenstra and Hanson, 1996).² Since this time, the growth of supply chain trade has only accelerated, due in large part to massive growth in Asia. From the late 1980s to the early 2000s, Asia saw its share of total supply chain trade more than double, accounting for nearly all of the global

1 To my knowledge the term ‘supply chain trade’ was coined by Baldwin and Lopez-Gonzalez (2015). In this article, I refer to any trade in intermediate goods that is part of a larger production process or supply chain as supply chain trade.

2 Production segmentation through the use of Maquiladoras was later studied by Bergin et al. (2009).

growth in supply chain trade during this period (Amador and Cabral, 2009).³ Despite the prevalence of global supply chains, there is still much we do not know about their development, organization and ownership.

The causes and consequences of the unbundling of the global value chain is an active area of research. Over the last 20 years, there have been important empirical studies documenting the prevalence of trade in parts and components (Ng and Yeats, 1999; Hummels et al., 2001; Kimura and Ando, 2005; Amador and Cabral, 2009; Hayakawa and Matsuura, 2011), which have motivated theoretical frameworks for understanding the organization of global value chains (Levine, 2012; Antràs and Chor, 2013 (hereafter AC); Baldwin and Venables, 2013; Costinot et al., 2013). The salient feature in most of this literature is the central role of sequential production (i.e. the need for production to follow a specific sequence in time). Costinot et al. (2013) highlight the importance of sequential production in determining where different stages of the value chain are produced, whereas AC focus on the role of sequential production in incentivizing vertical integration along the value chain.⁴ This literature has also been advanced empirically by the development of new measures of value chain position based on input–output accounting developed by Antras et al. (2012).⁵ This article contributes to the empirical literature by utilizing Chinese processing trade statistics to investigate how a firm’s position on the supply chain relates to the decision to be vertically integrated with foreign suppliers.

China has experienced drastic changes in its economy over the last 20 years, and today is the world’s largest exporter. From 1990 to 2010, the annual growth rate of Chinese trade was 17.6% (Keller et al., 2013) leading di Giovanni et al. (2014) to describe the pace of Chinese integration into the world economy as ‘nothing short of breathtaking’. Over this period the role of foreign firms in China has also changed markedly. As documented by Feenstra et al. (2000), U.S. firms have seen large increases in offshore assembly in China, and this growth is in large part due to various policies implemented by the Chinese government to promote Foreign Direct Investment (FDI) beginning in the early 1980s. One such policy was the creation of customs regimes for assembly and processing of imported materials for re-export—what I refer to as processing trade. These customs regimes include tax incentives, which have contributed to the enormous growth in processing trade over the subsequent decades. Processing trade accounted for about 57% of China’s total exports in 2005, and over 80% of foreign-invested enterprises’ exports (Fernandes and Tang, 2012). In addition to the growth of processing trade, other policy changes that have led to China’s significant role in the global growth of supply chain trade include the removal of restrictions on FDI in the late 1990s and China’s entry into the World Trade Organization (WTO) in 2001. I focus here on processing trade, not only because it accounts for such a large

3 Amador and Cabral (2009) construct a relative measure of supply chain trade (also called vertical specialization trade) that combines information from input–output matrices and international trade data, over the 1967–2005 period. This measure is based on a country’s exports relative to the world average and by its relative imports of the intermediates used in production of that export. Loosely speaking if both exports of a good and imports of intermediates used to produce that good are high, relative to the world average, then a country has relatively high levels of supply chain trade.

4 The Costinot et al. (2013) framework was later expanded to a multifactor setting by Costinot et al. (2012) to help explain how value chain trade can affect wage inequality.

5 The subject of market structure and integration of supply chains has also been addressed in industrial organization (Syverson, 2004; Hortaçsu and Syverson, 2007, 2009).

share of total Chinese trade, but also because it provides a unique opportunity to observe supply chain trade directly.

I focus on the organization and ownership of supply chains trade in China during this transformative period in its history, 1997–2013, in order to evaluate the role of sequential production in shaping global production sharing. Using variation in the value chain position of processing trade, along with foreign ownership shares of Chinese exports at the city level over time, I examine the role of value chains in determining the organization and ownership of global production. Specifically, I compare the foreign-owned share of exports in Chinese cities specializing in processing trade at different parts of the value chain, to identify how position in the value chain impacts foreign ownership. The ability to observe processing trade allows me to observe the global supply chain in a way that is impossible with traditional trade statistics, since processing trade is by definition part of a larger production process.

I uncover evidence that the value chain position of intermediates, along with the degree of substitutability across stages of the value chain, provide incentives for firms to own intermediate good suppliers. I also find support for the role of firm-level heterogeneity in determining the level of vertical integration. Specifically, I find that greater productivity dispersion, as measured by the dispersion of firm exports, increases the incentives for vertical integration. These findings support the theoretical framework developed by AC using very different data, as well as a different empirical strategy.⁶

In addition to finding evidence that value chain position of production provides an incentive for foreign ownership, I also find that the value added to gross output ratio (VAGO) of production is highly correlated with the supply chain position of a city. Cities that specialize in production of goods closer to the end of the value chain (final goods) are also the cities that have the highest VAGO. This finding may at first seem counterintuitive, since goods nearer the end of the value chain require greater amounts of intermediates, which tends to reduce value added as a share of output; however, this is entirely consistent with the empirical evidence presented by [Fally and Hillberry \(2015\)](#) (hereafter FH).⁷ FH argue that the optimal scope of a firm is a function of the value chain position of production. If the scope of the firm—as measured by the number of stages of production performed within a firm—is increasing as a firm moves closer to final goods production, then the VAGO would also increase as production moves toward the end of the value chain. Identifying this predicated relationship within Chinese processing trade provides additional evidence to support the theoretical prediction of FH.

Observing this relationship between value added and upstreamness provides a city-level measure of value chain position that does not depend on aggregate industry input–output linkages. Therefore, the VAGO as a measure of value chain position allows for a more flexible measure of the location of cities along the global value chain. I find evidence that this measure can be used to reduce bias due to classical measurement error

6 This article does not consider the locational choice of offshore assembly, as I focus only on assembly in China. There has been a great deal of interesting work investigating the locational choice including [Swenson \(2005\)](#), who demonstrated that own and competitor country costs affect overseas assembly in all countries, but more dramatically in developing countries.

7 Utilizing I-O tables developed by IDE-JETRO, FH measure gross output, value added and input purchases for 46 sectors and 10 countries. Using this data they demonstrate that at the country-by-industry level, the VAGO is negatively correlated with upstreamness.

relative to a measure of value chain position that relies on aggregate input–output (I–O) tables.

Studying China during this period of transformation also provides a unique opportunity to explore these effects in an environment of major changes in the organization of production and trade policy. I find strong evidence that both results discussed above strengthened after China’s entry into the WTO and the subsequent relaxation of foreign ownership restrictions. The fact that the results strengthen following the removal of foreign ownership restrictions adds robustness to the results, given that the theoretical predictions confirmed by the estimates are based on the assumption of no such restrictions. Additionally, this finding provides valuable insights into the role that policy can play in shaping production networks.

Below, I first review a model of value chain ownership developed by AC and highlights some testable predictions (Section 2). I then describe the data used (Section 3), outline the empirical strategy and describe my findings (Section 4). Section 5 concludes.

2. A model of ownership

AC develop a model of multistage sequential production in an environment of incomplete contracts. This framework demonstrates how ownership of different stages of production could be incentivized by the relative position of goods in the production process, the elasticity of substitution across stages of production and the degree of productivity dispersion within an industry. In this section, I briefly summarize a version of the AC model that incorporates firm-level productivity heterogeneity, detailing two testable predictions, which I bring to the data in Section 4.

2.1. Benchmark model of sequential production

AC consider an environment in which a firm produces a final good q by combining intermediate goods indexed by j , where $j \in [0, 1]$, with larger values of j corresponding to stages of production farther down the supply chain, hence closer to final production. Let $x(j)$ be the quantity of the intermediate j which is compatible with final production. The quality-adjusted quantity of the final production good can be written as:

$$q = \theta \left(\int_0^1 x(j)^\alpha I(j) dj \right)^{1/\alpha}, \quad (1)$$

where θ is a productivity parameter, $\alpha \in (0, 1)$ is a parameter governing the ability of intermediates to be substitutable. Lastly, $I(j)$ is an indicator function that is equal to one if j is produced *after* all intermediates that precede it, and zero otherwise. The inclusion of this indicator function captures the sequential nature of production. One could also think of this equation as representing stages of processing of intermediate goods. For stages of production j and j' , such that $j < j'$, intermediate good j' can be thought of as the further processing of j . This interpretation fits with the necessity of producing j before proceeding to j' , and also fits well with the data I utilize, which records flows of processing trade.

