Productivity and Organization in Portuguese Firms

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Using employer-employee matched and firm production quantity and input data for Portuguese firms, we study the endogenous response of productivity to firm reorganizations as measured by changes in the number of management layers. We show that, as a result of an exogenous demand or productivity shock that makes the firm reorganize and add a management layer, quantity-based productivity increases by about 6%, while revenue-based productivity drops by around 3%. Such

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a reorganization makes the firm more productive but also increases the quantity produced to an extent that lowers the price charged by the firm and, as a result, its revenue-based productivity as well.

I. Introduction

A firm's productivity depends on the way it organizes production. The decisions of its owners and managers on how to combine different inputs and factors of production with particular technologies, given demand for their product, determine the production efficiency of the firm. Clearly, these decision makers face many constraints and random disturbances. Random innovations or disruptions, regulatory uncertainties, and changes in tastes and fads, among many other idiosyncratic shocks, are undoubtedly partly responsible for fluctuations in firm productivity. However, these random—and perhaps exogenous—productivity or demand fluctuations also result in endogenous responses that change the way the firm's production is organized, thereby affecting its measured productivity. For example, a sudden increase in demand due to a product becoming fashionable can lead a firm to expand and add either a plant, a more complex management structure, a new division, or a new building. These investments are lumpy and, as such, will change the firm's production efficiency and prices discontinuously as well.

In this paper, we study the changes in productivity observed in Portuguese firms when they reorganize their management structure by adding or dropping layers of management. Consider a firm that wants to expand as a result of a positive demand shock and decides to add a layer of management (e.g., add another division and a CEO to manage the whole firm). The new organization is suitable for a larger firm and lowers the average cost of the firm, thereby increasing its quantity-based productivity. Moreover, the switch to an organizational structure fitted for a larger firm also reduces the marginal cost of the firm, leading to higher quantities and lower prices. Because organizational decisions are lumpy, at the moment of the switch, the firm will probably have an organizational structure that is still a bit large for its size. The implication is that changes in organization that add organizational capacity in the form of a new management layer lead to increases in quantity-based productivity but also reductions in revenue-based productivity through reductions in prices. Hence the endogenous response of firm productivity to exogenous shocks that trigger reorganization can be complex and differ depending on the measure of productivity used.

Using a recently developed measure of changes in organization, we show that these patterns are very much present in the Portuguese data. To illustrate the parallel case when a firm receives a negative shock, consider the example of a Portuguese firm producing "knitted and crocheted pullovers, cardigans, and similar articles" (NACE [Nomenclature des Activités Économiques dans la Communauté Européenne] 1772). This firm downsized heavily between 2002 and 2005 as a result of China's entry into the World Trade Organization (WTO) and the ensuing reduction in quotas and increased import competition. We observe that the quantity sold by the firm declined by 50%, but its price increased by 35%. The firm reduced its layers of management by firing several managers and employees performing secondary tasks and focusing on its main expertise by maintaining its sewers and embroiderers. Overall, its labor forced declined by 27 employees. Using the measures of productivity we explain in detail below, the result is a reduction in quantity-based productivity of 53%, combined with an increase in revenue-based productivity of 10.3%. The experience and behavior of this firm is by no means unique. Using many examples and a host of empirical measures, we show that reorganization and productivity are systematically linked in the way we describe.

Although the logic above applies to many types of organizational changes and other lumpy investments, we explain it in more detail using a knowledge-based hierarchy model that can guide us in our empirical implementation. Furthermore, this model provides an easy way to empirically identify changes in organization using occupational classifications. The theory of knowledge-based hierarchies was developed by Rosen (1982) and Garicano (2000) and, in an equilibrium context with heterogeneous firms, by Garicano and Rossi-Hansberg (2006) and Caliendo and Rossi-Hansberg (2012). In particular, we use the model of Caliendo and Rossi-Hansberg (2012), since it provides an application of this theory to an economy with firms that face heterogeneous productivity and demands for their products. In the context of Caliendo and Rossi-Hansberg (2012), we provide novel theoretical results that characterize the pattern of quantity-based and revenue-based productivity when firms reorganize as a result of exogenous demand or productivity shocks.

The basic technology is one that requires time and knowledge. Workers use their time to produce and generate problems, or production possibilities. Output requires solving these problems. Workers have knowledge that they use to try to solve these problems. If they know how to solve them, they do, and output is realized. Otherwise, they can redirect the problem to a manager one layer above. Such a manager tries to solve the problem and, if incapable of doing so, can redirect the problem to an even higher-level manager. The organizational problem of the firm is to determine how much each employee knows, how many employees to hire, and how many layers of management to use in production.

Using matched employer-employee data for the French manufacturing sector, Caliendo, Monte, and Rossi-Hansberg (2015) show how to use occupation data to identify the layers of management in a firm.[1] They show that the theory of knowledge-based hierarchies can rationalize the layer-level changes in the number of employees and wages as firms grow either with or without changing layers. For example, as implied by the theory, a reorganization that adds a layer of management leads to increases in the number of hours employed in each layer but also to a reduction in the average wage in each preexisting layer. In contrast, when firms grow without reorganizing, they add hours of work to each layer and increase the wages of each worker. This evidence shows that when firms expand and contract, they actively manage their organization by hiring workers with different characteristics. The Portuguese data exhibit the same patterns that Caliendo, Monte, and Rossi-Hansberg (2015) found for France. Importantly, the detailed input, revenue, and quantity data for Portugal allows us to go a step further and measure the productivity implications of changes in organization.

Measuring productivity well is notoriously complicated, and the industrial organization literature has proposed a variety of techniques to do so (see, e.g., Berry, Levinsohn, and Pakes 1995; Olley and Pakes 1996; Levinsohn and Petrin 2003; Wooldridge 2009; De Loecker and Warzinsky 2012; Ackerberg, Caves, and Frazer 2015). The first issue is whether we want to measure quantity-based or revenue-based productivity. The distinction is crucial, since the former measures how effective a firm is in transforming inputs and factors into output, while the latter also measures any price variation, perhaps related to markups, that results from market power. The ability of firms to determine prices due to some level of market power is a reality that is hard to abstract from, particularly when considering changes in scale that make firms move along their demand curve and change their desired prices.

To measure the effect of organizational change on quantity-based productivity, we need a methodology that can account for demand, markup, and productivity shocks over time and across firms.[2] We use the MULAMA methodology proposed by Forlani et al. (2016). This method uses the same cost-minimization assumptions as previous methodologies, such as that of De Loecker and Warzinsky (2012), but makes some relatively strong assumptions on the way demand differs across firms in order to allow for correlated demand and productivity disturbances. Furthermore, it is amenable to introducing the organizational structure we described

[1] Following Caliendo, Monte, and Rossi-Hansberg (2015), several studies have shown that occupational categories can be used to identify layers of management in other data sets. For example, Tåg (2013) uses Swedish data, and Friedrich (forthcoming) uses Danish data.

[2] See Marschak and Andrews (1944) and Klette and Griliches (1996) for a discussion of the output price bias when calculating productivity.

above. Note also that since we focus on changes in quantity-based productivity as a result of a firm reorganization, we can sidestep the difficulties in comparing quantity-based productivity across horizontally differentiated products. Using this methodology and quantity data available in the Portuguese data, we find that adding (dropping) layers is associated with increases (decreases) in quantity-based productivity.[3] In addition, we extend the methodology to structurally estimate revenue-based productivity and show that adding (dropping) layers is associated with decreases (increases) in revenue-based productivity, particularly when we properly control for past prices and shocks, as suggested by the theory.[4]

Up to this point, we have not addressed the issue of causality. The results above state only that adding layers coincides with increases in quantity-based productivity and declines in revenue-based productivity. To the extent that organization, like capital infrastructure, cannot adjust much in the short run in the wake of current-period shocks, the above results can be interpreted as causal. We relax this assumption by using a set of instruments represented by demand and cost shocks predicting organizational changes but uncorrelated with current productivity shocks. The MULAMA estimation strategy allows us to measure these past productivity, demand, and markups shocks. We show that our results on both revenue-based and quantity-based productivity remain large and significant.

Finally, we go one step further and use the quota removals in subindustries of the textile and apparel sector that resulted from China's entry into the WTO as an instrument for a firm's reorganization. Focusing on this sector allows us to explore the implications of a clearly exogenous negative demand shock on reorganization and productivity. In section III, we present a couple of detailed examples of individual firms in this industry that changed their labor force composition and therefore their organization and productivity. In section V.D, we use this exogenous demand shock as an instrument for the change in layers and apply our general methodology. We find that the behavior of firms as a result of the reduction in quotas is very much in line with the rest of our findings.[5]

[3] In Caliendo et al. (2018), a working-paper version of this publication, we show that our findings survive a variety of robustness checks and alternative formulations of the productivity process. For example, we can allow for changes in organization to have a permanent or only a contemporaneous impact on quantity-based productivity.

[4] In Caliendo et al. (2018), we also find, using a host of different measures of revenue productivity—from value added per worker to Olley and Pakes (1996), Wooldridge (2009), and De Loecker and Warzinsky (2012)—that adding layers is related to decreases in revenue-based productivity.

[5] In a related result, Garcia-Marin and Voigtländer (2019) find, among new Chilean exporters, a reduction in revenue-based productivity and an increase in quantity-based productivity. The mechanism and findings in our paper can be used directly to rationalize their findings, since exporting amounts to a firm revenue shock.

In sum, this paper shows that the organizational structure of firms, as measured by their hierarchical occupational composition, has direct implications on the productivity of firms. As they add organizational layers, their quantity-based productivity increases, although the corresponding expansion decreases their revenue productivity as they reduce prices.[6] This endogenous component of productivity determines, in part, the observed heterogeneity in both revenue-based and quantity-based productivity across firms. Failure to reorganize in order to grow can, therefore, result in an inability to exploit available productivity improvements. This would imply that firms remain inefficiently small, as has been documented in some developing countries (Hsieh and Klenow 2014).

The literature on firm organization and productivity is small and only broadly related to fully specified theories. Bloom and van Reenen (2011) and Henderson and Gibbons (2013) provide nice overviews of the findings relating organization or human resources management practices and productivity. Studies that focus on particular industries, like that of Ichniowski, Shaw, and Prennushi (1997), find large effects of certain management practices on productivity, although Bloom and van Reenen (2011) argue that causality is not always credibly established, and many results use only cross-sectional data or disappear when using time-series variation. Ichniowski and Shaw (2003) provide a survey of the literature and argue that advances in information technology and a skilled labor force seem to generate increases in productivity. Caroli and van Reenen (2001) provide perhaps the best example of a study that links organizational change to measures of productivity using detailed, firm-level data. Subsequently, Bloom and van Reenen (2011) have credibly established an empirical link between management practices and productivity, as have Lazear and Shaw (2007), from the perspective of personnel economics. Garicano and Hubbard (2016) study the role of organization on productivity among law firms and find large effects. Relative to this literature, we offer a consistent measure of a characteristic of a firm's organization: the number of layers.[7] Changes in this measure can be interpreted within a fully fledged theory of the organization of a firm's labor force. Furthermore, the theory specifies the effects that changes in layers should

[6] Our results also relate to the cost pass-through literature, given that a reorganization affects cost and, in turn, prices. As a result, in this paper, we also calculate the cost pass-through for all firms (what we refer to as the unconditional measure) and for firms that change organization (conditional). We find that the unconditional cost pass-through estimates are similar to the ones in the literature but that the estimates conditional on firms reorganizing are somewhat larger, as expected.

[7] Rajan and Wulf (2006) and Guadalupe and Wulf (2010) also measure changes over time in management layers and relate them to economic outcomes. They do not, however, link organizational change to structural measures of quantity- and revenue-based productivity.

have on revenue-based versus quantity-based productivity. The main contribution of this paper is thus to provide a theory-consistent estimation of the effect that this form of organizational change has on revenue-based and quantity-based productivity for a large fraction of firms in the Portuguese economy.

The rest of this paper is organized as follows. In section II, we provide a short recap of the knowledge hierarchy theory that we use to guide our empirical exploration and describe its implications for productivity. We then finish the section with several examples of Portuguese firms that went through a process of reorganization. Section III discusses the Portuguese manufacturing data set we use in the paper and presents the basic characteristics of Portuguese production hierarchies. In particular, we show that firms with different numbers of layers are in fact different and that changes in the number of layers are associated with the expected changes in the number of workers and wages at each layer. Section IV presents the methodology we use to measure quantity-based and revenue-based productivity. Section V presents our main empirical specifications and results, as well as our results for revenue-based and quantity-based productivity using the China textile shock. Section VI presents a variety of robustness checks and our estimates of aggregate effects. Section VII concludes. The appendix (apps. A–F are available online) includes more details on our data set, a description of all tables and figures, and additional derivations and robustness tests of the results in the main text.

II. Sketch of a Theory of Organization and Its Empirical Implications

The theory of knowledge-based hierarchies, initially proposed by Garicano (2000), has been developed using a variety of alternative assumptions (for a review, see Garicano and Rossi-Hansberg 2015). Here we discuss the version of the technology with homogenous agents and heterogeneous demand developed by Caliendo and Rossi-Hansberg (2012).

So consider firm i in period t that faces a Cobb-Douglas technology

$$Q_{it}(O_{it}, M_{it}, K_{it}) = A_{it} O_{it}^{\alpha_O} M_{it}^{\alpha_M} K_{it}^{\gamma - \alpha_M - \alpha_O}, \tag{1}$$

with quantity-based productivity A_{it}; returns to scale given by γ; and O_{it} denoting the labor input, M_{it} material inputs, and K_{it} capital. The parameter $\alpha_O \geq 0$ represents the expenditure share on the labor input, $\alpha_M \geq 0$ on material, and $\gamma - \alpha_M - \alpha_O$ on physical capital. The labor input is produced using the output of a variety of different workers with particular levels of knowledge. The organizational problem is embedded in this input. That is, we interpret the output of the knowledge hierarchy as generating the labor input of the firm. Hence, in the rest of this section, we focus on the organizational problem of labor and abstract from capital and material. We return to the other factors in our estimation of productivity below.

Production of the labor input requires time and knowledge. Agents employed as workers specialize in production and use their unit of time working in the production floor and their knowledge to deal with any problems they face in production. Each unit of time generates a problem that, if solved, yields 1 unit of output. Agents employed as managers specialize in problem-solving, use h units of time to familiarize themselves with each problem brought by a subordinate, and solve the problems using their available knowledge. Problems are drawn from a distribution $F(z)$, with $F''(z) < 0$. Workers in a firm know how to solve problems in an interval of knowledge $[0, z_L^0]$, where the superindex 0 denotes the layer (0 for workers) and the subindex the total number of management layers in the firm, L. Problems outside this interval are passed on to managers of layer 1. Hence, if there are n_L^0 workers in the firm, $n_L^1 = hn_L^0(1 - F(z_L^0))$, managers of layer 1 are needed. In general, managers in layer ℓ learn $[Z_L^{\ell-1}, Z_L^\ell]$, and there are $n_L^\ell = hn_L^0(1 - F(Z_L^{\ell-1}))$ of them, where $Z_L^\ell = \sum_{l=0}^{\ell} z_L^l$. Problems that are not solved by anyone in the firm are discarded. Agents with knowledge z_L^ℓ obtain a wage $w(z_L^\ell)$, where $w'(z_L^\ell) > 0$ and $w''(z_L^\ell) \geq 0$. Market wages simply compensate agents for their cost of acquiring knowledge.

The organizational problem of the firm is to choose the number of workers in each layer, their knowledge and therefore their wages, and the number of layers.[8] Hence, consider a firm that produces a quantity O of the labor input: $C_L(O; w)$ is the minimum cost of producing a labor input O with an organization with L layers at a prevailing wage schedule $w(\cdot)$; namely,

$$C_L(O; w) = \min_{\{n_L^\ell, z_L^\ell\}_{l=0}^{L} \geq 0} \sum_{\ell=0}^{L} n_L^\ell w(z_L^\ell), \tag{2}$$

subject to

$$O \leq F(Z_L^L) n_L^0, \tag{3}$$

$$n_L^\ell = hn_L^0[1 - F(Z_L^{\ell-1})] \text{ for } L \geq \ell > 0, \tag{4}$$

$$n_L^L = 1. \tag{5}$$

[8] Throughout, we refer to the number of layers of the firm by the number of management layers. So firms with only workers have zero layers, firms with workers and managers have one layer, etc.

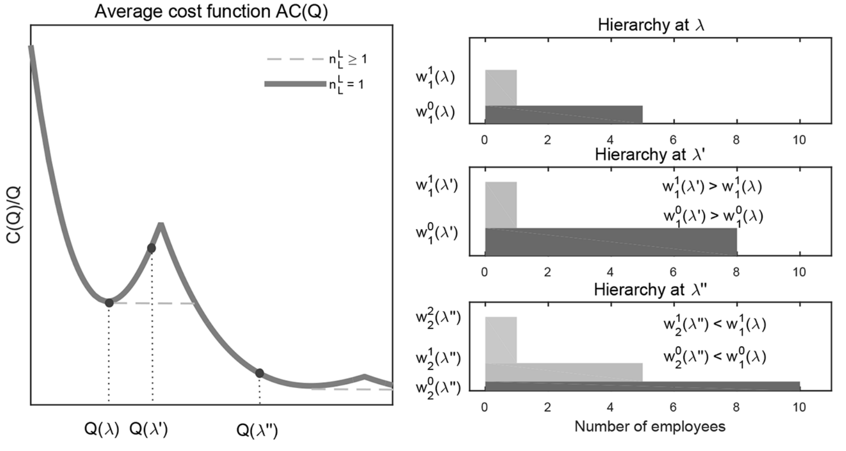

FIG. 1.—Average cost and organization.

The first constraint just states that total production of the labor input should be larger than or equal to O, the second is the time constraint explained above, and the third states that all firms need to be headed by one CEO. The last constraint is important since it implies that small firms cannot have a small fraction of the complex organization of a large firm. We discuss below the implications of partially relaxing this constraint. The variable cost function is given by

$$C(O; w) = \min_{L\geq 0} \{C_L(O; w)\}.$$

Caliendo and Rossi-Hansberg (2012) show that the average cost function ($AC(O; w) = C(O; w)/O$) that results from this problem exhibits the properties depicted in figure 1 (which we reproduce from Caliendo, Monte, and Rossi-Hansberg 2015). Namely, it is U-shaped given the number of layers, with the average cost associated with the minimum efficient scale that declines as the firm adds layers. Each point in the average cost curve in the figure corresponds to a particular organizational design. Note that the average cost curve faced by the firm is the lower envelope of the average cost curve for a given number of layers. The crossings of these curves determine a set of output thresholds (or, correspondingly, demand thresholds) at which the firms decide to reorganize by changing the number of layers.[9] The overall average cost, including material and capital, of a firm that is an input price taker will have exactly the same shape (given our specification of the production function in eq. [1] under $\gamma = 1$).

[9] Note that since output increases (decreases) discontinuously when the firm adds (drops) layers, the average cost curve is discontinuous as a function of the level of demand λ.

Consider the three dots in the figure, which correspond to firms that face different levels of demand as parameterized by λ.[10] Suppose that after solving the corresponding profit maximization using the cost function above, a firm that faces a demand level of λ decides to produce $Q(\lambda)$ (or $q(\lambda)$ in logs). The top right panel of figure 1 tells us that it will have one layer with five workers and one layer with one manager above them. The figure also indicates the wages of each of them (the height of each bar), which is increasing with their knowledge. Now consider a firm that as a result of a demand shock expands to $Q(\lambda')$ without reorganizing, that is, keeping the same number of layers. The firm expands the number of workers and increases their knowledge and wages. The reason is that the one manager needs to hire more-knowledgeable workers, who ask questions less often, in order to increase the manager's span of control. In contrast, consider a firm that expands to $Q(\lambda'')$. This firm reorganizes by adding a layer. It also hires more workers at all preexisting layers. However, it hires less-knowledgeable workers, at lower wages, in all preexisting layers. The reason is that by adding a new layer, the firm can avoid paying multiple times for knowledge that is rarely used by the bottom ranks in the hierarchy. In the next section, we show that all these predictions are confirmed by the data.

We can also use figure 1 to show how the organizational structure changes as we relax the integer constraint of the top manager, in (5). First, note that at the minimum efficient scale (MES), which is given by the minimum of the average cost, having one manager at the top is optimal for the firm. So the constraint in (5) is not binding. Hence relaxing the constraint can affect the shape of the average cost function on segments to the right and to the left of the MES. The reason why average costs rise for quantities other than the MES is that firms are restricted to having one manager at the top. Otherwise, the firm could expand the optimal organizational structure at the MES by just replicating the hierarchy proportionally as it adds or reduces managers at the top.

For instance, suppose we allow organizations to have more than one manager at the top; namely, $n_L^L \geq 1$. Figure 1 presents dashed lines that depict the shape of the average cost for this case. As we can see, the average cost is flat for segments to the right of the MES up to the point at which the firm decides to add a new layer. At the moment of the switch, the average cost starts falling until it reaches the MES, at which point it becomes flat again. All the predictions that we discussed before still hold

[10] In our examples here, we focus on changes in the level of demand. Below, we will further consider changes in the exogenous component of productivity and changes in markups. Indeed, whatever pushes the firm to change its desired output can affect a firm's organizational structure.

for this case. The only difference is the way in which firms expand after they reach their MES up to the point at which they reorganize. We allow for this extra degree of flexibility when we use the structure of the model and take it to the data.[11]

A. *Productivity Implications: Theory*

In section II.B, we show that firms that grow or shrink substantially do so by adding or dropping management layers. These reorganizations also have consequences on the measured productivity of firms. In the model above, quantity-based productivity of a firm in producing the labor input can be measured as the inverse of the average cost at constant factor prices; namely, $Q(\lambda)/\bar{C}(Q(\lambda); C(\cdot; 1), 1, 1)$, where $\bar{C}(Q(\lambda); C(\cdot; w), P_{M}, r)$ denotes the overall cost function of the firm and P_{M} and r the prices of material and capital. Note that $Q(\lambda)$ denotes quantity produced and not revenue. Revenue-based productivity is instead given by $P(\lambda)Q(\lambda)/\bar{C}(Q(\lambda); C(\cdot; 1), 1, 1)$, where $P(\lambda)$ denotes the firm's output price.

Quantity-based productivity increases with an increase in λ when the firm adds layers. The reason is simply that any voluntary increase in layers is accompanied by an increase in the quantity produced, which results in a lower average cost for the firm when using the new organizational structure. The firm is only willing to add an extra layer of management and hire more managers that do not generate production possibilities at a higher cost if it can use the new organization to produce more at a lower average and marginal cost. Of course, under standard assumptions that lead to a downward-sloping demand, the increase in quantity will also decrease the price that consumers are willing to pay for the good. Note that since the firm is choosing the level of λ at which it switches layers, we know that profits will be continuous in λ. This implies that the increase in revenue has to be identical to the increase in variable costs. Given that, in the presence of fixed production costs, total revenue has to be larger than variable costs in order for profits to be nonnegative, the proportional increase in revenue will be smaller than the proportional increase in costs. The result is a decline in revenue-based productivity.

[11] Alternatively, one could also relax the integer constraint by letting $n_L^L \geq \epsilon$, where $1 > \epsilon > 0$. Following the discussion above, in this case, the average cost also has flat segments to the left of the MES, up to the point at which it reaches $n_L^L = \epsilon$. At this point, the average cost jumps to the level of the MES of the new optimal (and lower) number of layers. Depending on the value of ϵ, this will imply that the firm might decide to drop more than one layer. If ϵ is low enough, the average cost curve will be a step function with no smoothing declining segments. The lower is ϵ, the easier it is for the firm to produce less quantity with more layers, and in the limit, as $\epsilon \rightarrow 0$, firms converge to $L = \infty$. This case is counterfactual, since we observe that in most cases, firms expand by adding one layer at the time (see sec. III).

The logic above uses the following assumptions, which are necessary for the proof of proposition 1 below.

ASSUMPTION 1. Firms face fixed production costs, and their chosen price is an increasing function of their marginal cost.

PROPOSITION 1. Given assumption 1, (*a*) quantity-based productivity increases with a marginal increase in λ when the firm adds layers, and (*b*) revenue-based productivity decreases with a marginal increase in λ when the firm adds layers.

Proof. Without loss of generality, we fix factor prices and focus on the problem of one firm. Profits of a firm with demand draw λ producing with L layers are denoted $\pi(\lambda, L) = P(\lambda, L)Q(\lambda, L) - \bar{C}(Q(\lambda, L); C_L(\cdot; 1), 1, 1) - F$, where we denote the price and quantity produced $P(\lambda, L)$ and $Q(\lambda, L)$, respectively, given λ and L, and the fixed production costs F. To ease notation, we let $\bar{C}(Q(\lambda, L); C_L) \equiv \bar{C}(Q(\lambda, L); C_L(\cdot; 1), 1, 1)$. The level of demand at which the firm is indifferent between producing with L and $L + 1$ layers is denoted $\bar{\lambda}$; namely, $\pi(\bar{\lambda}, L) = \pi(\bar{\lambda}, L + 1) \geq 0$.

We prove proposition 1*a* by contradiction. Consider first how quantity-based productivity changes when a firm at $\bar{\lambda}$ experiences demand $\bar{\lambda} + \varepsilon$—for $\varepsilon > 0$, infinitesimally small—and optimally decides to add a layer.[12] Toward a contradiction, suppose that quantity-based productivity is lower when the firm adds a layer; that is,

$$\frac{Q(\bar{\lambda}, L + 1)}{\bar{C}(Q(\bar{\lambda}, L + 1); C_{L+1})} \leq \frac{Q(\bar{\lambda}, L)}{\bar{C}(Q(\bar{\lambda}, L); C_L)}.$$

In the remainder of the proof, we show that there exists an alternative feasible choice of quantity, $Q'(\bar{\lambda}, L + 1)$, that attains higher profits than $Q(\bar{\lambda}, L + 1)$, therefore contradicting the optimality of $Q(\bar{\lambda}, L + 1)$. First, note that—as shown in proposition 2 of Caliendo and Rossi-Hansberg (2012)—since the minimum average cost for a given number of layers decreases with the number of layers, that is,

$$Q_L^* \equiv \min_Q \frac{\bar{C}(Q; C_L)}{Q} \geq Q_{L+1}^* \equiv \min_Q \frac{\bar{C}(Q; C_{L+1})}{Q},$$

and the level of output that achieves this minimum increases with the number of layers, there exists a quantity $Q'(\bar{\lambda}, L + 1) > Q(\bar{\lambda}, L)$ such that

$$\frac{Q(\bar{\lambda}, L + 1)}{\bar{C}(Q(\bar{\lambda}, L + 1); C_{L+1})} \leq \frac{Q(\bar{\lambda}, L)}{\bar{C}(Q(\bar{\lambda}, L); C_L)} \leq \frac{Q'(\bar{\lambda}, L + 1)}{\bar{C}(Q'(\bar{\lambda}, L + 1); C_{L+1})}. \tag{6}$$

Note that $Q'(\bar{\lambda}, L + 1) > Q(\bar{\lambda}, L + 1)$ always, since $Q(\bar{\lambda}, L + 1)$ is in the decreasing segment of the average cost curve, that is, $Q(\bar{\lambda}, L + 1) \leq Q_{L+1}^*$.