In the AC environment there are a large number of profit-maximizing suppliers who can engage in intermediate input production. There are relationship-specific

investments necessary for production, so the final good-producing firm will source each stage j from only one supplier. It is assumed that each intermediate is completely specialized to each final good, therefore is worthless to other final good-producing firms.

The final goods are distinct and sold by firms competing under monopolistic competition, where consumers preferences over these final goods are given by,

$$U = \left(\sum_{\omega \in \Omega} q(\omega)^\rho d\omega \right)^{1/\rho}, \quad \text{with } \rho \in (0, 1), \quad (2)$$

where Ω denotes the set of all varieties of the final good, which is taken as fixed, and ρ governs the elasticity of substitution across varieties of the final good. Preferences of this type, along with the production technology from Equation (1) imply a revenue function for the firm which is given by,

$$r = A^{1-\rho} \theta^\rho \left(\int_0^1 x(j)^\alpha I(j) dj \right)^{\rho/\alpha}, \quad (3)$$

where A is an industry demand shifter, which will be treated as exogenous.

Following a large literature on the organization of the firm, AC assume there are incomplete contracts, and that the exchange between final good producers and their suppliers are not subject to ex ante enforceable contracts. Instead, the contracts are only able to specify whether there is a vertical integration between the two parties—whether the final good producer owns the intermediate supplier or not. Due to a lack of contracts, the payment to an intermediate supplier is negotiated bilaterally after the stage of production is complete.⁸

For a given stage of production m where $I(j) = 1$ for all $j < m$, revenue of the final good associated with all intermediates up to stage m is given by:

$$r(m) = A^{1-\rho} \theta^\rho \left[\int_0^m x(j)^\alpha dj \right]^{\rho/\alpha}. \quad (4)$$

AC show that one can obtain the marginal contribution of stage m to the production of the final good, from the equation:

$$r'(m) = \frac{\rho}{\alpha} (A^{1-\rho} \theta^\rho)^{\rho/\alpha} r(m)^{\frac{\rho-\alpha}{\alpha}} x(m)^\alpha. \quad (5)$$

AC also assume that ownership of an intermediate supplier is a source of bargaining strength.⁹ If a final good-producing firm owns the intermediate supplier of stage m production, it will receive a share of the revenue associated with stage m equal to $\beta_V \in (0, 1)$, whereas if the producer of stage m is an arms-length supplier the final good-producing firm will only receive β_O where $0 < \beta_O < \beta_V$. Having described the basic

8 Since it has been assumed that the intermediate is fully customized to the final good producer and therefore useless to all other producers, the suppliers outside option is 0, and the rents that both parties bargain for are the incremental contribution to total revenue of the supplier's stage of production to the overall final good.

9 This is a standard assumption in the literature and has been employed Grossman and Hart (1986); Grossman and Helpman (2002, 2005); and Antràs (2003). One could micro-found this result by implementing a bargaining game, but for simplicity the exact form of the game is ignored.

environment of AC, I will not detail the full derivation of the equilibrium, which can be found in AC, but will rather focus on the key testable predictions that are brought to the data.

The final good-producing firm seeks to maximize profits of selling its final good after all payments to its intermediate suppliers have been made. Profits (Π_F) can be characterized by:

$$\Pi_F = A \frac{\rho}{\alpha} \left(\frac{1-\rho}{1-\alpha} \right)^{\frac{\rho-\alpha}{\alpha(1-\rho)}} \left(\frac{\rho\theta}{c} \right)^{\frac{\rho}{1-\rho}} \int_0^1 \beta(j)(1-\beta(j))^{\frac{\alpha}{1-\alpha}} \left[\int_0^j (1-\beta(k))^{\frac{\alpha}{1-\alpha}} dk \right]^{\frac{\rho-\alpha}{\alpha(1-\rho)}} dj, \quad (6)$$

where the final good-producing firm chooses its ownership structure $\beta(j) \in \{\beta_V, \beta_O\}$ for $j \in [0, 1]$ such that it maximizes profits Π_F . To understand how firms' incentives to be vertically integrated vary across the value chain, one can solve for the optimal division of surplus at each stage by maximizing Π_F with respect to β_m to obtain:

$$\beta^*(m) = \max \left\{ (1-\alpha) - \frac{\frac{\rho-\alpha}{1-\rho} \int_m^1 \beta(j)(1-\beta(j))^{\frac{\alpha}{1-\alpha}} \left[\int_0^j (1-\beta(k))^{\frac{\alpha}{1-\alpha}} dk \right]^{\frac{\rho-\alpha}{\alpha(1-\rho)}-1} dj}{\left[\int_0^m (1-\beta(k))^{\frac{\alpha}{1-\alpha}} dk \right]^{\frac{\rho-\alpha}{\alpha(1-\rho)}}}, 0 \right\}. \quad (7)$$

Equation (7) is admittedly complicated, but its interpretation is relatively straightforward. Due to the sequential nature of this problem, the final good producer's choice of $\beta(m)$ for each stage m , not only affects the level of investment of an intermediate supplier at m and the surplus extracted at that stage, but also the choice of $\beta(m)$, the optimal investment at each stage that follows m . How $\beta(m)$ affects downstream investment depends critically on whether investment in each stage is a 'sequential complement' ($\rho > \alpha$) or 'sequential substitute' ($\rho < \alpha$) to production at all other stages. As one can see from Equation (7), the sign of $\rho - \alpha$ determines whether $\beta^*(m)$ is increasing or decreasing with m .

Ignoring the sequential nature of the problem—the effect of investment at one stage on optimal investment at each subsequent stage—the optimal trade-off between rent extraction and investment would lead to a bargaining share equal to $1 - \alpha$. Therefore, for the last stage of production $m = 1$, $\beta(1) = 1 - \alpha$, since no latter stage investment needs to be considered.

The ownership decision at stage $m \neq 1$ also affects the incentives for investment at each stage of production that follows. In the case of substitutes, less investment at stage m increases the incentive to invest for downstream suppliers. The magnitude of this effect depends on the position of m within the total supply chain, increasing with the upstreamness of m . This is because the more the stages that follow stage m , the more the stages' optimal investment strategies are affected by investment at m . As a result, the optimal bargaining share, and therefore optimal ownership, depends on the stage of production as well as whether investment in each stage are complements ($\rho > \alpha$) or substitutes ($\rho < \alpha$). This can be seen clearly in Figure 1 where I plot $\beta^*(m)$ for the case where $\beta_O < \beta_V < 1 - \alpha$ for strategic complements, and where $1 - \alpha < \beta_O < \beta_V$ for strategic substitutes. Under these restrictions on parameter values, the final good-producing firm, in the complements case, will choose to vertically integrate the most downstream production, and in the substitutes case, to vertically integrate the most upstream production. As a result of incomplete contracting and sequential production,

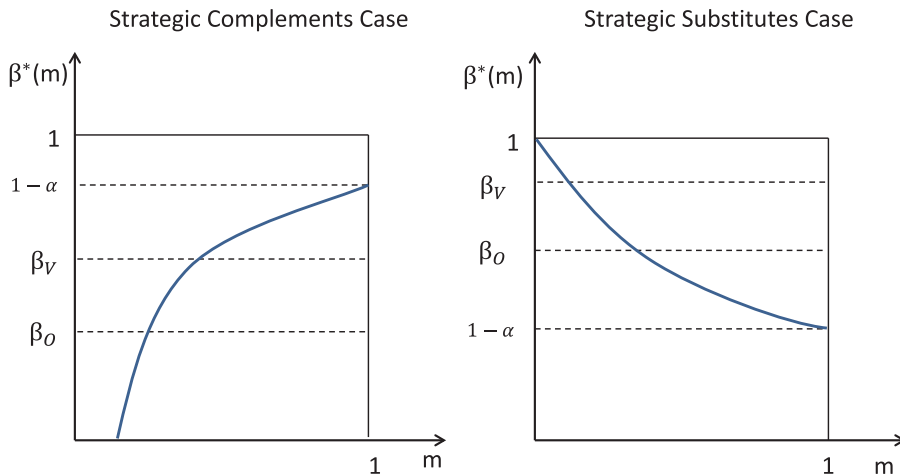


Figure 1. Optimal bargaining share by value chain position.

this model presents a clear pattern of optimal value chain ownership, which is summarized by Proposition 2 of AC as follows:

AC Proposition 2. *In the complements case ($\rho > \alpha$), there exists a unique $m_C^* \in (0, I]$, such that: (i) all production stages $m \in [0, m_C^*)$ are outsourced; and (ii) all stages $m \in [m_C^*, I]$ are integrated within firm boundaries. In the substitutes case ($\rho < \alpha$), there exists a unique $m_S^* \in (0, I]$, such that: (i) all production stages $m \in [0, m_S^*)$ are integrated within firm boundaries; and (ii) all stages $m \in [m_S^*, I]$ are outsourced.*

In section 3, I test this prediction utilizing city-level variation in value chain position and the share of exports sold by foreign-owned firms in China. Next, I describe a second testable prediction, which relates extension of the AC model to an environment of firm heterogeneity.