[12] To ease notation, we drop from the proof, from now on, ε.

To see this, note that if the firm had chosen a quantity level associated with the same average cost but on the increasing segment of the average cost curve, that is, $Q''(\bar{\lambda}, L+1) \geq Q^*_{L+1}$, such that

$$\frac{Q''(\bar{\lambda}, L+1)}{\bar{C}(Q''(\bar{\lambda}, L+1); C_{L+1})} = \frac{Q(\bar{\lambda}, L+1)}{\bar{C}(Q(\bar{\lambda}, L+1); C_{L+1})},$$

the firm would have set lower prices and obtained lower profits. Therefore, $Q'(\bar{\lambda}, L+1) > Q(\bar{\lambda}, L+1)$.

Since the marginal cost is increasing in quantity—as shown in proposition 1 of Caliendo and Rossi-Hansberg (2012)—if prices are increasing in the marginal cost, then $P(Q'(\bar{\lambda}, L+1)) \geq P(Q(\bar{\lambda}, L+1))$. Combined with inequality (6), the latter implies that

$$\frac{P(Q'(\bar{\lambda}, L+1))Q'(\bar{\lambda}, L+1)}{\bar{C}(Q'(\bar{\lambda}, L+1); C_{L+1})} \geq \frac{P(Q(\bar{\lambda}, L+1))Q(\bar{\lambda}, L+1)}{\bar{C}(Q(\bar{\lambda}, L+1); C_{L+1})}.$$

Since the cost function—as shown in proposition 1 of Caliendo and Rossi-Hansberg (2012)—is strictly increasing in quantity, a fortiori

$$\begin{aligned} &P(Q'(\bar{\lambda}, L+1))Q'(\bar{\lambda}, L+1) - \bar{C}(Q'(\bar{\lambda}, L+1); C_{L+1}) \\ &\geq P(Q(\bar{\lambda}, L+1))Q(\bar{\lambda}, L+1) - \bar{C}(Q(\bar{\lambda}, L+1); C_{L+1}); \end{aligned}$$

that is, the profits associated with $Q'(\bar{\lambda}, L+1)$ are higher than those associated with $Q(\bar{\lambda}, L+1)$. This is a contradiction. Hence quantity-based productivity is strictly higher after adding layers at $\bar{\lambda}$. So we have proven proposition 1*a*, namely, that quantity-based productivity increases with a marginal increase in λ when the firm adds layers.

We prove proposition 1*b* directly. Consider how revenue-based productivity changes when the firm with demand level $\bar{\lambda}$ adds a layer. Since $\pi(\bar{\lambda}, L) = \pi(\bar{\lambda}, L+1)$,

$$\begin{aligned} &P(\bar{\lambda}, L+1)Q(\bar{\lambda}, L+1) - P(\bar{\lambda}, L)Q(\bar{\lambda}, L) \\ &\quad = \bar{C}(Q(\bar{\lambda}, L+1); C_{L+1}) - \bar{C}(Q(\bar{\lambda}, L); C_L). \end{aligned}$$

Since $\pi(\bar{\lambda}, L+1) \geq 0$ and $F > 0$, $P(\bar{\lambda}, L+1)Q(\bar{\lambda}, L+1) > \bar{C}(Q(\bar{\lambda}, L+1); C_{L+1})$, which implies that

$$\begin{aligned} &\frac{P(\bar{\lambda}, L+1)Q(\bar{\lambda}, L+1) - P(\bar{\lambda}, L)Q(\bar{\lambda}, L)}{P(\bar{\lambda}, L+1)Q(\bar{\lambda}, L+1)} \\ &\quad < \frac{\bar{C}(Q(\bar{\lambda}, L+1); C_{L+1}) - \bar{C}(Q(\bar{\lambda}, L); C_L)}{\bar{C}(Q(\bar{\lambda}, L+1); C_{L+1})}, \end{aligned}$$

or

$$\frac{P(\bar{\lambda}, L)Q(\bar{\lambda}, L)}{\bar{C}(Q(\bar{\lambda}, L); C_L)} > \frac{P(\bar{\lambda}, L+1)Q(\bar{\lambda}, L+1)}{\bar{C}(Q(\bar{\lambda}, L+1); C_{L+1})}.$$

Hence, we have proven proposition 1*b*, namely, that revenue-based productivity decreases with a marginal increase in λ when the firm adds layers. QED

This effect in both types of productivity is illustrated in figure 2, where we consider the effect of a shock in λ that leads to a reorganization that adds one layer of management.

In sum, firms that add layers as a result of a marginal revenue shock increase their quantity discontinuously. The new organization is more productive at the new scale, resulting in an increase in quantity-based productivity, but the quantity expansion decreases price and revenue-based

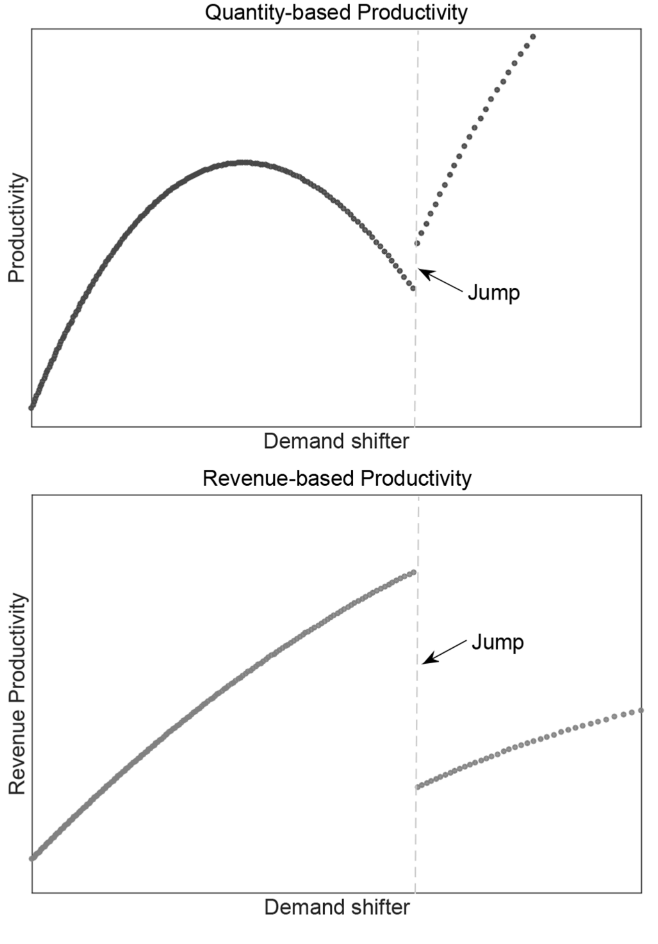

Fig. 2.—Changes to quantity- and revenue-based productivity as a firm adds layers.

productivity. When firms face negative shocks that make them drop layers, we expect the opposite effects.

B. *Some Portraits of Actual Reorganizations*

The mechanism described above is naturally an abstraction of reality. To illustrate the way in which firms actually reorganize in the data, we present a series of examples of firms that go through this process of reorganization. We choose a variety of examples that include firms in many industries—some that grow and some that decline. For each example, we briefly describe the firm and the process of reorganization that it went through. In addition, we show how quantity-based productivity, revenue-based productivity, and value added per worker changed. The precise methodology and data used to measure quantity-based productivity and revenue-based productivity are presented in detail in section IV.

1. Example: A Firm That Adds Layers

We start with the example of a single-product firm producing aluminium cookware (anonymous, given confidentiality requirements). It increased its workforce over time and, in particular, by 27% between 1996 and 1998. In the same period, exports increased by 170% and went from representing 10% of the firm's sales in 1996 to 16% in 1998. Between 1997 and 1998, the firm reorganized and added a layer of management.

Our firm had a layer of workers and a layer of managers until 1997 and added a new layer of management in 1998 (so it went from one to two layers of management). As the theory suggests, its quantity-based productivity grew by 16.9% when we compare the 2 years prior to the reorganization (1996–97) to the 2 years after it (1998–99). In contrast, value added per worker fell by 15.8%, and revenue-based productivity fell by 10%. Of course, we discuss the details of the estimation of both types of productivity extensively below. In section V, we show that this pattern of changes in productivity is typical in our data when a firm increases the number of layers.

To explore this case further, figure 3 shows the corresponding levels of output, prices, and revenue for the same firm and time period. The graph shows how, in fact, the increase in quantity-based productivity is accompanied by an increase in quantity, a fairly large decrease in price, and a small increase in revenue. These changes align exactly with our story, in which the increase in quantity-based productivity generated by the reorganization (that adds a layer of management) leads to an increase in quantity, a lower marginal cost that leads to a decline in price, and a correspondingly muted increase in revenue and decline in revenue-based productivity. Note that quantity in this firm grows not only at the time of the reorganization but before and after it as well. This is consistent with a firm that is

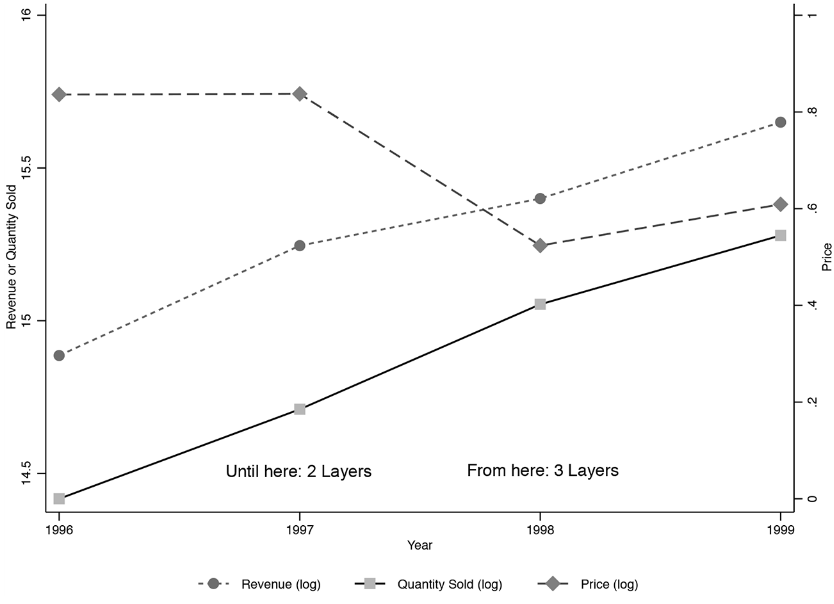

Fig. 3.—Example of a firm that adds layers: output, price, and revenue.

progressively moving toward the quantity threshold at which it decides to reorganize. In these other years, demand and productivity shocks do not trigger a reorganization, and so we do not see the corresponding decline in price.

2. Example: A Shock to Textile and Apparel Firms

One issue with the previous example is that we do not know what caused the growth of this firm. Fortunately, our sample covers the period in which China entered the WTO. So we now present two more examples of firms producing in the textile and apparel industry. The reorganization of these firms was arguably triggered by an exogenous event, namely, the reductions in quotas that resulted from China's entry into the WTO.[13]

The first firm we analyze is one that was hit hard by the (quota) shock and that we referred to in the introduction. The firm produces "knitted and crocheted pullovers, cardigans, and similar articles" (NACE 1772). Between 2002 and 2005, as a result of the quota reduction, it downsizes

[13] As a consequence of China joining the WTO, a number of quotas that were imposed at the European Union level on Chinese imports—as well as on imports from other non-WTO countries—were removed. In sec. V.D, we describe in greater detail how we identify the shock and the implications that this shock had for the entire industry.

TABLE 1
Textile and Apparel Firm Reorganization: NACE 1772 Example

	Layer 0	Layer 1	Layer 2	Layer 3
Firm with three layers (2004):				
Managers			1	2
Technicians and associate professionals		1		
Clerks	2			
Crafts workers	15		4	
Plant and machine operators	11			
Elementary occupations	1			
Firm with two layers (2005):				
Managers				
Technicians and associate professionals		1	1	
Clerks		1		
Crafts workers	4			
Plant and machine operators	1		1	
Elementary occupations	1			

Note.—Occupations correspond to ISCO-88 one-digit major groups.

rapidly. Table 1 illustrates the hierarchy of the firm before and after the reorganization resulting from the trade shock.[14] The labor force goes down from 37 to 10 employees. The quantity sold by the firm declines by 50%, value added falls by 70%, and prices increase by 35%. Imported inputs double. We see that the firm reorganizes and decreases the number of management layers from three to two. Accordingly, and as expected, the firm exhibits a reduction in quantity-based productivity of 51%, an increase in revenue-based productivity of 10.3%, and an increase in value added per worker of 9.3%.

The reorganization of the firm takes a natural form. It fires the three managers it used to have (two in production and operations and one in sales and marketing).[15] In lower layers, the firm fires its fiber preparers

[14] As we describe below, throughout the paper, we use the variable qualif (see table A.1) to map occupations to layers. However, for illustration purposes, while describing the reorganization of the firm, we use the occupational variable profissão (which is built following ISCO [International Standard Classification of Occupations]-88). This variable allows us to talk about more concrete and detailed occupations such as "sewers and embroiderers."

[15] Note that within each of the broad occupational categories that we present in the table, there are several subcategories of occupations that can map to different layers. In app. A, we present in greater detail how we map occupations to layers based on the tasks performed and skill requirements (qualif). For example, in 2004, the firm has two clerks: a statistical and finance clerk and a stock clerk. The statistical and finance clerk has a qualif of 60, which corresponds to semiskilled professionals (with higher numbers representing lesser-skilled employees). Based on this qualif, we assign it to layer 0. The stock clerk has a qualif of 71, which corresponds to nonskilled professionals. Based on this qualif, we assign it to layer 0 as well. The stock clerk is fired in 2005. The remaining statistical and finance clerk changes qualif from 60 to 51, which corresponds to skilled professionals. Based on this qualif, we assign it to layer 1. That is, this clerk got a promotion to a more demanding job.

and pattern-makers and cutters and now focuses on sewers and embroiderers (reduces the total number but hires a new one). Similarly, it fires a variety of machine operators to focus exclusively on sewing-machine operators. It also fires the one designer it used to employ. The result is the elimination of the top layer and reductions in employment in the bottom layers. Essentially, the firm focuses on its top tasks and substitutes some of the others by producing less and importing more intermediate goods. Even though the firm is shrinking tremendously, the workforce that remains now earns more, as our model predicts, with increases in median wages of 73% in layer 2, 33% in layer 1, and 3% in layer 0.

Our second example of a firm affected by the quota is a larger firm producing woven fabrics (NACE 1720). This firm also goes through a substantial downsizing from 1999 to 2000. Quantity sold decreases by 46% and value added by 30%, but prices rise by 13.8%. In the previous example, we saw that the firm shrank by focusing on its core activities. In contrast, this firm reduces its product scope. It specializes in cotton fabrics (its core product) and drops the production of synthetic fabrics. This is achieved with a reduction in the number of layers of management from three to two and a 46% smaller labor force. Correspondingly, the firm's quantity-based productivity decreases by 11%, but its revenue-based productivity increases by 1.7% and value added per worker by 30%. Table 2 presents the organization of the firm before and after the reorganization.

The firm reduces the number of workers in the lowest layer by firing the workers who are not involved in the production process of the core product. The firm fires its fiber-preparing-, spinning-, and winding-machine operators; weaving- and knitting-machine operators; bleaching-, dyeing- and cleaning-machine operators; and steam-engine and boiler operators.

TABLE 2
Textile and Apparel Firm Reorganization: NACE 1720 Example

	Layer 0	Layer 1	Layer 2	Layer 3
Firm with three layers (1999):				
Professionals				3
Technicians and associate professionals	1	5	2	
Clerks	14	10	2	
Crafts workers	17			
Plant and machine operators	71	2	1	
Elementary occupations	17			
Firm with two layers (2000):				
Professionals			2	
Technicians and associate professionals	1	5	2	
Clerks	16	8	1	
Crafts workers	15			
Plant and machine operators	49	3	1	
Elementary occupations	17			

Note.—Occupations correspond to ISCO-88 one-digit major groups.

In addition, the firm reduces the number of designers (decorators and commercial designers) from three, to one, to none within 3 years. Regarding the top layers of the firm, we see clear changes in its leading structure. In 1999, the top layer of the hierarchy includes three top management business professionals, specialized in accounting. In 2000, the firm drops the top layer. Layer 2, the new top layer, now focuses on dealing with less specialized tasks, including two middle-management business professionals, and two administrative secretaries and related associate professionals—to "implement and support the communication, documentation and internal managerial coordination activities of an organizational unit to assist the head of unit" (ISCO 3411). As a result of the restructuring, the median wage in layer 0 goes up, by 7.5%, while in layers 1 and 2, wages do not change much (reductions of 1.4% in median wages but an increase of 1% in the mean wages of layer 0).

3. Example: Downsizing and Growing

These cases exemplified well the way in which the abstract mechanism highlighted by our theory works in practice. However, one concern is that the way the restructuring takes place could be particular to the textile and apparel industry and not present in other industries. Therefore, we finish this section by briefly presenting two other examples: one of a negative shock to a firm in the footwear industry and one of a positive shock to a firm in the cork industry (where Portugal is a main producer).[16] In these cases, we have not identified the exact source of the shock, but we observe similar, theory-consistent behavior of firms as they expand or contract.

Consider a firm producing "women's town footwear with leather uppers" (NACE 19301352) that goes through a downsizing process from 1998 to 1999. The firm experiences a reduction in value added of 10%, reduced its labor force from 71 to 58 workers, and switched from three to two layers of management. Accordingly, the firm's quantity-based productivity decreases by 20%, quantity sold decreases by 24%, and prices rise by 39%. Our theory predicts that when a firm reduces the number of layers, we should observe an increase in revenue-based productivity conditional on past prices and other shocks (see proposition 1). In all the previous cases, this conditioning did not seem to matter much. Here it does, since we observe revenue-based productivity decline by 12%, even though value added per worker grows by 9%. Table 3 presents the organizational structure of the firm in 1998, the last year the firm has three layers of

[16] Footwear and cork are two traditional Portuguese industries. For instance, footwear represents about 6% of Portuguese exports in the 1993–2009 period, while Portugal is the biggest producer of cork in the world.

TABLE 3
Footwear Firm Reorganization: NACE 19301352 Example

	Layer 0	Layer 1	Layer 2	Layer 3
Firm with three layers (1998):				
Managers				1
Technicians and associate professionals		1		
Clerks		1		1
Crafts workers	56	1	1	
Elementary occupations	9			
Firm with two layers (1999):				
Managers				
Technicians and associate professionals		1		
Clerks		1		
Crafts workers	47		2	
Elementary occupations	7			

Note.—Occupations correspond to ISCO-88 one-digit major groups.

management, and in 1999, when the firm has two layers of management. The firm reorganizes by simplifying its management structure. The new organization has neither a manager nor a statistical and finance clerk. The firm also reduces the number of shoemakers (identified in the table as crafts workers). As a result of the restructuring, the median wage rises in all the preexisting layers (by 3% in layer 2, 23% in layer 1, and 8% in layer 0).

Our final example studies a small firm producing "manufacture of articles of cork, straw and plaiting materials" (NACE 2052) that goes through a growth spell between 2004 and 2005, experiencing a 3% increase in value added. The firm starts with one layer of management and adds another layer. Its labor force goes from nine to 12 workers. As expected, the firm's quantity-based productivity increases by 13%, quantity sold increases by 28%, and prices decrease by 21%. Revenue-based productivity declines but only by −0.2%, while value added per worker decreases by 29%, indicating again that the proper conditioning on past prices and shocks is relevant. Table 4 shows the organizational structure of the firm before and

TABLE 4
Cork Firm Reorganization: NACE 2052 Example

	Layer 0	Layer 1	Layer 2	Layer 3
Firm with one layer (2004):				
Managers				
Clerks		1		
Crafts workers	8	1		
Firm with two layers (2005):				
Managers			2	
Clerks		1		
Crafts workers	9			

Note.—Occupations correspond to ISCO-88 one-digit major groups.

after the reorganization. The structure of the firm remains simple, with the only addition a layer of management that includes two production and operations department managers. The small reinforcement of layer 0, where the number of crafts workers—all "wood treaters"—rises from eight to nine, hides a more substantial churning, with two wood treaters leaving the firm and three new ones entering. As a result of the restructuring, the median wage decreases in all the preexisting layers (by 1.4% in layer 1 and 7% in layer 0).

C. *The Effect of Organization across Industries: Some Simple Statistics*

The arguments and examples presented so far indicate that when a firm receives a positive (negative) shock that makes it reorganize by adding (dropping) layers, its revenue-based productivity decreases (increases). Note, however, that this is the expected response only for firms that reorganize by changing the number of management layers. Firms that experience similar shocks but do not change layers expand much less, which implies that the price response is more muted, and so revenue-based productivity increases due to the direct effect of the reduction in costs. We now show evidence of these patterns at the sectoral level.

Figure 4*A* shows the change in value-added per worker by industry between 1996 and 2005, when we condition on firms that do not reorganize. Clearly, for firms that grow in terms of sales, value added per worker increases as well. In contrast, firms that experience a decrease in total sales see their value added per worker decline. The figure shows that all 19 industries exhibit this relationship. This is not surprising, given that revenue productivity and sales are positively related in many theories of the firm.

Figure 4*B* presents again the change in value added per worker but now for firms that increase or decrease the number of layers. As predicted by our theory, but perhaps more surprising in light of the previous literature, in this case we see that firms that increase layers tend to decrease value added per worker and vice versa for firms that drop layers. This is the case for all industries except communications equipment, medical and precision instruments, and other transportation equipment, where some of the effects are not significant. The switch in sign depending on whether a firm reorganizes is perhaps remarkable, given that increases (decreases) in sales are highly correlated with increases (decreases) in layers.

The examples above are illustrative, we believe, of the different forms that reorganizations take in practice. Sometimes firms focus or expand the set of production tasks performed, sometimes they restrict or increase the set of products produced, and sometimes they simply add or

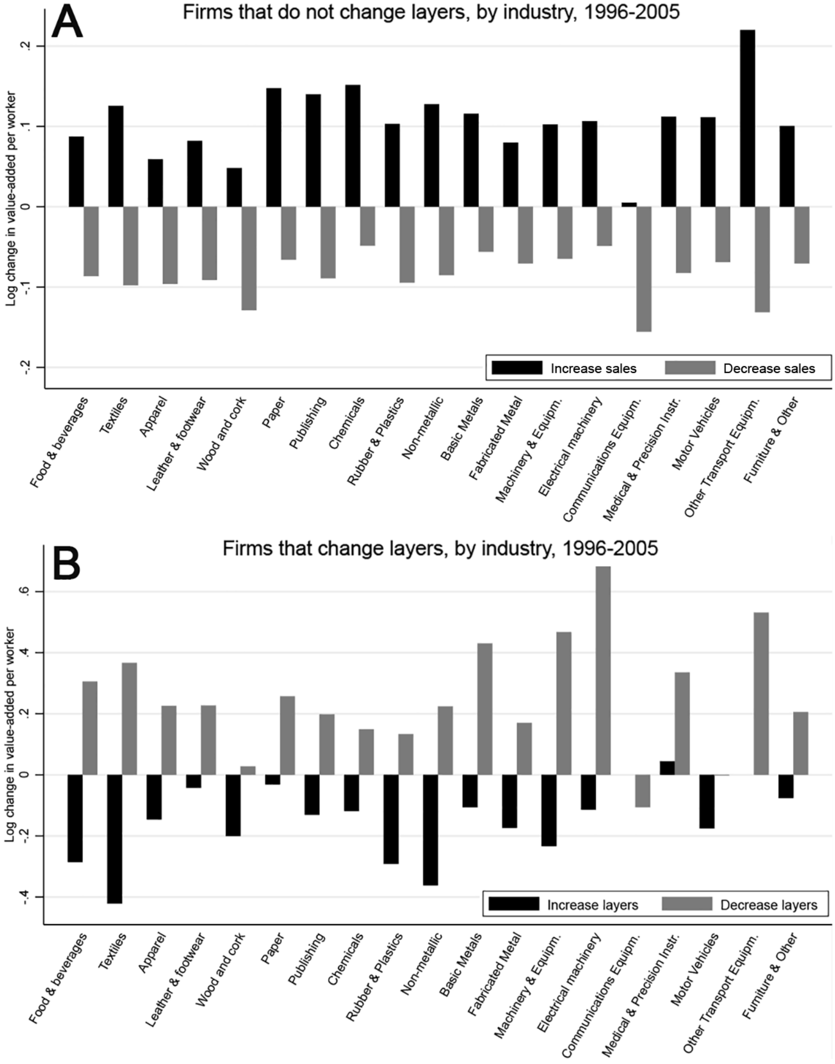

FIG. 4.—Reorganization and value added per worker.

take away managerial structure to do less or more of the same. In all these cases, however, we find that the behavior of these firms exhibits the patterns we expect, even though these patterns are quite complicated and multidimensional. Not only do the firms reshuffle their labor force as predicted, but the wages they pay—as well as the implications for both types of productivity—are consistent with our mechanism. Of course, there are some exceptions, so the rest of our paper is dedicated to presenting systematic evidence of the ubiquitousness of these patterns as firms reorganize.

III. Data Description and Processing

Our data set is built from three data sources: a matched employer-employee panel data set, a firm-level balance sheet data set, and a firm-product-level data set containing information on the production of manufactured goods. Our data cover the manufacturing sector of continental Portugal for the years 1995–2005.[17] As explained below in detail, the matched employer-employee data virtually cover the universe of firms, while both the balance sheet data set and the production data set cover only a sample of firms. We build two nested samples. The larger of them sources information from the matched employer-employee data set for the subset of firms for which we also have balance sheet data. It contains balance sheet information but no production data. We use it to provide basic statistics on firm organization. The smaller sample covers a subset of firms for which we also have production data. This data set is necessary to calculate quantity-based productivity at the firm-product-year level, and so we use this sample in most of our analysis. Appendixes A and B include further descriptions of these data sets.

Employer-employee data come from Quadros de Pessoal, a data set made available by the Ministry of Employment of Portugal, drawing on a compulsory annual census of all firms in Portugal that employ at least one worker.[18] Currently, Quadros de Pessoal collects data on about 350,000 firms and 3 million employees. Reported data cover the firm itself, each of its plants, and each of its workers. Each firm and each worker entering the database is assigned a unique, time-invariant identifying number, which we use to follow firms and workers over time. Variables available in the data set include the firm's location, industry, total employment, and sales. The worker-level data cover information on all personnel working for the reporting firms in a reference week in October of each year. This includes information on occupation, earnings, and hours worked (normal and overtime). The information on earnings includes the base wage (gross pay for normal hours of work), seniority-indexed components of pay, other regularly

[17] Information for the year 2001 for the matched employer-employee data set was not collected. Hence, our sample excludes the year 2001 (see app. A).