2.2. Firm heterogeneity and sequential production

In the baseline presentation of the AC model, I took firm productivity θ as given and homogeneous across firms. AC also consider an extension which incorporates firm heterogeneity, similarly to Melitz (2003). Firms draw a distinct productivity parameter from a Pareto distribution with shape parameter z and lower bound θ_{min} , given by:

$$G(\theta) = 1 - (\theta_{min}/\theta)^z \text{ for } \theta \geq \theta_{min} > 0 \quad (8)$$

AC also follow Antràs and Helpman (2004) by introducing fixed costs associated with each organizational form, where $f_O < f_V$, capturing the higher cost of vertical integration. The introduction of fixed costs, as well as productivity heterogeneity, endogenizes the cutoff production stage at which firms are indifferent between ownership regimes (m_C^* in the complements case and m_S^* in the substitutes case) with respect to firm productivity. As firms become more productive, and therefore increase total production, they have an incentive to internalize more stages of the value chain. In the case of both complements and substitutes, greater productivity leads to less outsourcing. At the industry level, AC also show that vertical integration is decreasing

in z and therefore increasing in the dispersion of the productivity distribution, leading to AC Proposition 5:

AC Proposition 5. *The share of firms integrating a particular stage m is weakly increasing in the downstreamness of that stage in the complements case ($\rho > \alpha$), while it is decreasing in the downstreamness of the stage in the substitutes case ($\rho < \alpha$). Furthermore, the share of firms integrating a particular stage m is weakly increasing in the dispersion of productivity within the industry.*

This result does not require firm-level data to test the effect of heterogeneity on ownership; rather, a reasonable estimate of the dispersion of productivity is sufficient. In their empirical exercises, AC use the standard deviation of export values by industry across partner countries. As I discuss in the following section, I use more detailed customs trade statistics from China to estimate the power law parameter of the firm size distribution, which is positively correlated with the firm productivity shape parameter z and therefore provides a theoretically consistent proxy.

2.3. Bringing the AC model to the data

The theoretical model developed by AC provides a simple framework for understanding how the value chain position relates to incentives for vertical integration. Furthermore, it provides clear testable hypotheses which can be brought to the data. The first testable hypothesis is summarized by AC Proposition 2, which states that the relationship between value chain position and vertical integration should be critically dependent on whether intermediates are complements or substitutes in production. The second hypothesis summarized by AC Proposition 5, is that for both complements and substitutes, vertical integration is increasing in the dispersion of firm productivity. Using Chinese Customs Trade Statistics (CCTS), I test both of these predictions for the world's second largest economy and the world's largest exporter—China. The data described in the following section, allows me to identify the ownership structure, location of production and product type of processing trade, with which I develop a novel test of these hypotheses. This analysis uses different data and a different empirical strategy than that used by AC, providing additional support for their theoretical model and empirical exercise.

3. Description of data

The main source of data I draw on are the CCTS reported at the Harmonized System (HS) product classification over the period 1997–2013.¹⁰ The CCTS allow me to identify the source country of imports and the destination country of exports, the specific Chinese city importing or exporting goods, the ownership of the importing or exporting firm and whether the goods are imported or exported under the processing trade regime

¹⁰ These data were accessed at the Center for International Data (CID) at UC Davis with support from Robert Feenstra. This data has in the past been used by many authors (Feenstra et al., 2000; Feenstra and Hanson, 2005; Feenstra and Spencer, 2005; Fernandes and Tang, 2012). Recently more disaggregate Chinese firm-level import and export data has become available and is being used by several researchers (Manova and Zhang, 2009; Ahn et al., 2011; Feenstra et al., 2014).

or as ordinary trade.¹¹ Chinese imports and exports designated as processing trade are goods that are imported for the purpose of being processed in China, then re-exported and are traded duty-free.

Processing trade requires a contractual relationship between the Chinese producer and the firm seeking processing of its intermediates, but it does not require a specific ownership structure. Processing trade is further broken down into two subcategories: under ‘Pure-Assembly’, the Chinese factory takes possession of the imported materials during processing, but the foreign firm retains ownership over the materials; under ‘Import-and-Assembly’, the Chinese factory has a more active role, importing materials independently and taking ownership of them during the processing.¹² Both of these processing regimes provide a unique opportunity to test the theory summarized in the previous section. Unlike standard trade data, customs trade statistics reported as processing trade allow me to observe value chain trade, since these trade flows are by definition part of a larger production process.

To evaluate their theoretical model, AC utilized industry-level, intra-firm trade data reported by the U.S. Census Bureau, along with an industry-specific measure of value chain position developed by Antras et al. (2012).¹³ This study contributes to the literature by expanding on their work in two ways. First, employing city-level processing trade data allows me to precisely measure city-level value added. This allows me to provide additional evidence that firm scope is a function of value chain position, and allows me to use the VAGO as an alternative measure of value chain position in order to test the main predictions of AC.¹⁴ Second, employing city-level processing trade data allows me to precisely measure the value added. This in turn provides additional evidence that firm scope is a function of value chain position, and allows me to use the VAGO as a measure of value chain position.

Testing the AC model and investigating the role of sequential production in shaping firm organization and scope requires three key measurements: a measure of value chain position, an estimate of the elasticity of substitution for final goods and an estimate of the dispersion of firm productivity. In the following section, I detail the geographic measures employed in this article.

3.1. City-level value chain position

The first measure of city-level value chain position is based on an industry-level measure developed by Antras et al. (2012), which I attribute to cities based on local production patterns. The industry-level upstreamness measure U_i developed by Antras et al. (2012) intuitively measures a product’s position in the economy-wide supply chain as its average distance from end use. This measure of an industry’s position on the supply

11 Firm ownership classification include private, state-owned, joint ventures and foreign-owned. The sample is limited to the period 2002–2013, after China’s entry into the WTO, and also limited to only those goods for which foreign ownership was allowed under WTO membership. Goods removed from the sample include various earth metals including gold, silver and platinum, as well as various manufactured goods and pharmacological goods.

12 For a more detailed discussion of these processing regimes, see Feenstra et al. (2013).

13 AC utilized U.S. Related Party trade data reported at the NAICS 6-digit level, which allowed them to identify just over 420 manufacturing industries. For more information about related party US trade data, see: <http://sasweb.ssd.census.gov/relatedparty/>.

14 Since all processing imports must, by rule, be re-exported by comparing the value of processing imports to exports at the city level, I can fairly accurately measure the value added by Chinese processing.

chain, U_i , is greater than or equal to 1, with more upstream industries having larger values. Antras et al. (2012) show that a column vector containing each industry's measure of U_i (I will call this vector U) can be generated with the following formula:

$$U = [1 - \Delta]^{-1} \mathbf{1}$$

where Δ is an $N \times N$ matrix with elements $\hat{d}_{ij}$ and $\mathbf{1}$ is a column vector of ones. $\hat{d}_{ij}$ is an open economy adjustment of d_{ij} such that $\hat{d}_{ij} = d_{ij} \frac{Y_i}{Y_i - X_i + M_i}$, where M_i and X_i denote exports and imports of sector i 's output.¹⁵

To construct U_i , I use Chinese I-O tables that distinguish between the input requirements for domestic production and for processing trade. This is critically important since I restrict the analysis to processing trade only, which may be produced with different technology and a different mix of inputs than other domestic production. The disadvantage of relying on I-O tables specific to processing trade is that they are only available at a relatively aggregate level, resulting in only 40 industries for which processing trade is observed.¹⁶ Therefore, I leverage variation in production patterns across cities and over time to identify the relationship between upstreamness and ownership at the city level. I construct the following measure of upstreamness:

$$U_{kt} = \sum_{i=1} U_i \times \left(\frac{\text{EX}_{ikt} + \text{IM}_{ikt}}{\text{EX}_{kt} + \text{IM}_{kt}} \right), \quad (9)$$

where EX_{ikt} and IM_{ikt} are processing exports and imports in industry i from or to city k in year t , while EX_{kt} and IM_{kt} are total processing exports and imports for city k in year t . U_{kt} measures city k 's weighted average of industry upstreamness, where each industries' weights are given by that industry's share of city k 's total processing trade in year t . In order to limit the possibility of introducing bias due to misreporting of trade flows, the sample is limited to cities for which imports and exports of processing trade are observed for at least 5 years in the sample. During the sample period, there are a total of 483 cities engaged in processing trade, of which 414 cities report data for 5 or more years.¹⁷

3.2. Optimal firm scope and value chain position

The above measure of supply chain position, U_{kt} provides an intuitive measure of city-level variation in value chain position; however, as noted above, it relies on fairly aggregate industry groups. Within these industry groups there could be significant variation in the true value chain position of processing trade, which could lead to measurement error and attenuation bias. For this reason, I also develop, and focus on, an alternative measure of value chain position that does not explicitly rely on U_i , but rather relies on the observed empirical relationship between value chain position and

15 Antras et al. (2012) show that an additional assumption must be made that $X_{ij}/X_i = M_{ij}/M_i$. This assumption imposes that the share of a country's industry i output used in industry j is the same both at home and abroad.