[18] Public administration and nonmarket services are excluded. Quadros de Pessoal has been used by, among others, Blanchard and Portugal (2001) to compare the US and Portuguese labor markets in terms of unemployment duration and worker flows; Cabral and Mata (2003) to study the evolution of the firm size distribution; and Mion and Opromolla (2014) to show that the export experience acquired by managers in previous firms leads their current firm toward higher export performance, and it commands a sizeable wage premium for the manager.

paid components, overtime work, and irregularly paid components. It does not include employers' contributions to social security.[19]

The second data set is Central de Balanços, a repository of yearly balance sheet data for nonfinancial firms in Portugal. Prior to 2005, the sample was biased toward large firms. However, the value-added and sales-coverage rates were high. For instance, in 2003, firms in the Central de Balanços data set accounted for 88.8% of the national account's total of nonfinancial firms' sales. Information available in the data set includes a firm's sales, material assets, costs of material, and third-party supplies and services.

The third data set is the Inquérito Anual à Produção Industrial, which is made available by Statistics Portugal and contains information on sales and volume sold for each firm-product pair for a sample of firms with a minimum of 20 employees covering at least 90% of the value of aggregate production. From this third data set, we use information on the volume and value of a firm's production. The volume is recorded in units of measurement (number of items, kilograms, liters) that are product specific, while the value is recorded in current euros. From the raw data, it is possible to construct different measures of the volume and value of a firm's production. For the sake of this project, we use the volume and value corresponding to a firm's sales of its products. This means that we exclude products produced internally and to be used in other production processes within the firm as well as products produced for other firms, using inputs provided by these other firms. The advantage of using this definition is that it nicely corresponds to the cost of material coming from the balance sheet data. For example, the value of products produced internally and to be used in other production processes within the firm is part of the cost of material, while products produced for other firms, using inputs provided by these other firms, is neither part of the cost of material nor part of a firm's sales from the Inquérito Anual à Produção Industrial data. We aggregate products at the two-digit unit of measurement pairs and split multiproduct firms into several single-product firms using product revenue shares as weights (see app. A).[20]

[19] The Ministry of Employment implements several checks to ensure that a firm that has already reported to the database is not assigned a different identification number. Similarly, each worker also has a unique identifier, based on a worker's social security number. The administrative nature of the data and their public availability at the workplace—as required by law—imply a high degree of coverage and reliability. It is well known that employer-reported wage information is subject to less measurement error than worker-reported data. The public availability requirement facilitates the work of the services of the Ministry of Employment that monitor the compliance of firms with the law.

[20] In our analysis, we also experimented with using the sample of single-product firms only. Results, available on request, are qualitatively identical and quantitatively very similar.

A. *Occupational Structure*

To recover the occupational structure at the firm level, we exploit information from the matched employer-employee data set. Each worker, in each year, is assigned to a category following a (compulsory) classification of workers defined by Portuguese law.[21] Classification is based on tasks performed and skills required, and each category can be considered as a level in a hierarchy defined in terms of increasing responsibility and task complexity. Table A.1 (tables A.1, B.1–B.10, D.1, E.1, and F.1–F.4 are available online) contains more information about the exact construction of these categories.

On the basis of this hierarchical classification and taking into consideration the actual wage distribution, we partition the available categories into management layers. We assign "top executives (top management)" to occupation 3; "intermediary executives (middle management)" and "supervisors, team leaders" to occupation 2; "higher-skilled professionals" and some "skilled professionals" to occupation 1; and the remaining employees, including "skilled professionals," "semi-skilled professionals," "nonskilled professionals," and "apprenticeship" to occupation 0.

We then translate the number of different occupations present in a firm into layers of management. A firm reporting c occupational categories will be said to have $L = c - 1$ layers of management: hence, in our data, we will have firms spanning from zero to three layers of management (as in Caliendo, Monte, and Rossi-Hansberg 2015). In terms of layers within a firm, we do not keep track of the specific occupational categories but simply rank them. Hence, a firm with occupational categories 2 and 0 will have one layer of management, and its organization will consist of a layer 0 corresponding to some skilled and nonskilled professionals and a layer 1 corresponding to intermediary executives and supervisors.[22]

B. *Portuguese Production Hierarchies: Basic Facts*

In this section, we reproduce some of the main results of Caliendo, Monte, and Rossi-Hansberg (2015) for France using our larger but less complete data set for Portugal. We focus here on the main findings; for brevity, we relegate all the tables and figures with the exact results to appendix B.

Firms with different numbers of layers are different. If we group firms by their number of management layers, firms with more layers are larger

[21] Following Caliendo, Monte, and Rossi-Hansberg (2015), we use occupational categories to identify layers of management. In the case of French firms, Caliendo, Monte, and Rossi-Hansberg (2015) use the PCS (Professions et Catégories Socioprofessionnelles) classification. In this study, we use the Portuguese classification (Decreto Lei 121/78 of July 2, 1978), which is not the ISCO.

[22] One potential concern with using this methodology to measure the number of layers is that many firms might have layers with occupations that are not adjacent in the rank. This does not seem to be a large problem. More than 75% of firms have adjacent layers.

in terms of value added, hours, and higher wages, on average (see table B.2). In fact, the distributions of value added, employment, and hourly wage by layer for firms with more layers are shifted to the right and exhibit higher variance (see figs. B.1–B.3; figs. B.1–B.3 and E.1 are available online). Thus, these results underscore our claim that the concept of layers we use is economically meaningful.

Our definition of layers of management is supposed to capture the hierarchical structure of the firm. So it is important to verify that the implied hierarchies are pyramidal in the sense that lower layers employ more hours and pay lower hourly wages. The implied hierarchical structure of firms is hierarchical in the majority of cases (table B.3). The implied ranking holds for 76% of the cases when comparing any individual pair of layers. As for compensation, employees in lower layers are paid lower wages in the vast majority of cases (table B.4). For example, the proportion of firms that exhibit a hierarchical ranking for any given bilateral comparison between layers is also greater than 75%. We conclude that, although with some exceptions, our definition of layers does a good job of capturing the hierarchical structure of firms.

Our primary goal is to study the endogenous productivity responses of firms that reorganize. So it is important to establish how often they do so.[23] In a given year, about half the total number of firms keep the same number of layers, with the number increasing to 70% for firms with four layers (three layers of management). Most of the firms that do not reorganize just exit, with the percentage of exiting firms declining with the number of layers. About 12% of firms in a layer reorganize by adding a layer, and about the same number downscale and drop one. Overall, as in France, there seem to be many reorganizations in the data. Every year, around 20% of firms add and/or drop occupations and therefore restructure their labor force (the number is lower for firms with three layers of management since, given that the maximum number of management layers is three, their only option is to drop layers).

A reorganization is accompanied by many other firm-level changes. To see this, we divide firms depending on whether they add, do not change, or drop layers and present measured changes in the total number of hours, number of hours normalized by the number of hours in the top layer, value added, and average wages. First, we find that firms that either expand or contract substantially do so by reorganizing. This is the case in terms of both hours and value added. Furthermore, changes in either hours or value added seem to be symmetric, but in opposite directions, for firms that add or drop layers. After detrending, firms that add (drop) layers tend to pay higher (lower) average wages. However, once we focus on average wages in preexisting layers, wages decline (increase), as the

[23] Table B.5 presents a transition matrix across layers.

theory predicts. So, in firms that add layers, average wages increase because the agents in the new layer earn more than the average, but workers in preexisting layers earn less as their knowledge is now less useful (as found for France by Caliendo, Monte, and Rossi-Hansberg [2015]).[24]

The results above can be further refined by looking at layer-level outcomes for firms that expand without reorganizing and firms that expand as a result of a reorganization. The theory predicts that firms that expand but keep the same number of layers will increase employment and wages in all layers. In contrast, firms that expand and add layers will increase employment in all layers but will decrease wages (and, according to the theory, knowledge) in all preexisting layers. That is, adding a layer allows the firm to economize on the knowledge of all the preexisting layers. Hence, we expect the elasticity of normalized hours (hours at each layer relative to the top layer) and wages to value added for firms that do not add layers to be positive. This prediction is confirmed for all elasticities, except for one case where the estimate is not significant (see tables B.8, B.9). We conclude that firms that grow without reorganizing increase employment and wages in all layers.

Adding layers should lead to increases in employment but declines in wages in all preexisting layers. These implications are verified for all transitions in all layers, except for two nonsignificant results for firms that start with zero layers of management (see table B.10). Similar to the results of Caliendo, Monte, and Rossi-Hansberg (2015) for France, our estimates for Portugal show that firms that add layers in fact concentrate workers' knowledge, as proxied by their wages, at the top layers. This is one of the consequences of a firm's reorganization and supports empirically the underlying mechanism that, we hypothesize, leads to an increase (decrease) in quantity-based productivity as a result of a reorganization that adds (drops) layers.

IV. Estimation

We now present our methodology, based on Forlani et al. (2016), to measure changes in revenue-based and quantity-based productivity induced by firm reorganization. We first discuss our production and timing assumptions, preferences, and market structure. After that, we define the stochastic process for productivity and demand. Finally, we discuss our estimation strategy and derive our estimating equations to estimate the parameters of the production function and the effects of changes in layers on productivity.

[24] All these results are presented in table B.7.

A. Production

A firm's technology is given by the production function in (1), which we discussed above. A full specification of the production process requires us to take a stand on the timing of a firm's decisions relative to the realization of productivity and demand shocks. We assume that capital K_{it} is chosen by the firm prior to the realization of shocks in t. We also assume that at some time between period $t-1$ and t, the firm has some knowledge about the realizations of the productivity and demand shocks (which we denote v_{ait} and $v_{\lambda it}$, respectively) materializing in t. It is at this point that the firm chooses the number of management layers. Hence, we allow current-period shocks to affect the choice of the number of layers L_{it} but not of the capital stock K_{it}. Of course, past capital and past numbers of layers, K_{it-1} and L_{it-1}, as well as lagged productivity and demand shocks, can affect the number of layers too. All other inputs are chosen conditional on the realization of shocks, as well as the current-period capital and number of layers.[25]

The constrained (by number of management layers) labor-input choice the firm makes in t is denoted O_{it}^{*}.[26] Note that O_{it}^{*} is not directly observable, but we can infer that $O_{it}^{*} = C(O_{it}^{*}; w_t)/AC(O_{it}^{*}; w_t)$, where $C(O_{it}^{*}; w_t)$ is the total expenditure on the labor input—that is, the total wage bill of the firm (which is observable)—and $AC(O_{it}^{*}; w_t)$ is the unit cost of the labor input that is not observable and depends on the number of layers. Hence, the production function (1) in logs becomes

$$q_{it} = \tilde{a}_{it} + \alpha_{\mathrm{O}} \ln C\left(O_{it}^{*}; w_t\right) + \alpha_{\mathrm{M}} m_{it} + (\gamma - \alpha_{\mathrm{M}} - \alpha_{\mathrm{O}}) k_{it}, \tag{7}$$

where $\tilde{a}_{it} = \ln \tilde{A}_{it} \equiv \ln A_{it} - \alpha_{\mathrm{O}} \ln AC(O_{it}^{*}; w_t)$. Hence, measured quantity-based productivity $\tilde{a}_{it}$ depends on the number of layers L_{it} through the term O_{it}^{*}.[27] Note that, conditional on the total wage bill $C(O_{it}^{*}; w_t)$, the number of layers is not a traditional input in that it does not cost the firm anything. Hence, it is more natural to treat it as a characteristic of the firm that determines the ability to transform inputs (including the labor input through the total wage bill, as well as capital and material) into output. In this sense, it parallels a firm's technological capabilities, so we treat them in a similar way.

[25] Our timing assumption on layer choice is guided by the observed frequency of changes in layers relative to changes in the total real wage bill. Table B.5 shows that, in a given year, about half the total number of firms keep the number of layers constant. Nevertheless, table B.6 shows that these firms with constant layers do change their real wage bill by more than 15% in about 46% of the observations.

[26] The firm in t can choose the number of workers in each layer and the amount of knowledge in each layer.

[27] Note that $-\alpha_{\mathrm{O}} \ln AC(O_{it}^{*}; w_t) = \beta L_{it}$ is what is implied by the Caliendo and Rossi-Hansberg (2012) model, if we substitute the constraint $n_L^L = 1$ in the organizational problem with $n_L^L \geq \epsilon$, for small enough $\epsilon > 0$, as discussed in sec. II. Hence, in that case, $\tilde{a}_{it} = a_{it} + \beta L_{it}$.

B. Demand and Market Structure

We assume the presence of a representative consumer with generalized constant elasticity of substitution preferences (Spence 1976). The inverse demand is then given by

$$P_{it} = \Lambda_{it}^{(\eta_{it}-1)/\eta_{it}} Q_{it}^{-1/\eta_{it}},$$

where Λ_{it} is a demand shifter, η_{it} is the elasticity of demand, and P_{it} and Q_{it} are the price and quantity of variety i, respectively. Multiplying both sides by quantity and taking logs, we obtain the following expression for revenue,

$$r_{it} = \left(1 - \frac{1}{\eta_{it}}\right)(\lambda_{it} + q_{it}), \tag{8}$$

where lowercase letters denote log values, namely, $\lambda_{it} = \ln \Lambda_{it}$, $q_{it} = \ln Q_{it}$, and $r_{it} = \ln R_{it}$.