16 I would like to thank Robert Feenstra for sharing these I-O tables, which were originally published by the Chinese government.

17 Results reported in Section 4 are robust to including these 69 excluded cities.

the VAGO. I generate a city-level measure of VAGO for processing exports in city k in time t , given by:

$$VA/GO_{kt} = \frac{EX_{kt} - IM_{kt}}{EX_{kt}}. \quad (10)$$

According to FH, this measure of VAGO should be negatively correlated with upstreamness. They argue that this empirical regularity results from the fact that there are greater gains from integrating stages of production within a firm closer to final production. Therefore, as firm scope increases, so too does VAGO. Utilizing Equation (10) as a proxy for value chain position has the advantage of relaxing the assumption that an industry's output, measured at the aggregate or disaggregate levels, enter each supply chain at the same position. However, utilizing this measure does require that Equation (10) accurately measures VAGO at the city-by-year level.

This measure assumes that processing trade flows are imported and exported to and from the same city. In the event that this is not the case, this measure would overestimate city-level value added when there is a net inflow of processing imports from other cities, and underestimate when there is a net outflow. This potential source of bias is mitigated by the fact that, in order to avoid duties, Chinese factories must provide documentation to customs authorities to prove that all processing imports are used to create exports, and as mentioned previously, processing trade requires a contractual relationship between the Chinese producer and the firm seeking processing. For these reasons, most processing trade is processed within a single establishment, and so it is reasonable to assume that goods imported into a given city are usually re-exported from the same city. Additionally, I find limited empirical evidence to support substantial cross-city flows of processing trade imports. At the city-by-industry level, the correlation between processing imports and exports is 0.978, which suggests that this source of measurement error is limited.¹⁸ Even in the event of cross city processing trade flows, so long as they are not correlated with foreign ownership, such flows would only lead to a classical measurement error which would attenuate my results.

3.3. Substitutes vs. complements in production

The AC framework and Proposition 2 predicts that the incentive to own parts of the value chain depend not only on an intermediate's position in that chain, but also on the relative size of the elasticity of substitution between intermediate goods (α) and the elasticity of substitution of demand for final goods (ρ). To test this prediction, I require estimates of the final good demand elasticities for Chinese processing exports. To estimate the average demand elasticity of the production of each Chinese city, I employ demand elasticities estimated by Broda and Weinstein (2006) at the HS level. Using I-O tables for Chinese processing trade, I attribute an industry j 's demand elasticities to industry i , by i 's share of total intermediates needed to produce j .¹⁹ This provides an

18 Additionally, regressing total processing exports on processing imports, city- and industry fixed effects, I find that for every 1 dollar of processing imports generates 1.15 dollars of processing exports. This estimate is extremely precise, which further supports the assumption that cross-city processing trade flows are not a major source of measurement error.

19 Alfaro et al. (2015) have recently shown using firm-level data that the elasticity of substitution a firm faces does impact their ownership decision.

average final good demand elasticity for each intermediate i . I then construct an average city–year demand elasticity by constructing a weighted average in which a city’s exports of good i in time t act as weights. At the province level, average demand elasticity ranges from 32.01 for Hubei Province to 2.53 for Hainan Province. As noted by Antrás and Chor, no reliable estimate of the elasticity of substitution across segments of the value chain exists; therefore, I follow their strategy of focusing only on the implied demand elasticity, allowing for heterogeneity in the effect of value chain position on ownership by a city’s average demand elasticity.

3.4. Firm heterogeneity and productivity dispersion

When the framework developed by AC is generalized to allow for firm productivity heterogeneity, it is shown in AC Proposition 5 that an increase in the dispersion of productivity leads to more stages of the value chain being integrated. AC provide suggestive evidence that this is reflected in their data, by using the standard deviation of exports at the destination-by-industry level as a proxy for the dispersion of firm productivity. The CCTS allow me to conduct an alternative test of this hypothesis. While the CCTS are not at the firm level, they are very disaggregate. I observe exports by city of origin, destination country, HS8 product category (totaling over 7000 unique products) as well as ownership and customs regimes. All told, these categories yield just shy of 10 million unique export observations. Utilizing the distribution of exports, I estimate the slope coefficients of a power law distribution, as a proxy for the firm size distribution at the city level. For robustness I employ two methods to estimate the power law coefficient, both employed by [di Giovanni et al. \(2011\)](#).²⁰ The use of a power law distribution is supported by a wide range of studies that find it to be a good approximation of many economic relationships including firm size, productivity and sectoral trade flows ([Zipf, 1949](#); [Axtell, 2001](#); [Easterly et al., 2009](#)). The probabilistic statement of firm size following a power law distribution can be written in its continuous forms as:

$$Pr(S_i > s) = \left(\frac{s}{z_{max}} \right)^{-\zeta}. \quad (11)$$

Making the simplifying assumption that the observations of exports are reflective of the exporting firm size distribution, the parameter of interest is ζ . This parameter should not be read as the parameter governing the distribution of firm productivity (z from [Equation \(8\)](#)), but rather as combination of z and the elasticity of substitution between goods, where ζ is increasing in θ . As θ , and therefore ζ , increase, the dispersion of productivity declines. Therefore, according the AC model, one should expect a negative correlation between foreign ownership and ζ .

The first method of estimating the shape parameter, recently employed by [di Giovanni et al. \(2011\)](#), is based on a measure by [Axtell \(2001\)](#), and it makes direct use of the cumulative density function (CDF) in log form:

$$\ln(Pr[S_{it} > s]) = \alpha_{it} - \zeta_t^k \ln(s), \text{ for each } k \text{ and } t \quad (12)$$

20 Another recent example of estimation of the firm size distribution is [Eaton et al. \(2011\)](#).

Where $Pr(S_i > s)$ is the probability that firm i has exports greater than s . For each city, I take each observation of exports by destination, customs regime, ownership and HS8 product and compute $Pr(S_i > s)$ as the count of observations with export size greater than s , for every firm i . I then regress the natural log of exports on this implied probability to estimate ζ_t^k . I estimate Equation (12) using repeated cross sections for each year from 1997 to 2013.

The second method of estimating ζ_t^k is suggested by Gabaix and Ibragimov (2007) and relies on the relationship between firm rank and size under a power law distribution, $\log(\text{Rank}_{it}) = \text{constant} + \zeta_t^k \log(\text{size})$, while making a simple alteration to account for the strong bias in small samples. Following this method, I can simply regress the natural log of the rank of observation i minus $1/2$ on log sales:

$$\ln\left(\text{Rank}_{it} - \frac{1}{2}\right) = \alpha_{it} + \zeta_t^k \ln(S_{it}) + \epsilon, \text{ for each } k \text{ and } t. \quad (13)$$

Again, i indexes a unique export observation and S_i is the value of exports. Both methods of estimating the power law exponent of firm size provide estimates similar to those reported by di Giovanni et al. (2011), although slightly lower. The median slope coefficients are 0.43 and 0.42, respectively with a standard deviation of 2.8 and 1.4. Pooling across industries di Giovanni et al. (2011) report estimates of 1.048 and 0.869, respectively for these two measures. The lower estimates indicate higher levels of dispersion in the trade data than in firm sales data used by di Giovanni et al. (2011). One possible explanation for this difference is that the low end of the export sales distribution poorly represents the firm size distribution. Both of these measures are positively correlated; however, with a correlation of 0.52, significant deviation does remain across cities. I report the dispersion of Equations (12) and (13) in Figure 2, which demonstrates that outlier cities are also those cities less engaged in international trade.²¹

4. Estimation strategy and results

With the building blocks of the two measures of value chain position (derived from processing trade upstreamness and value added), a measure of foreign ownership (calculated as a share of processing exports produced in foreign-owned facilities), a measure of final demand elasticity (derived from trade elasticities as calculated by Broda and Weinstein (2006)) and lastly, various measures of the dispersion of firm size, all at the city-year level, I have the data necessary to construct a test both of the theory developed by AC and of my own measure of value chain position based on FH.

21 The correlation between these two measures, while not perfect, is highly significant, with a $p < 0.01$. I also investigated the method developed by Naldi (2003), which relies on the fact that under the assumption that firm size follows a power law distribution, there is a relationship between the Herfindahl-Hirschman index (HHI) and the power law exponent of firm size. While this method produced estimates that were closer on average to di Giovanni et al. (2011), the variance in these estimates was much higher than those estimates produced by Equations (12) and (13). This may be due to the fact that the method developed by Naldi (2003) uses only information about the tail of the distribution of exports and the fact that it requires a grid search over parameter space. For these reasons I do not report these estimates here.

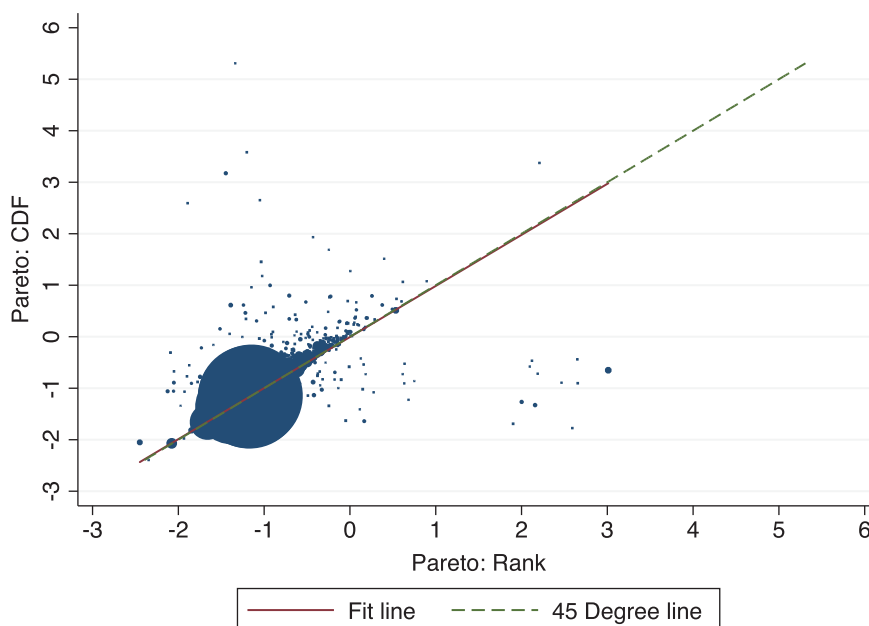


Figure 2. Correlation between CDF and rank-based measures of productivity dispersion.

Notes: The figure plots the correlation between two measures of log dispersions. The measure on the vertical axis is the CDF measure described in Equation (11) and the measure on the horizontal axis is described in Equation (12). The correlation between these two measures in levels is 0.52.

4.1. Value added as a measure of value chain position

I begin by providing evidence to support the use of VAGO as a measure of value chain position. Table 1 reports the correlation between U_{kt} and VAGO, as defined by Equations (9) and (10), respectively. Controlling for common time series variation, as well as fixed differences across provinces or cities, I find a strongly statistically significant relationship between these two measures of value chain position. City-level fixed effects do explain a large portion of the remaining variation in VAGO, as evidenced by R^2 in Column (5), despite this, city-level fixed effects do not materially impact the precision of the estimates. Because city-level fixed effects restrict identifying variation to within-city changes over time and because my measure of productivity dispersion is not time varying, inclusion of city-level fixed effects in my empirical model would preclude testing AC Proposition 5. For these reasons, my preferred specification includes province- rather than city-level fixed effects. Additionally, controlling for time-varying province characteristics in Column (6) has no meaningful effect on the point estimate, and increases precision slightly. In Columns (7) and (8), I split my sample into cities above and below the median of average elasticity of substitution of demand for final goods. While the correlation is negative in both cases as predicted by the theory, the relationship is much stronger for those cities specializing in goods with low elasticity of substitution. This implies that VAGO may be a better proxy for value chain position for these cities than for those specializing in goods with higher elasticity.

Utilizing VAGO as a measure of supply chain position requires not only that there be a relationship between VAGO and supply chain position, but also that this relationship

Table 1. Correlation between VAGO and upstreamness

	Dependent var.: Value added/gross output							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Upstreamness: U_{kt}	-0.047 (-1.41)	-0.038 (-1.17)	-0.079** (-2.40)	-0.068** (-2.09)	-0.113** (-2.49)	-0.114*** (-2.59)	-0.151*** (-2.70)	-0.094 (-1.37)
Year fixed effects		X		X	X	X	X	X
Prov. fixed effects			X	X				
City fixed effects					X	X	X	X
Add'l controls						X	X	X
$\rho^k < \rho^{med}$							X	
$\rho^k > \rho^{med}$								X
R^2	0.002	0.005	0.041	0.043	0.426	0.429	0.563	0.503
Observations	4515	4515	4515	4515	4515	4515	2216	2299

Notes: The dependent variable is the VAGO of all processing exports from China in year t from city k ($VAGO_{kt}$) which is regressed on the share of all processing exports from China in year t from city k that are sold by a foreign owned facility (U_{kt}). Z-scored 'Beta' coefficients reported. Standard errors are clustered by city and t -stats reported in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

is generally monotonic. As noted by Baldwin (2012), the relationship between VAGO and supply chain position may not be monotonic. Baldwin instead argues that there may be a U or 'smile'-shaped relationship, where the most value is generated at the ends of the supply chain. Since I do not directly observe supply chain position, in order to test for a quadratic relationship between VAGO and supply chain position, I perform a nonparametric local polynomial regression of U_{kt} on VAGO, which I report in Figure 3. I interpret these results as generally supportive of a monotonic and negative relationship between upstreamness and VAGO; however, it should be noted that the correlation does appear to dissipate at very low levels of U_{kt} . The monotonicity observed in the data need not be inconsistent with the 'smile' curve proposed by Baldwin, for two reasons. First, most of China's participation in the global value chain skews toward final production, and this is even more true for processing trade. Therefore, Chinese processing trade flows may predominantly represent the portion of the supply chain where value added is increasing in downstreamness as Figure 3 would suggest. Alternatively, it may be the case that the value added along stages of production does in fact follow the 'smile' curve relationship, but that due to the ability of firms to choose an optimal scope of production, as is suggested by FH, firms engaging in upstream production tend to specialize in a very narrow segment of the value chain, thereby reducing their VAGO. Determining which of these two possible explanations accounts for the difference between the results reported in this article and the smile curve hypothesis is an important area for future research and is beyond the scope of this article.

4.2. Testing the baseline model

Having established the link between value chain position and VAGO in Chinese processing trade flows, I next utilize VAGO as a proxy for value chain position to test

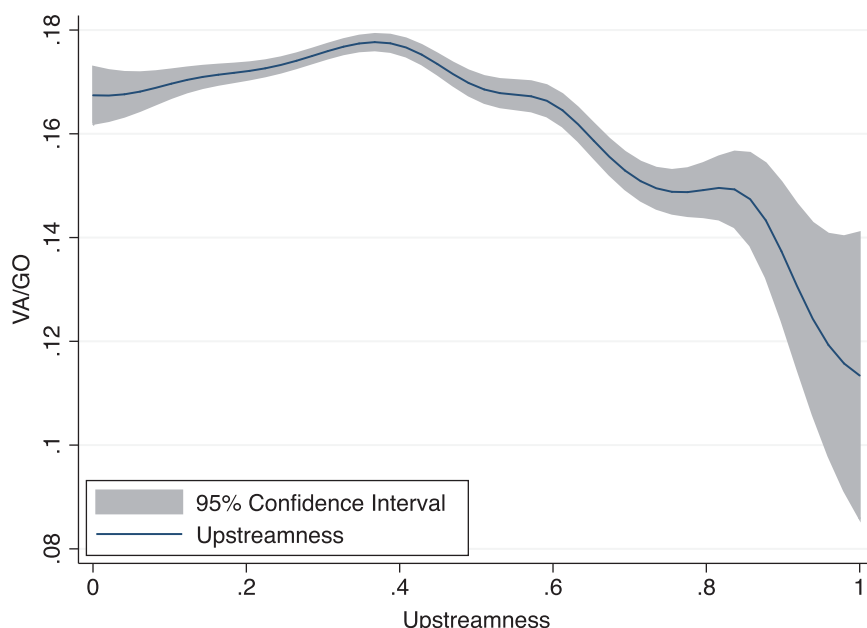


Figure 3. Nonparametric regression: VA/GO and upstreamness.