We consider a monopolistically competitive environment. Hence, given preferences, markups are given by

$$\mu_{it} = \frac{\eta_{it}}{\eta_{it} - 1}.$$

From the first-order conditions of the cost-minimization problem, we obtain that markups will equal the ratio of the output elasticity of the optimized input to the share of that input expenditure in revenue (Hall 1986). Defining $s_{Mit} = W_{Mt}M_{it}/R_{it}$ as the revenue expenditure share on material, where W_{Mt} is the price of material (and, equivalently, s_{Oit} on the labor input), it follows that markups are given by

$$\mu_{it} = \frac{\alpha_M}{s_{Mit}} = \frac{\alpha_O}{s_{Oit}}. \tag{9}$$

Therefore, with estimates of the production function parameters, we can recover μ_{it} by simply combining them with data on revenue and expenditures.

C. Assumptions on the Stochastic Processes for Productivity and Demand

We denote the log of quantity-based productivity $\tilde{a}_{it}$ and assume that it follows a stochastic process. In particular, we assume that

$$\tilde{a}_{it} = \begin{cases} \alpha_i + \delta_t + \phi_a \tilde{a}_{it-1} + v_{ait} & \text{if } \Delta L_{it} = 0 \\ \alpha_i + \delta_t + \phi_a \tilde{a}_{it-1} + \phi_L \Delta L_{it} + v_{ait} & \text{if } \Delta L_{it} \neq 0 \end{cases}, \tag{10}$$

where $\Delta L_{it} = L_{it} - L_{it-1}$ is the change in the number of management layers between $t - 1$ and t and where v_{ait} is a mean zero productivity shock that is independent and identically distributed across firms and time. Here, α_i and δ_t represent, respectively, firm-product and time fixed effects. We incorporate the effect of changes in the number of layers on measured quantity-based productivity, implied by equation (7), parsimoniously through the term ΔL_{it}.

Regarding the demand process, we assume the following stochastic process for demand shifter

$$\lambda_{it} = \delta_t^{\lambda} + \phi_{\lambda}\lambda_{it-1} + v_{\lambda it}, \tag{11}$$

where $v_{\lambda it}$ is an idiosyncratic mean zero demand shock that is independent and identically distributed across firms and time and that can potentially be correlated with the productivity shock v_{ait}.

We further assume that v_{ait} and $v_{\lambda it}$ are uncorrelated with past values of productivity and demand and, more generally, with all past variables. Precisely, we assume that

$$E[v_{ait}\tilde{a}_{is}] = E[v_{ait}\lambda_{is}] = E[v_{\lambda it}\tilde{a}_{is}] = E[v_{\lambda it}\lambda_{is}] = 0 \quad \forall\ s < t.$$

Given our timing assumption for L_{it}, it follows that

$$E[v_{ait}L_{it}] \neq 0; \quad E[v_{\lambda it}L_{it}] \neq 0 \tag{12}$$

and likewise that

$$E[v_{ait}\Delta L_{it}] \neq 0; \quad E[v_{\lambda it}\Delta L_{it}] \neq 0. \tag{13}$$

Regarding capital, $k_{it} = \ln K_{it}$, our timing assumptions imply that

$$E[v_{ait}k_{it}] = E[v_{\lambda it}k_{it}] = 0. \tag{14}$$

Note that the total cost of the labor input $C(O_{it}^*; w_t)$ conditional on the number of layers and material, $m_{it} = \ln M_{it}$, is endogenous to both current productivity and demand shocks, namely,

$$\begin{gathered} E\left[v_{ait}\ln C\left(O_{it}^*; w_t\right)\right] \neq 0; \text{ and } E\left[v_{\lambda it}\ln C\left(O_{it}^*; w_t\right)\right] \neq 0, \\ E[v_{ait}m_{it}] \neq 0; \text{ and } E[v_{\lambda it}m_{it}] \neq 0. \end{gathered} \tag{15}$$

Finally, given estimates of the production function, we can compute revenue-based productivity $\bar{a}_{it}$ simply by adding the log price; that is,

$$\begin{aligned} \bar{a}_{it} &= p_{it} + \tilde{a}_{it} \\ &= r_{it} - \alpha_{\mathrm{O}}\ln C\left(O_{it}^*; w_t\right) - \alpha_{\mathrm{M}}m_{it} - (\gamma - \alpha_{\mathrm{M}} - \alpha_{\mathrm{O}})k_{it}. \end{aligned} \tag{16}$$

D. *Estimation Strategy*

Our empirical strategy is to first estimate the parameters of the production function (α_{O}, α_{M}, γ). With these estimates, we obtain quantity- and revenue-based productivities and use the process in equation (10) to obtain the equations to estimate ϕ_a and ϕ_L. Finally, we incorporate firm-product fixed effects in the estimation.

1. Production Function Estimation

To derive our estimating equation, we start by substituting the production function (7) into the revenue equation (8).[28] We then use the measure of markups (9) and substitute $\tilde{a}_{it-1}$ from (10) and λ_{it-1} from (11) as a function of observables. Here, we drop the firm-product fixed effects in order to minimize problems coming from measurement errors, as suggested in the literature (Griliches and Mairesse 1998).[29] We incorporate firm-product fixed effects again in the final step of the estimation. The resulting equation is

$$\mathrm{LHS}_{it} = \delta_t^q + b_1 k_{it} + b_2 \mathrm{LHS}_{it-1} + b_3 k_{it-1} + b_4 \frac{r_{it-1}}{s_{Mit-1}} + b_5 q_{it-1} + b_6 \Delta L_{it} + u_{it}, \tag{17}$$

where

$$\mathrm{LHS}_{it} = \frac{r_{it} - s_{O_{it}}\left(\ln C\left(O_{it}^*; w_t\right) - k_{it}\right) - s_{Mit}(m_{it} - k_{it})}{s_{Mit}},$$

$\delta_t^q = (1/\alpha_{\mathrm{M}})(\delta_t + \delta_t^\lambda)$, $b_1 = (\gamma/\alpha_{\mathrm{M}})$, $b_2 = \phi_a$, $b_3 = -\gamma(\phi_a/\alpha_{\mathrm{M}})$, $b_4 = \phi_\lambda - \phi_a$, $b_5 = (1/\alpha_{\mathrm{M}})(\phi_a - \phi_\lambda)$, $b_6 = \phi_L/\alpha_{\mathrm{M}}$, and $u_{it} = (1/\alpha_{\mathrm{M}})(v_{ait} + v_{\lambda it})$.

In order to estimate the parameters of the production function using (17), we need to deal with two issues: first, that the error term u_{it} might be correlated with at least one of the regressors and, second, that identification of the parameters (α_{O}, α_{M}, γ) requires point estimates $\hat{b}_5$ to be significantly different from zero. Then,

$$\hat{\alpha}_{\mathrm{O}} = -\frac{s_{Oit}}{s_{Mit}}\frac{\hat{b}_4}{\hat{b}_5}, \quad \hat{\alpha}_{\mathrm{M}} = -\frac{\hat{b}_4}{\hat{b}_5}, \quad \hat{\gamma} = -\hat{b}_1\frac{\hat{b}_4}{\hat{b}_5}.$$

To deal with the first issue, we propose an instrument consistent with the model and timing introduced above. Note that given (12) and (14),

[28] Please refer to app. C for a detailed derivation of all the expressions in this section.

[29] Following the argument of Griliches and Mairesse (1998), fixed effects are, in general, not included in the productivity process and/or in the estimation of the production function; see Olley and Pakes (1996), Levinsohn and Petrin (2003), Wooldridge (2009), and De Loecker and Warzynski (2012). For a more recent discussion of this issue, see Ackerberg, Caves, and Frazer (2015).

the error term u_{it} is uncorrelated with all regressors except ΔL_{it}. Hence, we can simply instrument ΔL_{it} with ΔL_{it-1} and L_{it-2}.

Regarding the second issue, note that $b_5 > 0$ implies that the autoregressive parameters of demand and productivity are significantly different from each other (recall that $b_5 = (1/\alpha_M)(\phi_a - \phi_\lambda)$). As we argue below, this is a problem in practice. In the estimation, we find that in many industries, $\hat{b}_5$ is not significantly different from zero.

To deal with this practical issue, we can proceed as follows. Substitute $\tilde{a}_{it-1}$ using (10) (after again dropping the firm-product fixed effects in order to minimize problems coming from measurement errors) into the production function (7). Then use the estimates of $\hat{b}_1$ and $\hat{b}_2$ to compute

$$Z_{it} = \frac{1}{\hat{b}_1}\frac{s_{Oit}}{s_{Mit}}(\ln C(O_{it}; w_t) - k_{it}) + \frac{1}{\hat{b}_1}(m_{it} - k_{it}) + k_{it} + \frac{\hat{b}_2}{\hat{b}_1}\mathrm{LHS}_{it-1} - \hat{b}_2 k_{it-1} - \frac{1}{\hat{b}_1}\frac{\hat{b}_2}{s_{Mit-1}} r_{it-1},$$

and substitute to obtain the estimating equation,

$$q_{it} - \hat{b}_2 q_{it-1} = \delta_t + b_7 Z_{it} + b_8 \Delta L_{it} + v_{ait}. \tag{18}$$

Note that in light of (13) and (15), the variables Z_{it} and ΔL_{it} are endogenous, so we require instruments. Based on (12) and (14), we can use k_{it}, ΔL_{it-1}, and L_{it-2} as instruments. Using this second estimating equation,[30] we can obtain identification of the parameters $(\alpha_O, \alpha_M, \gamma)$ using

$$\hat{\alpha}_O = \frac{\hat{b}_7}{\hat{b}_1}\frac{s_{Oit}}{s_{Mit}}, \quad \hat{\alpha}_M = \frac{\hat{b}_7}{\hat{b}_1}, \quad \hat{\gamma} = \hat{b}_7.$$

Finally, after estimating the parameters of the production function, our estimate of the quantity-based productivity process is given by

$$\widehat{\tilde{a}}_{it} = q_{it} - \hat{\alpha}_O(\ln C(O_{it}; w_t) - k_{it}) - \hat{\alpha}_M(m_{it} - k_{it}) - \hat{\gamma} k_{it},$$

and our estimate of revenue-based productivity by

$$\widehat{\tilde{\tilde{a}}}_{it} = r_{it} - \hat{\alpha}_O(\ln C(O_{it}; w_t) - k_{it}) - \hat{\alpha}_M(m_{it} - k_{it}) - \hat{\gamma} k_{it}.$$

With the measures of quantity- and revenue-based productivity in hand, we can estimate the effect of changes in layers on both types of productivity using equations (10) and (16), where we incorporate product or

[30] Note that b_8 is related to ϕ_L but cannot be used directly as an estimate of this parameter. The reason is that, as explained above, we are not using fixed effects to estimate the parameters of the production function. In contrast, ϕ_L is defined in eq. (10) as the effect of layers on quantity-based productivity controlling for firm-product and time fixed effects. This is exactly what we do in sec. V when we estimate ϕ_L using eq. (19).

firm-product fixed effects, as well as time fixed effects.[31] In this step, the endogeneity of ΔL_{it} can be addressed as in the previous steps or using a specific exogenous shock. We pursue both strategies below.

V. Results

Following our estimation strategy, we first use (17) to estimate the parameters of the production function. Table D.1 presents the results. Note that $\hat{b}_5$ is significantly different from zero only in two out of 42 cases. Thus, as explained above, we are not able to identify α_M and γ directly. We then proceed to use the estimates of b_1 and b_2, together with specification (18), to estimate $(\alpha_O, \alpha_M, \gamma)$ and obtain our productivity processes. The estimates $\hat{b}_1$ and $\hat{b}_2$ are significantly different from zero in all cases (see table D.1, where we present bootstrapped standard errors).

A. *Estimating Equations*

Armed with our structurally estimated productivity processes, we use (10) to derive our estimating equation for quantity-based productivity:

$$\tilde{a}_{it} = \alpha_i + \delta_t + \phi_a \tilde{a}_{it-1} + \phi_L \Delta L_{it} + v_{ait}. \tag{19}$$

An observation, *it*, corresponds to a firm-product sequence *i* at time *t*. A firm-product is a two-digit Prodcom code-firm combination. Furthermore, in the regressions below, we use *it* sequences with either one change or no change in layers to better pinpoint reorganization events. In case of a change in layers, the change might be either increasing or decreasing the number of layers. So we have four cases: increasing sequences, decreasing sequences, constant sequences, and all of the above sequences.[32]

The underlying idea is to compare the productivity of firms that are, for example, increasing their number of layers, both among those firms and with firms that are not changing their number of layers. In the former case, we obtain identification of the impact on productivity by comparing firms increasing their number of layers before and after the change. In the latter case, we also get identification by comparing the productivity of firms changing layers with those that do not. To better isolate reorganization events and ease comparability of an otherwise complex structure,

[31] This last step is similar to standard approaches aimed at finding determinants of productivity (see Foster, Haltiwanger, and Syverson 2008; De Loecker et al. 2016).

[32] A potential concern when estimating eq. (19) is that, as dictated by the theory, we have used observations on layers to estimate the productivity processes. This might generate a mechanical relationship between those processes and changes in layers that could affect our estimates of ϕ_L. In app. F, we present all the results of this section when we use estimated productivity processes that abstract completely from layers and so do not use information on layers. The estimates of ϕ_L are very similar.

we break firms into sequences that correspond to at most one change in the hierarchical structure.[33]

In order to derive the estimating equation for revenue-based productivity, we use the fact that $\tilde{a}_{it} = \bar{a}_{it} - p_{it}$ and, together with the process for productivity (10), we obtain

$$\bar{a}_{it} = \alpha_i + \delta_t + \phi_a \bar{a}_{it-1} + \phi_L \Delta L_{it} + p_{it} - \phi_a p_{it-1} + v_{ait}. \quad (20)$$

Prices are functions of marginal costs, which in turn are functions of quantities and hence productivities. As a result, we use the first-order conditions of the cost-minimization problem to substitute for prices into (20) to derive the following estimating equation:

$$\bar{a}_{it} = \bar{\alpha}_i + \bar{\delta}_t + \bar{\phi}_a \bar{a}_{it-1} + \bar{\phi}_L \Delta L_{it} + \bar{\phi}_R X_{it} + v_{\bar{a}it}, \quad (21)$$

where $X_{it} = [\lambda_{it-1}, p_{it-1}, \ln(\mu_{it}), k_{it}]$. Appendix C.2 includes a step-by-step derivation of this equation.

B. *Reorganization and Quantity-Based Productivity*

1. Ordinary Least Squares

We start by presenting the results using simply ordinary least squares (OLS), namely, ignoring the potential endogeneity of ΔL_{it}. The specification we run is (19),

$$\tilde{a}_{it} = \alpha_s + \delta_t + \phi_a \tilde{a}_{it-1} + \phi_L \Delta L_{it} + v_{ait}, \quad (22)$$

where we substitute α_i for an industry/product fixed effect, α_s, to reduce the number of fixed effects.

Table 5 provides OLS estimation results. In all the results in this section, we present standard errors clustered at the firm level. All of the point estimates of ϕ_L are positive and significant and point to an impact of reorganization on quantity-based productivity of about 3%. Adding (dropping) a layer increases (decreases) quantity-based total-factor productivity (TFP)

[33] We follow the exact same procedure as in sec. IV. More specifically, we define a sequence of type L–L' as the series of years in which a firm has the same consecutively observed number of management layers L plus the adjacent series of years in which a firm has the same consecutively observed number of management layers L'. For example, a firm that we observed all years between 1996 and 2000 and that has one layer in 1996, 1997, and 2000 and two layers in 1998 and 1999 would have two sequences: a 1–2 sequence (1996–99) as well as a 2–1 sequence (1998–2000). Firms that never change layers in our sample form a constant-layer sequence. We then separately analyze sequences characterized by an increasing, decreasing, or constant number of layers, as well as all sequences together. As a result, each firm-product can produce multiple sequences: e.g., a firm-product with one layer for 3 years, then two layers for an additional 3 years, and then back to one layer for another 3 years gives rise to two sequences, an increasing one (111222) and a decreasing one (222111).

TABLE 5
QUANTITY-BASED TOTAL-FACTOR PRODUCTIVITY: ORDINARY LEAST SQUARES ESTIMATOR WITH PRODUCT FIXED EFFECTS

	Increasing (1)	Decreasing (2)	Constant (3)	All (4)
Quantity-based productivity $t-1$	.892***	.875***	.905***	.895***
	(.014)	(.015)	(.013)	(.008)
Change in layers	.025**	.032***		.025***
	(.011)	(.012)		(.007)
Constant	−.161**	.112***	.309**	.082**
	(.063)	(.035)	(.130)	(.033)
Observations	4,141	2,829	3,031	10,001
Adjusted R^2	.779	.752	.801	.781

NOTE.—Year and industry dummies are included in the estimations. Firm-level-clustered standard errors are in parentheses.
** $p < .05$.
*** $p < .01$.

by around 3%. We find that downward transitions seem to be characterized by somewhat larger effects than upward transitions.

2. Instrumental Variable

There are two issues with specification (19). The first issue is that ΔL_{it} is endogenous. The second issue is that due to the simultaneous presence of fixed effects and the lagged dependent variable, the usual strategy of first differencing the estimating equation to remove panel effects may create problems in the presence of predetermined variables, such as the lags of the dependent variable.

We deal with the first issue by instrumenting ΔL_{it} using demand, λ_{it-1}, and markups, μ_{it-1}, at time $t-1$, number of layers, revenue and quantity in $t-1$, productivity at time $t-2$, and capital at time t, as well as all of these variables lagged to the first available year. All of these variables meet the requirements of good instruments under the timing assumptions of our model. In order to deal with the second issue and incorporate a full set of firm-product-sequence fixed effects exactly as in (19), we use the dynamic panel data system generalized method of moment (GMM) estimator developed by Arellano and Bover (1995).

Table 6 reports the estimations of the structural quantity-based TFP equation. The results show a positive relationship between changes in layers and quantity-based productivity, even when controlling for changes in quantity and allowing both variables to be endogenous. Coefficients are positive and significant. Point estimates are larger than before when the effect of a firm adding a layer is 3% and that of dropping layers is 5%. However, we find a larger effect of around 6% when we pull all the observations in column 4.

TABLE 6
Quantity-Based Total-Factor Productivity: Dynamic Panel Data Estimator with Firm-Product-Sequence Fixed Effects

	Increasing (1)	Decreasing (2)	Constant (3)	All (4)
Quantity-based productivity $t-1$	.912***	.880***	.926***	.910***
	(.012)	(.018)	(.014)	(.008)
Change in layers	.037**	.052**		.062***
	(.017)	(.023)		(.016)
Constant	−.014	.127	.211***	.116***
	(.016)	(.123)	(.042)	(.031)
Observations	4,141	2,829	3,031	10,001
Number of fixed effects	1,663	1,274	1,290	4,227
AR(2) test stat	.468	.117	2.443	1.980
p-value AR(2)	.640	.907	.015	.048

Note.—Year and industry dummies are included in the estimations. Firm-level-clustered standard errors are in parentheses.
** $p < .05$.
*** $p < .01$.

C. *Reorganization and Revenue-Based Productivity*

The purpose of this section is to study the relationship between organization and revenue-based productivity. As we did before, we start by showing the OLS results first and then the instrumental variable (IV).

1. OLS

The specification we run is, following (21),

$$\bar{a}_{it} = \bar{\alpha}_s + \bar{\delta}_t + \bar{\phi}_a \bar{a}_{it-1} + \bar{\phi}_L \Delta L_{it} + \bar{\phi}_R X_{it} + v_{\bar{a}it}, \qquad (23)$$

where $X_{it} = [\lambda_{it-1}, p_{it-1}, \ln(\mu_{it}), k_{it}]$, and as we did before, we use an industry/product fixed effect, $\bar{\alpha}_s$, to reduce the number of fixed effects.

Table 7 presents the results. All of the point estimates of $\bar{\phi}_L$ are negative and significant and point to an impact of reorganization of about −3%. Adding (dropping) layers leads to an decrease (increase) in revenue-based TFP of around 3%.[34] Interestingly enough, and parallel to the quantity-based TFP analysis, downward transitions seem to be characterized by somewhat larger effects than upward transitions. The differences here are somewhat more pronounced, however.

2. IV

In order to estimate (21), we need to deal with the same two issues we dealt with in the case of quantity-based productivity. Now, however, in

[34] We use the terms "TFP" (total-factor productivity) and "productivity" synonymously throughout the text.

TABLE 7
Revenue-Based Total-Factor Productivity: Ordinary Least Squares Estimator with Product Fixed Effects

	Increasing (1)	Decreasing (2)	Constant (3)	All (4)
Revenue-based productivity $t-1$	.925***	.940***	.955***	.943***
	(.017)	(.021)	(.017)	(.011)
Change in layers	−.023***	−.032***		−.027***
	(.006)	(.006)		(.003)
Demand $t-1$	−.019***	−.018***	−.025***	−.020***
	(.004)	(.003)	(.003)	(.003)
Price $t-1$	.010*	.005	.019***	.012***
	(.005)	(.005)	(.007)	(.004)
Log markup	.484***	.434***	.553***	.486***
	(.043)	(.044)	(.059)	(.036)
Capital	.004**	.003	.005**	.004***
	(.002)	(.003)	(.002)	(.001)
Constant	.237***	.095*	−.704***	.707***
	(.046)	(.051)	(.153)	(.057)
Observations	4,141	2,829	3,031	10,001
Adjusted R^2	.851	.844	.882	.860

Note.—Year and industry dummies are included in the estimations. Firm-level-clustered standard errors are in parentheses.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

addition to finding an instrument for ΔL_{it}, we have to instrument for ln (μ_{it}) in X_{it}, which is endogenous, according to our assumptions. Our solution strategy is to use the same set of instruments for $\ln(\mu_{it})$, namely, demand, λ_{it-1}, and markups, μ_{it-1}, at time $t-1$, number of layers, revenue and quantity in $t-1$, productivity at time $t-2$, and capital at time t, as well as all of these variables lagged to the first available year. As we did for quantity-based productivity, here we use a full set of firm-product-sequence fixed effects.

Table 8 reports the results obtained using the same dynamic panel data system GMM estimator used above. The results paint a picture very similar to the one emerging from the OLS results in table 7. While the effect of changing layers is now a bit smaller across the board, it is negative and significant in all specifications. Table 8 indicates again that decreasing the number of layers has a larger impact on productivity than adding layers. The overall causal effect of adding a layer is around −3%.

D. A Case Study: Textile and Apparel

As a final attempt to identify a causal effect of reorganization, we now use the textile sector as an example of an industry that experienced an exogenous shock. The shocks we study are the changes in quotas applied to

TABLE 8
Revenue-Based Total-Factor Productivity: Dynamic Panel Data Estimator Results with Firm-Product-Sequence Fixed Effects

	Increasing (1)	Decreasing (2)	Constant (3)	All (4)
Revenue-based productivity $t-1$	.935***	.956***	.967***	.953***
	(.014)	(.019)	(.016)	(.009)
Change in layers	−.018**	−.035***		−.025***
	(.008)	(.011)		(.009)
Demand $t-1$	−.006	−.008***	−.008*	−.006***
	(.003)	(.002)	(.004)	(.002)
Price $t-1$	−.007	−.011*	−.001	−.006*
	(.005)	(.006)	(.006)	(.003)
Log markup	.075	.059	.074	.049
	(.070)	(.046)	(.081)	(.042)
Capital	.001	.002	.001	.001
	(.002)	(.002)	(.002)	(.001)
Constant	−.027***	.079	.000	−.014**
	(.009)	(.051)	(.000)	(.006)
Observations	4,141	2,829	3,031	10,001
Number of fixed effects	1,663	1,274	1,290	4,227
AR(2) test stat	.043	1.352	1.548	1.805
p-value AR(2)	.966	.177	.122	.071

Note.—Year and industry dummies are included in the estimations. Firm-level-clustered standard errors are in parentheses.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

the textile and apparel industry associated with China's entry into the WTO. We use the data on reductions in quotas across subindustries and follow the methodology of Bloom, Draca, and Van Reenen (2016). The underlying identifying assumption of this strategy is that unobserved demand/technology shocks are uncorrelated with the strength of quotas to non-WTO countries (such as China) in 2000. This is reasonable, since these quotas were built up from the 1950s, and their phased abolition negotiated in the late 1980s was in preparation for the Uruguay Round.

To measure the degree of exposure to the quota removal, we compute for each six-digit Prodcom product category p the proportion of the more detailed six-digit harmonized system (HS6) products that were covered by a quota, weighting each HS6 product by its share of EU15 imports over the period 1995–97. Call this QuotaCoverage_p. Then, for each firm-product i, where by "firm-product," we mean a two-digit Prodcom code-firm combination, as in the rest of the analysis, we measure the level of exposure to the quota as a weighted average, where weights are the initial shares of products p for a particular firm-product i of QuotaCoverage_p. We label this variable QuotaCoverage_i and focus on the relevant period 2000–2005.

We estimate the specification

$$\tilde{a}_{it} = \delta_t + \phi_a \tilde{a}_{it-1} + \phi_L \Delta L_{it} + v_{ait}, \tag{24}$$

where δ_t is a time fixed effect. Note that there is no product fixed effect, since we are only conditioning on firms in the textile and apparel industry. We estimate the regression using OLS and IV estimators. The IV specification for quantity-based TFP uses the variable QuotaCoverage_i as an instrument. Note that since QuotaCoverage_i is time invariant, it precludes us from using firm-product-sequence fixed effects. We are interested in events occurring in the relevant time frame 2000–2005 only, so we lump together all of the available sequences. We obtain our set of instruments from a fourth-order polynomial in QuotaCoverage_i and the lagged number of layers. We present the first stage in appendix E.

The revenue-based TFP specifications is given by

$$\bar{a}_{it} = \bar{\delta}_t + \bar{\phi}_a \bar{a}_{it-1} + \bar{\phi}_L \Delta L_{it} + \bar{\phi}_R X_{it} + v_{\bar{a}it}, \tag{25}$$

where, as before, $X_{it} = [\lambda_{it-1}, p_{it-1}, \ln(\mu_{it}), k_{it}]$ and $\bar{\delta}_t$ is a time fixed effect. Again, we drop the product fixed effect since we analyze only one industry. We instrument ΔL_{it} and $\ln(\mu_{it})$ with a fourth-order polynomial in QuotaCoverage_i and the lagged number of layers.

Table 9 reports the results. We find that firms that reduce layers exhibit a reduction in quantity-based productivity (significant at 1% for the OLS and IV) and an increase in revenue-based productivity (although the results are not significant). The results on quantity-based productivity are consistent with the main claim of our paper, significant, and quite large. When focusing on the firms that experienced the shock, the IV results show that, in this industry, reducing a layer reduces quantity-based productivity by 14%. Without instrumenting, we find that these results are dampened, as we would expect in the presence of reverse causality. The results are also larger than for the whole manufacturing sector. This might be the result of the tighter identification of the shock or of the particular characteristics of the textile sector. Firms in the textile sector are larger and more labor intensive than firms in the rest of manufacturing.