Notes: The figure plots the estimates of a nonparametric regression. It plots a local polynomial regression using local mean smoothing marginal effect. Observations are at the city–year level and the gray bands show the 95% confidence bands. U_{kt} is transformed from 0 to 1.

the predictions of AC. In order to test the baseline model, I estimate how city-level position on the global value chain affects foreign ownership. The baseline specification employs city-by-year variation in $VAGO_{kt}$, and the share of exports that are foreign-owned, and the implied final good demand elasticity as follows:

$$FO_{kt} = \alpha + \beta_1 VAGO_{kt} \times \mathbf{1}(\rho^k < \rho^{med}) + \beta_2 VAGO_{kt} \times \mathbf{1}(\rho^k > \rho^{med}) + \beta_3 \mathbf{1}(\rho^k > \rho^{med}) + X_{pt}' \beta_X + \rho_t + \mu_p + \epsilon_{kt}. \quad (14)$$

The dependent variable FO_{kt} is the share of all processing exports from China in year t from city k that are sold by a foreign owned facility, which I use as a proxy for vertical integration. $VAGO_{kt}$ is the baseline measure of upstreamness and is given by Equation (10). I interact $VAGO$ with two indicator variables meant to capture the potential heterogeneous effect of value chain position on foreign ownership for the sequential complements and substitutes cases.

As I mentioned above, there are no reliable estimates of α —the elasticity of substitution across intermediate goods in the value chain. However, since the substitute vs. complement case is distinguished by the magnitude of α relative to ρ , I use estimates of the demand elasticity for the final good as a proxy. When ρ is high, a firm is more likely in the ‘sequential complements case’ ($\rho > \alpha$), conversely, when ρ is low, a firm is more likely in the ‘sequential substitutes case’ ($\rho < \alpha$). Using city-level average demand elasticities, I categorize cities with ρ^k above the median demand elasticity, ρ^{med} , as complement cities and those with ρ^k below the median as substitute cities. In Equation

(14), $1(\rho^k < \rho^{med})$ and $1(\rho^k > \rho^{med})$ are indicator variables for the substitute and complement cases, respectively. AC Proposition 2 would predict that $\beta_1 < 0$ and $\beta_2 > 0$. I also include a vector of control variables that vary by province and year, including income, population, average wages, gross capital and the literacy rate. Lastly, I include year- and province fixed effects to control for any remaining differences across provinces and over time.

The inclusion of population, gross capital and literacy rates is intended to control for differences in factor endowments across provinces, while the inclusion of average wages is intended to control for productivity differences. The use of these types of controls is common in the literature and, given that my preferred measure of value chain position is VAGO, it may be important to control for differences in endowments and productivity.²² It is conceivable that some of these variables are endogenous to VAGO and therefore poor controls; however, my results are robust to the exclusion of these variables from the model and therefore this possibility is of minimal concern.

Table 2 reports estimates from Equation (14) for processing trade. All estimates are Z-scored and standard errors are clustered at the city level. In Columns (2)–(5), I allow the marginal effect of value chain position to have a heterogeneous effect on foreign ownership above and below the median demand elasticity. Doing so produces estimates that are consistent with the predictions of AC: $\beta_1 < 0$ and highly significant, while is $\beta_2 > 0$; however, it is indistinguishable from zero. Across all specifications $VAGO_{kt}$ as a measure of value chain position provides considerably more precise estimates for the sequential substitutes case. Under the assumption U_{kt} is an unbiased estimate of value chain position, the greater precision in estimates of the sequential substitutes case (i.e. $\rho^k < \rho^{med}$) is intuitive given that the correlation between U_{kt} and $VAGO_{kt}$ is stronger for cities with lower than the median elasticities of substitution—the substitute case. This can be seen in Columns (7) and (8) of Table 1, where I separately estimate the correlations between U_{kt} and $VAGO_{kt}$ for cities above and below the median level of average elasticity of substitution for exports. Despite the lack of precision in estimating β_2 , I am still able to reject the null hypothesis of a common coefficient at the 1% level of significance in all models.

In order to test AC Proposition 5, in Columns (6)–(7) of Table 2, I allow the foreign ownership share of processing exports to be a function of city-level productivity dispersion, as estimated by the power law parameter of export size. Columns (6) and (7) report estimates when measure productivity dispersions are measured using Equation (13) and (12), respectively. For both measures, as predicted by AC Proposition 5, I find a strongly significant negative relationship between firm productivity dispersion and foreign ownership. A one standard deviation increase in the estimated Pareto parameters leads to between a 0.3 and 0.5 standard deviation decrease in foreign ownership.

In an effort to establish the robustness of the above results, I estimate the effect of value chain position on ownership allowing for greater heterogeneity by final good demand elasticity, allowing flexibility in the determining the cutoff between substitutes and complements. This provides a useful test of the validity of the 50th percentile baseline cutoff. To do so, I estimate:

22 Similar controls are employed by Feenstra et al. (2013).

Table 2. The effect of supply chain position on foreign ownership: measured by VAGO

	Total	Substitutes vs. complements				Productivity dispersions	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\mathbf{1}(\rho^i > \rho^{med})$	−0.004 (−0.04)	0.173 (1.28)	0.303*** (3.01)	0.284*** (2.80)	0.302*** (2.85)	0.233** (2.19)	0.204* (1.90)
$\beta^1 : \text{VA}/\text{GO}_{kt} \times \mathbf{1}(\rho^k < \rho^{med})$		−0.310*** (−4.84)	−0.239*** (−3.83)	−0.187*** (−2.75)	−0.204*** (−2.76)	−0.149*** (−2.79)	−0.125** (−2.31)
$\beta^2 : \text{VA}/\text{GO}_{kt} \times \mathbf{1}(\rho^k > \rho^{med})$		0.081 (0.71)	0.146 (1.44)	0.146 (1.45)	0.149 (1.44)	0.111 (1.15)	0.093 (0.98)
Pareto: CDF						−0.413*** (−2.92)	
Pareto: Rank							−0.537*** (−9.71)
Year fixed effects	X	X		X	X	X	X
Prov. fixed effects	X		X	X	X	X	X
Add'l controls	X				X	X	X
p-val: $\beta^1 = \beta^2$		0.002	0.000	0.002	0.002	0.019	0.040
R^2	0.368	0.068	0.380	0.391	0.395	0.505	0.553
Observations	4055	3660	3660	3660	3660	3618	3621

Notes: The dependent variable is the share of all processing exports from China in year t from city k that is sold by a foreign-owned facility, which I use as a proxy for vertical integration. Z-scored ‘Beta’ coefficients reported. Standard errors are clustered by city and t -stats reported in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

$$\text{FO}_{kt} = \sum_{l=1}^5 \beta_{1,l} \text{VA}/\text{GO}_{kt} \times \mathbf{1}(\rho^k \in \Omega^{\rho,l}) + \sum_{l=1}^5 \beta_{2,l} \mathbf{1}(\rho^k \in \Omega^{\rho,l}) + \beta_X X_{pt} + \rho_t + \mu_p + \epsilon_{kt}. \tag{15}$$

where $\Omega^{\rho,l}$ is the subset of city-level final good demand elasticity corresponding to the l th quintile of VAGO_{kt} . I report estimates from Equation (15) in Table 3. These results, while qualitatively similar to those using the median, provide evidence of additional heterogeneity masked by the previous specification.

Employing this more flexible model leads to greater precision for estimates at the extreme ends of the distribution of city-level elasticities, and it appears that the substitute case may extend beyond the median of ρ , as I estimate the expected sign for this case ($\beta < 0$) for all but the top quartile. Moreover, these estimates are strongly significant in all but the second highest quartile, once productivity dispersion is also accounted for. This change in model specification appears to have little impact on the estimated role of firm-level heterogeneity, which remains highly significant. These results provide additional support for the hypothesis that the effect of value chain position on ownership does in fact depend on whether intermediates are complements or substitutes in production, and suggests that tests of this relationship should allow for considerable heterogeneity.

In a final test of this model, I additionally include city-level fixed effects in Column (4). Doing so substantially reduces the available variation to only within city over time changes in foreign ownership and VAGO. It also precludes testing AC Proposition 5,

Table 3. The effect across deciles of value chain position on foreign ownership

	Dependent var.: Foreign-owned trade share			
	(1)	(2)	(3)	(4)
$\beta^{0-20} : VA/GO^{kt} \times \mathbf{1}(\rho^i < \rho^{20})$	-0.236*** (-6.05)	-0.172*** (-4.51)	-0.146*** (-4.66)	-0.040** (-2.05)
$\beta^{20-40} : VA/GO^{kt} \times \mathbf{1}(\rho^{20} < \rho^i < \rho^{40})$	-0.114*** (-3.40)	-0.075** (-2.22)	-0.055* (-1.65)	0.015 (0.74)
$\beta^{40-60} : VA/GO^{kt} \times \mathbf{1}(\rho^{40} < \rho^i < \rho^{60})$	-0.056 (-1.51)	-0.055** (-2.03)	-0.054** (-1.96)	0.041 (1.49)
$\beta^{60-80} : VA/GO^{kt} \times \mathbf{1}(\rho^{60} < \rho^i < \rho^{80})$	-0.001 (-0.03)	-0.001 (-0.02)	0.003 (0.06)	0.064*** (2.87)
$\beta^{80-100} : VA/GO^{kt} \times \mathbf{1}(\rho^{80} < \rho^i)$	0.123*** (2.63)	0.115** (2.49)	0.110** (2.32)	0.027 (1.09)
Pareto: CDF		-0.405*** (-2.89)		
Pareto: Rank			-0.539*** (-20.50)	
Year fixed effects	X	X	X	X
Prov fixed effects	X	X	X	
City fixed effect				X
Add'l controls	X	X	X	X
Prov. productivity contrl.	X	X	X	X
p-val: $\beta^i = \beta^j \forall i \neq j$	0.000	0.000	0.000	0.003
Foreign-owned trade share mean	0.532	0.532	0.532	0.532
R^2	0.426	0.527	0.575	0.911
Observations	3660	3618	3621	3660

Notes: The dependent variable is the share of all processing exports from China in year t from city k that are sold by a foreign-owned facility, which I use as a proxy for vertical integration. Z-scored 'Beta' coefficients reported. Standard errors are clustered by city and t -stats reported in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

because my measure of productivity dispersion does not vary within cities. In this model, the estimated effect is smaller and my estimates are less precise; however, the general pattern of results remains. This implies that the identifying variation is not only coming from within cities over time but also across cities within provinces.