In sum, throughout our investigation, we did not find any significant evidence to falsify the hypothesis proposed by the knowledge-based hierarchy model. All the significant evidence is in line with its predictions. Hence, we conclude that when firms receive an exogenous shock that makes them reorganize, both quantity-based and revenue-based productivity are significantly affected.[35]

[35] Of course, there could always be some other unobserved concurrent response that causes the productivity changes and is correlated with changes in layers in the required way. Our claim of causality is qualified by this standard caveat to virtually all instrumental variable empirical strategies.

TABLE 9
Textile and Apparel: Ordinary Least Squares (OLS) and Instrumental Variable (IV) Estimates

	Revenue-Based Total-Factor Productivity		Quantity-Based Total-Factor Productivity	
	OLS (1)	IV (2)	OLS (3)	IV (4)
Revenue-based productivity $t-1$	.834***	.827***		
	(.040)	(.042)		
Quantity-based productivity $t-1$			.865***	.864***
			(.030)	(.030)
Change in layers	−.014	−.026	.085***	.147**
	(.014)	(.018)	(.028)	(.066)
Demand $t-1$	−.011***	−.008***		
	(.002)	(.003)		
Price $t-1$	.004	.002		
	(.008)	(.008)		
Log markup	.145***	.097*		
	(.033)	(.058)		
Capital	.003*	.002		
	(.002)	(.002)		
Constant	−.077**		.019	
	(.033)		(.027)	
Observations	554	554	554	554
Adjusted R^2	.666	.660	.729	.725
Kleibergen-Paap statistic		32.50		42.03

Note.—Year dummies are included in the estimations. Firm-product-level-clustered standard errors are in parentheses.
* $p < .1$.
** $p < .05$.
*** $p < .01$.

VI. Additional Results

A. *The Effect of Organization on Prices*

As we have emphasized, the main difference between the impacts of a reorganization on revenue-based and quantity-based productivity is its effect on prices. Therefore, one obvious reaction is to try to look directly at the effect of reorganizations on prices. While it is important to note that we do not actually observe prices in our data—we have information on quantities sold and related revenues—we can still construct unit values (revenue over quantity) in lieu of actual prices and study how they change as firms reorganize.

Using unit values as a measure of prices to gauge relative changes in revenue- and quantity-based productivity could be problematic, since any measurement error in quantity and/or revenue will add into this residual measure of prices. With this caveat in mind, we can measure the effect of a firm's reorganization on our measure of prices by estimating the nonstructural price equation,

TABLE 10
PRICES: DYNAMIC PANEL DATA ESTIMATOR RESULTS WITH FIRM-PRODUCT-SEQUENCE FIXED EFFECTS

	Increasing (1)	Decreasing (2)	Constant (3)	All (4)
Price $t-1$	.878***	.851***	.905***	.882***
	(.012)	(.021)	(.017)	(.009)
Change in layers	−.059***	−.074***		−.074***
	(.015)	(.021)		(.015)
Constant	.162**	−.060	−.383**	−.001
	(.067)	(.067)	(.152)	(.005)
Observations	4,141	2,829	3,031	10,001
Number of fixed effects	1,663	1,274	1,290	4,227
AR(2) test stat	.940	−.395	1.833	1.354
p-value AR(2)	.347	.693	.067	.176

NOTE.—Year and industry dummies are included in the estimations. Firm-level-clustered standard errors are in parentheses.
** $p < .05$.
*** $p < .01$.

$$p_{it} = b_{1,i} + b_{2,t} + b_p p_{it-1} + b_L \Delta L_{it} + u_{it}, \tag{26}$$

where the dependent variable is the log price p_{it}, computed as the difference between revenue-based TFP $\bar{a}_{it}$ and quantity-based TFP $\tilde{a}_{it}$. We also include firm-product-sequence fixed effects $b_{1,i}$ and time fixed effects $b_{2,t}$. We instrument ΔL_{it} as we did before.

Table 10 reports estimations using the Arellano and Bover (1995) estimator. We find that the results using prices are consistent with our main results; that is, firms that increase (decrease) layers reduce (increase) their prices.[36]

1. Cost Pass-Through Conditional on Reorganization

One way to think about the price responses implied by our results above is through the pass-through of a change in cost into prices. A simple calculation taking the responses of revenue- and quantity-based productivity to a change in layers delivers a cost pass-through that is greater than one.[37]

[36] Of course, we could use a similar reduced-form approach to run identical regressions for all three variables of interest, i.e., quantity-based productivity, revenue-based productivity, and prices. This estimation leads to results very similar to the ones above. In this case, by construction, the effect of change in layers on revenue-based productivity is simply the sum of the effect of a change in layers on quantity-based productivity plus the effects on prices.

[37] For instance, take the elasticity of a change in revenue-based productivity to a change in layers, −0.025 (table 8, col. 4) and the elasticity of a change in quantity-based productivity to a change in layers, 0.062 (table 6, col. 4) and note that the implied response to prices is −0.088, which is 1.4 times larger than the change in costs. The response is 1.2 times larger if we use the results in col. 4 of table 10.

This number might seem high relative to other studies of cost pass-through that, in general, find values between 0.6 and 0.9. However, note that this calculation measures the cost pass-through conditional on a reorganization. This conditional pass-through has never been estimated before and so has no direct counterpart in the literature. In order to compare the cost pass-through into prices in our data with the estimations in the literature, we need to instead calculate an unconditional measure. In doing so, we follow two approaches.

First, we use Portuguese trade data to study the effect of exchange rate shocks on export behavior of multiproduct firms, following the recent approach of Chatterjee, Dix-Carneiro, and Vichyanond (2013). We find an import price elasticity to the real exchange rate of 0.85, which is very close to what Chatterjee et al. find for Brazil. Berman, Martin, and Mayer (2012) find 0.83 with firm-level French data, while Campa and Goldberg (2010) find 0.64 with country- and industry-level data from the Organisation for Economic Co-operation and Development. Therefore, our findings for this period in Portugal are clearly in line with the literature.

These results use export prices and not the Prodcom-based prices we use in our main analysis. So, as an additional exercise, we compute the price response of changes in quantity-based productivity (obtained using the procedure in our main exercise). We find almost identical elasticities with respect to cost changes (we can do the estimation separately for multiproduct and single-product firms and find price elasticities to quantity-based productivity of 0.81 and 0.64, respectively, exactly in line with the literature).

Why do we obtain results that seem to suggest large pass-through? The key is that our results are not measuring average responses of prices to changes in costs or demand. They are measuring changes in prices (or revenue-based productivity) conditional on changes in layers. That is, a cost or demand shock can be quite small, but it might trigger a reorganization since the firm was right at the threshold that determines the decision to reorganize. The reorganization then changes the firm size substantially, which results in a large change in prices (as we argue above). As a result, the associated pass-through will seem too large because the original shock was small relative to the change in prices due to the reorganization (even the augmented shock, once we take into account the endogenous effect on quantity-based productivity of the reorganization, will seem small). Given that the literature has only calculated average pass-throughs without conditioning on shocks that trigger a reorganization, our results are not directly comparable with the literature and predictably somewhat larger. However, as we discussed above, once we calculate the unconditional pass-through, we obtain exactly the same numbers others have computed.

B. Aggregate Productivity Effects from Reorganization

The results in the previous section indicate that reorganizations lead to large changes in quantity-based productivity for a firm. If we want to gauge the importance of organization for aggregate productivity dynamics, we need to understand how important is the effect of reorganizations for the average firm that reorganizes. So, for the firms that reorganize, we want to ask how important is the change in productivity that resulted from the reorganization, compared with changes in productivity due to shocks or the mean reversion implied by the process in (10).

Consider a firm i that we observe from $t-T$ to t. Iterating over equation (10), we obtain that

$$\tilde{a}_{it} - \tilde{a}_{it-T} = \sum_{v=0}^{T-1} \phi_a^v(\alpha_i + \delta_{t-v}) + (\phi_a^T - 1)\tilde{a}_{it-T} + \phi_L \sum_{v=0}^{T-1} \phi_a^v \Delta L_{it-v} + \sum_{v=0}^{T-1} \phi_a^v v_{ait-v}.$$

Hence, the overall change in productivity for a firm, given by $\tilde{a}_{it} - \tilde{a}_{it-T}$, can be decomposed into three components. The first term is the compounded set of fixed effects. The second term is a mean reversion component that is negative when $\tilde{a}_{it-T}$ is positive since $\phi_a < 1$. Namely, productivity tends to revert to its long-term mean given the number of layers. The cumulative change in productivity due to a reorganization, the term of interest, is given by the third term, namely, $\phi_L \Sigma_{v=0}^{T-1} \phi_a^v \Delta L_{it-v}$. The fourth term is just the accumulated effect of past shocks. Note that, because of mean reversion, the third and fourth components explain more than 100% of the overall change in productivity. We now explore how large is the third term, the change in productivity due to a reorganization, relative to the total.

We calculate these terms for firms that increase and decrease the number of layers between $t-T$ and t. Using our results for ϕ_L and ϕ_a from column 4 of table 6, we calculate each of these terms for the whole distribution of firms. Clearly, the actual change in productivity across firms is very heterogeneous. Some firms that add layers experience a large decline in productivity, while some experience a very large increase. Hence, we order firms by their overall change in productivity and in table 11 present the distribution of the overall changes in productivity and the change in productivity due to changes in layers.[38] Columns 2 and 3 present the results for firms that increase layers, while columns 4 and 5 present the results for firms that drop layers.

[38] The unit of observation is actually a firm-product, and we allow $t-T$ and T to vary across firm-product pairs.

TABLE 11
Change in Quantity Total-Factor Productivity due to Reorganization

	Firms That Increase Layers		Firms That Reduce Layers	
Percentile (%)	Overall Change	Due to Reorganization	Overall Change	Due to Reorganization
10	−.483	.042	−.523	−.093
25	−.179	.051	−.272	−.062
50	.055	.056	−.034	−.062
75	.318	.062	.200	−.053
90	.673	.100	.517	−.047
Mean	.066	.062	−.019	−.063
Observations	810	810	465	465

The results are stark. On average, or for the median firm, the increase in productivity due to reorganization explains more than the total increase in overall mean productivity. This is clearly not the case for all firms, as some of them receive large positive or negative productivity shocks that account for most of the changes in productivity, but on average those shocks (and the associated reversion to the mean) contribute to more than the aggregate mean variation. The result is that reorganization can account for an increase in quantity-based productivity, when firms reorganize by adding layers, of about 6.3%, while the average increase in productivity for these firms is 6.6%. Similarly, when firms reduce the number of layers, reorganization accounts for a 6.3% decrease in quantity-based productivity, while the average decrease in productivity for these firms is about 2%. Reorganization accounts for more than 100% of the overall change in productivity of expanding and downsizing firms. These results underscore the importance of the reorganization of firms as a source of aggregate productivity gains in the economy.

VII. Conclusion

Large firm expansions involve lumpy reorganizations that affect firm productivity. Firms that reorganize and add a layer increase hours of work by 25% and value added by slightly more than 3%, while firms that do not reorganize decrease hours slightly and value added by only 0.1%. Reorganization therefore accompanies firms' expansions. A reorganization that adds layers allows the firm to operate at a larger scale. We have shown that such a reorganization leads to increases in quantity-based productivity of about 6%. Even though the productive efficiency of the firm is enhanced by adding layers, its revenue-based productivity declines by around 3%. The new organizational structure lowers the marginal cost of the firm and allows it to increase its scale. This makes firms expand their quantity and move down their demand curves, thereby lowering prices and revenue-based productivity.

We use a detailed data set of Portuguese firms to show that these facts are very robustly present in the data. Our data set is somewhat special in that it includes not only employer-employee matched data, which are necessary to build a firm's hierarchy, but also information on quantity produced. This allows us to contrast the effect of reorganization, using fairly flexible methodologies, to calculate quantity- and revenue-based productivity. Furthermore, given that we have a relatively long panel, we show that the results hold using a large number of fixed effects on top of time and industry dummies. We do not find any case in which the evidence significantly falsifies the main hypothesis of the effect of a reorganization on both types of firm productivity. In contrast, we present significant evidence of a causal effect of an increase in layers on both revenue-based and quantity-based productivity.

Our findings underscore the role that organizational decisions play in determining firm productivity. Our results, however, can be viewed more broadly as measuring the impact of lumpy, firm-level changes on the endogenous component of firm productivity. Many changes that increase the capacity of the firm to grow (such as building a new plant or production line or creating a new export link with a foreign partner) will probably result in similar effects on quantity- and revenue-based productivity. In our view, the advantage of looking at reorganizations using a firm's management layers, as defined by occupational classifications, is that firms change them often and in a very systematic way. Furthermore, this high frequency implies that many of the observed fluctuations in both quantity-based and revenue-based productivity result from these endogenous firm decisions and should not be treated as exogenous shocks to the firm.

We also provide new evidence on how firms change prices conditional on changes in layers. These results relate to a large body of literature trying to underscore the magnitude of cost pass-through into prices. While our conditional results are larger than the ones found in this literature, once we calculate the unconditional pass-through, we obtain exactly the same numbers others have computed in similar data sets. Hence, conditioning on whether or not a firm has reorganized is important to understanding the pricing decisions of firms.

Recognizing that part of a firm's productivity changes are endogenous is relevant because the ability of firms to change their organization might depend on the economic environment in which they operate. We have shown that changing the number of management layers is important for firms to realize large productivity gains when they grow. Environments in which building larger hierarchies is hard or costly—due to, for example, the inability to monitor managers or to enforce detailed labor contracts—prevent firms from obtaining these productivity gains.[39] This, among other

[39] See Bloom et al. (2013) for some evidence on potential impediments in India.

factors, could explain why firms in developing countries tend to grow less rapidly (Hsieh and Klenow 2014).

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