4.3. Upstreamness as an alternative measure of value chain position

As explained above, given the aggregate nature of available I-O tables, VAGO is my preferred measure of city-level value chain position. However, it is still informative to investigate the robustness of my finding to using local upstreamness, as defined by Equation (9), as an alternative measure of value chain position. Table 4 reports estimates of Equations (14) and (15) for processing trade. All estimates are Z-scored and standard errors are clustered at the city level. According to both theory and the observed correlation (i.e. $VAGO_{kt}$ is decreasing in upstreamness) the signs for β_1 and β_2 should reverse.

Consistent with the hypothesis that U_{kt} is a less precise measure of value chain position in this context, using U_{kt} as the measure of upstreamness produces somewhat

Table 4. The effect of value chain position on foreign ownership of processing trade

	Dependent var.: Foreign-owned trade share							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
$\mathbf{1}(\rho^k > \rho^{med})$	-0.012 (-0.16)	-0.748** (-2.13)	-0.769** (-2.29)	-0.641* (-1.95)	-0.659** (-2.01)	-0.553* (-1.87)	-0.436 (-1.60)	
$\beta^1 : U^{kt} \times \mathbf{1}(\rho^k < \rho^{med})$		0.476** (2.16)	0.265** (2.02)	0.139 (1.05)	0.157 (1.20)	0.175 (1.46)	0.199* (1.70)	
$\beta^2 : U^{kt} \times \mathbf{1}(\rho^k > \rho^{med})$		-0.110 (-0.30)	-0.493 (-1.49)	-0.508 (-1.55)	-0.507 (-1.55)	-0.388 (-1.33)	-0.250 (-0.92)	
Pareto: CDF						-0.336*** (-2.82)		
Pareto: Rank							-0.530*** (-9.61)	
$\beta^{0-20} : U^{kt} \times \mathbf{1}(\rho^i < \rho^{20})$								0.182* (1.95)
$\beta^{20-40} : U^{kt} \times \mathbf{1}(\rho^{20} < \rho^i < \rho^{40})$								0.060 (0.56)
$\beta^{40-60} : U^{kt} \times \mathbf{1}(\rho^{40} < \rho^i < \rho^{60})$								0.061 (0.34)
$\beta^{60-80} : U^{kt} \times \mathbf{1}(\rho^{60} < \rho^i < \rho^{80})$								-0.194 (-1.43)
$\beta^{80-100} : U^{kt} \times \mathbf{1}(\rho^{80} < \rho^i)$								-0.429*** (-3.64)
Year fixed effects	X	X		X	X	X	X	X
Prov. fixed effects	X		X	X	X	X	X	X
Add'l controls	X				X	X	X	X
p-val: $\beta^i = \beta^j \forall i \neq j$		0.120	0.021	0.043	0.037	0.050	0.095	0.000
RP mean	0.529	0.529	0.529	0.529	0.529	0.529	0.529	0.532
R ²	0.352	0.058	0.346	0.357	0.361	0.439	0.509	0.412
Observations	5725	5725	5725	5725	5725	5659	5664	4055

Notes: The dependent variable is the share of all processing exports from China in year t from city k that are sold by a foreign owned facility, which I use as a proxy for vertical integration. U_{kt} is the baseline measure of upstreamness and is given by equation (10). Z-scored ‘Beta’ coefficients reported. Standard errors are clustered by city and t -stats reported in parenthesis.
*p < 0.10, **p < 0.05, ***p < 0.01.

noisier estimates than VAGO. In Columns (4)–(7), when controlling for province- and time fixed effects, as well as time-varying province characteristics, the expected sign for both the sequential complement and substitute case is observed, $\beta_1 > 0$ and $\beta_2 < 0$, although almost all estimates are statistically indistinguishable from zero. I can, however, reject the null hypothesis that $\beta_1 = \beta_2$ at the 5% level in all but one specification. Additionally, once I estimate a more flexible model, allowing for the marginal effect to vary across quintiles, I once again observe a similar pattern of nonlinearity, in which the largest effects are concentrated at the ends of the distribution of final good elasticities. In Columns (6) and (7), I once again test AC Proposition 5. For both measures, as predicted by AC Proposition 5, I find a negative relationship between firm productivity dispersion and foreign ownership. A one standard deviation increase in the estimated Pareto parameters leads to between a 0.3 and 0.5 standard deviation decrease in foreign ownership. Lastly, in Column (8), I investigate the possibility of additional heterogeneity in the effect of U_{kt} on vertical integration. Similar to my findings using VAGO as a measure of value chain position, I find evidence that

Table 5. The effect of supply chain position on foreign ownership: measurement error and attenuation bias

	Dependent var.: Foreign-owned trade share			
	(1)	(2)	(3)	(4)
$\beta^1 : U_{kt} \times \mathbf{1}(\rho^k < \rho^{med})$	5.932 (0.84)	2.574 (0.97)	2.884 (0.76)	3.475 (0.76)
$\beta^2 : U_{kt} \times \mathbf{1}(\rho^k > \rho^{med})$	-1.209 (-0.69)	-2.294* (-1.78)	-2.288* (-1.75)	-2.499* (-1.93)
Year fixed effects	X		X	X
Prov. fixed effects		X	X	X
Add'l controls				X
p-val: $\beta^1 = \beta^2$	0.339	0.037	0.125	0.152
RP mean	0.529	0.529	0.529	0.529
Observations	3660	3660	3660	3660

Notes: The dependent variable is the share of all processing exports from China in year t from city k that are sold by a foreign owned facility, which I use as a proxy for vertical integration. To correct for measurement error I estimate the effect of U_{kt} on foreign ownership use 2SLS with $VAGO_{kt}$ as an instrument. RP mean is the average foreign ownership share across cities and over time. Z-scored 'Beta' coefficients reported. Standard errors are clustered by city and t -stats reported in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

the effects are concentrated within cities specializing high- and low-elasticity final goods.

These estimates, while less precise than those using $VAGO$ as a measure of value chain position, re-affirms the findings of AC. The lack of precision of these estimates is likely due to the aggregate nature of the underlying industry upstreamness measure, which may be biasing my estimates toward zero due to classical measurement error. One way to explore the possibility of bias due to measurement error is to use $VAGO_{kt}$ as an instrument for U_{kt} . In Table 5, I report the results of estimating Equation (14) using Two Stage Least Squares (2SLS) with $VAGO_{kt}$ interacted with indicator variables for the substitute and complement cases as instruments. Much like the Ordinary Least Squares (OLS) estimates measuring upstreamness with U_{kt} directly, β_2 is more precisely estimated, with β_1 being indistinguishable from zero. However, both point estimates are significantly larger than the OLS estimates, almost 10 times so. These results highlight the underlying challenge of accurately measuring position on the global supply chain, and provide suggestive evidence that the measure of upstreamness does suffer from measurement error, leading to attenuation of the estimated marginal effects of supply chain position on foreign ownership. As the study of supply chains advances, it will be important to continue to innovate and improve these measures.

4.4. Upstreamness as an alternative measure of value chain position

The baseline sample is restricted to the period 2002 through 2013, due to substantial restrictions on foreign ownership of Chinese firms prior to its entry to the WTO in 2001. Because foreign ownership was severely restricted prior to 2002, both across industries

and provinces, one would not expect to observe the optimal foreign ownership patterns as predicted by the AC framework, nor the optimal VAGO, as a proxy for optimal firm scope, predicted by FH. Therefore, this pre-period provides a helpful test of the identification strategy. If the same pattern of foreign ownership is present during these prior years as during the sample period of 2002 through 2013, it would suggest another, perhaps non-market explanation for the pattern.

In [Table 6](#), I report estimates for different subsamples. In Column (1), I estimate a common marginal effect for the entire sample period of 1997 through 2012. In Column (2), I allow the marginal effect to differ before and after Chinese WTO accession, while in Column (3), I further split the post-WTO period into 2002–2007 and 2008–2013. For the pre-WTO period, I observe the opposite signed effect as would be predicted by AC, while for the post-WTO period I observe the expected relationship. These results are consistent with pre-WTO prohibitions on foreign ownership that severely distorted optimal firm behavior. Additionally, splitting the post WTO period in Column (3), I find that point estimate in both the complements and substitutes case increase in absolute value after 2007. While these changes are not statistically significant, they may indicate a transition period after WTO entry. I further demonstrate this change by estimating the effect of value chain position on ownership with a 3-year moving sample window. I report the marginal effects for the complement and substitute cases over time in [Figure 4](#). It is clear that after WTO entry, the marginal effect in the substitute case changes dramatically. By the end of the sample period it is statistically different from the complements case, which is itself negative as predicted by AC. Not surprisingly, I also find that the correlation between VAGO and value chain position also strengthens after 2002. In [Figure 5](#), I report the sign of this correlation estimated across cities for a 3-year rolling window. Not only do these results provide a useful test of the identification strategy, but they also provide evidence regarding how much policies, such as the restriction on foreign ownership, can impact the formation of global value chains. Any important question, which is beyond the scope of this article due to data limitations, is to what extent the relaxation of these ownership restrictions impacted firm productivity by allowing firms to optimize the scope of production.

5. Conclusion

This investigation aims to deepen the understanding of the organization of the global value chain. Toward that end, I developed a novel test of the theoretical framework developed by [Antràs and Chor \(2013\)](#). Utilizing detailed CCTS, I use geographic variation in city-level value chain position of Chinese processing trade, along with foreign ownership shares of exports across cities over time, to evaluate the role of value chains in determining the organization and ownership of global trade. The findings support the following predictions of the AC model: (i) the incentive to own segments of the value chain depends critically on whether intermediates are substitutes or complements in production, and (ii) the share of vertically integrated firms is increasing in the dispersion of firm productivity. Additionally, I find evidence that the VAGO depends critically on supply chain position—VAGO increases moving down the supply chain, toward final production—which is consistent with FH. This finding allows me to use VAGO, as a proxy for city-level supply chain position. One advantage of this measure is that it does not require highly disaggregate industry input–output data.

Table 6. The effect of supply chain position on foreign ownership over time, measured by VAGO

	Dependent var.: Foreign-owned trade share		
	(1)	(2)	(3)
$\mathbf{1}(\rho^i > \rho^{med})$	0.247** (2.50)		
$\beta^1 : VA/GO^{kt} \times \mathbf{1}(\rho^i < \rho^{med})$	-0.188*** (-2.75)		
$\beta^2 : VA/GO^{kt} \times \mathbf{1}(\rho^i > \rho^{med})$	0.124 (1.28)		
$\mathbf{1}(\rho^i > \rho^{med}) \times t^{Pre2002}$		-0.236*** (-3.08)	-0.234*** (-3.01)
$\beta^1 : VA/GO^{kt} \times \mathbf{1}(\rho^i < \rho^{med}) \times t^{Pre2002}$		-0.023 (-0.49)	-0.024 (-0.50)
$\beta^2 : VA/GO^{kt} \times \mathbf{1}(\rho^i > \rho^{med}) \times t^{Pre2002}$		-0.210*** (-2.73)	-0.211*** (-2.76)
$\mathbf{1}(\rho^i > \rho^{med}) \times t^{Post2002}$		0.281*** (2.79)	
$\beta^1 : VA/GO^{kt} \times \mathbf{1}(\rho^i < \rho^{med}) \times t^{Post2002}$		-0.191*** (-2.72)	
$\beta^2 : VA/GO^{kt} \times \mathbf{1}(\rho^i > \rho^{med}) \times t^{Post2002}$		0.143 (1.49)	
$\mathbf{1}(\rho^i > \rho^{med}) \times t^{2002-2007}$			0.072 (1.02)
$\beta^1 : VA/GO^{kt} \times \mathbf{1}(\rho^i < \rho^{med}) \times t^{2002-2007}$			-0.127** (-2.12)
$\beta^2 : VA/GO^{kt} \times \mathbf{1}(\rho^i > \rho^{med}) \times t^{2002-2007}$			0.047 (0.57)
$\mathbf{1}(\rho^i > \rho^{med}) \times t^{Post2008}$			0.291*** (2.69)
$\beta^1 : VA/GO^{kt} \times \mathbf{1}(\rho^i < \rho^{med}) \times t^{Post2008}$			-0.148** (-2.22)
$\beta^2 : VA/GO^{kt} \times \mathbf{1}(\rho^i > \rho^{med}) \times t^{Post2008}$			0.140 (1.54)
Year fixed effects	X	X	X
Prov. fixed effects	X	X	X
Add'l controls	X	X	X
R^2	0.370	0.381	0.382
Observations	5131	5131	5131

Notes: The dependent variable is the share of all processing exports from China in year t from city k that are sold by a foreign-owned facility, which I use as a proxy for vertical integration. I allow for the effect to be heterogeneous over time, both before and after Chinese WTO accession entry, as well as before and after 2008. Z-scored 'Beta' coefficients reported. Standard errors are clustered by city and t -stats reported in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Using this proxy I provide additional support for the theoretical predictions of [Antràs and Chor \(2013\)](#).

Investigating the incentives of firms to own their intermediate goods supplies and to adjust the scope of production in the Chinese context not only provides the ability to

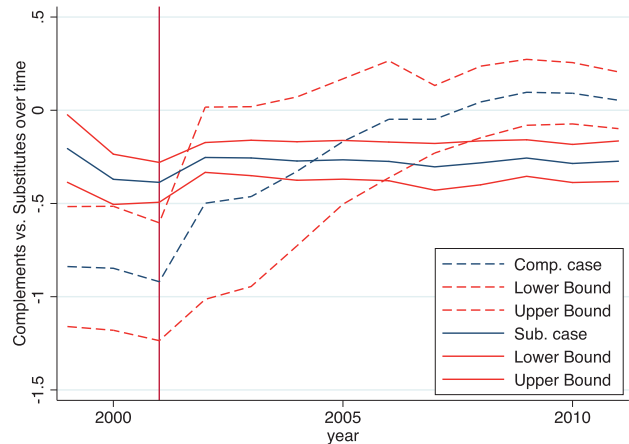


Figure 4. Effect of value chain position on ownership, evolution over time.
Notes: The figure plots the marginal effect of VAGO on foreign ownership separately for the sequential complements and sequential substitutes case with an OLS model, controlling for city- and year fixed effects as well as province-by-time controls. For each year the marginal effect is calculated using a moving 5-year window, including 2 lag and 2 lead years. Two standard error confidence bands are reported by the dashed lines above and below the marginal effect.

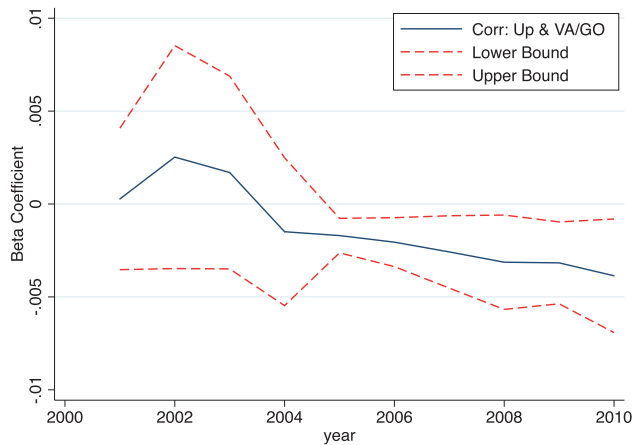


Figure 5. Correlation between upstreamness and VAGO over time.
Notes: The figure plots the correlation between upstreamness, as measured by U_k , and the VAGO ratio as measured by the marginal effect of VAGO ratio on upstreamness in a OLS model, controlling for city- and year fixed effects as well as province-by-time controls. For each year the marginal effect is calculated using a moving 5-year window, including 2 lag and 2 lead years. Two standard error confidence bands are reported by the dashed lines above and below the marginal effect.

examine these incentives using detailed data on processing trade, but also studying the Chinese economy provides a unique opportunity to explore these effects in an environment of major changes in economic development, organization of production and institutional policy. I find evidence to support the predictions of both AC and FH, and that both mechanisms strengthen after China's entry into the WTO and the subsequent relaxation of foreign ownership restrictions, indicating the importance of institutional policy in affecting organization of the global value chain.

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