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Export Destinations and Input Prices†

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This paper examines the relationship between the destination of exports and the input prices paid by firms, using detailed customs and firm-product-level data from Portugal. Both ordinary least squares regressions and an instrumental-variable strategy using exchange-rate movements (interacted with indicators for initial exports) as a source of variation in destinations indicate that exporting to richer countries leads firms to pay higher prices for inputs, other things equal. The results are supportive of what we call the income-based quality-choice channel: selling to richer destinations leads firms to raise the average quality of goods they produce and to purchase higher-quality inputs. (*JEL* D22, D24, F14, F31, L15)

A growing body of research suggests that exporting has important effects on firm behavior. Although results for residual-based measures of productivity are mixed,[1] recent studies have found causal effects of exporting on a variety of directly observable outcomes. For instance, Bustos (2011) and Lileeva and Trefler (2010) find effects on technology investments by Argentinian and Canadian firms, respectively. Verhoogen (2008) finds effects on wages and ISO 9000 certification (an international production standard) in Mexico. Tanaka (2017) finds improvements in working conditions in garment and food-processing firms in Myanmar. Atkin, Khandelwal, and Osman (2017) find effects on various directly observable dimensions of product quality among Egyptian rug producers.

A number of theoretical explanations for such effects have been advanced. Perhaps the most common class of models emphasizes *scale effects:* in the presence of fixed investment costs, for instance for purchases of technology or worker

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[1] See, e.g., Clerides, Lach, and Tybout (1998); Bernard and Jensen (1999); Alvarez and López (2005); Van Biesebroeck (2005); De Loecker (2007); Park et al. (2010).

screening, increases in sales volume due to exports reduce the fixed costs per unit and tend to induce firms to undertake such investments (Yeaple 2005; Bustos 2011; Helpman, Itskhoki, and Redding 2010). A key feature of this class of models is that the effects of exporting on firm behavior depend on the volume of exports per se, and not on the characteristics of particular export destinations. A separate class of explanations focuses on *quality choice:* the varieties that firms sell on export markets may differ from those that they sell on domestic markets, and the different varieties may require different technologies, skills, and other inputs in production. This class encompasses two distinct mechanisms. One is that per-unit transport costs may lead firms to export goods with higher value per unit, a phenomenon known as the "Washington apples" effect following a famous example in Alchian and Allen (1964).[2] The other is that, if richer consumers are more willing to pay for product quality, firms may choose to sell higher-quality varieties in richer markets to appeal to them.[3] These mechanisms both suggest that destinations matter, but they emphasize different characteristics. In the first, what matters is distance from the home market (or trade costs more broadly). In the second, what matters is the income level of consumers in the destination.[4]

Empirically, the relative importance of these different mechanisms remains an open question. Plant-level datasets typically do not provide information on the destination of exports, which makes it difficult to distinguish among the various channels. Newly available customs datasets on firms' international transactions have provided some support for the income-based quality-choice channel. In Portuguese data, Bastos and Silva (2008, 2010) show that individual firms charge higher prices for goods sold to richer destination markets within narrow product categories, controlling for distance and other destination characteristics.[5] Subsequent papers have documented similar patterns in China, France, and Hungary (Manova and Zhang 2012; Martin 2012; Görg, Halpern, and Muraközy 2010). This cross-sectional evidence is not definitive, however, for two reasons. First, firms may charge higher markups in richer countries, even for homogeneous goods (Krugman 1987; Goldberg and Knetter 1997; Goldberg and Hellerstein 2008; Alessandria and Kaboski 2011; Fitzgerald and Haller 2014; Simonovska 2015). Second, the cross-sectional evidence does not settle the issue of causality: even if export prices did reflect product quality, shocks at the firm level could affect both which products a firm chooses to sell and where it is able to sell them, possibly generating a positive correlation

[2] See also Feenstra (1988); Hummels and Skiba (2004); and Feenstra and Romalis (2014).

[3] The idea that richer consumers are more willing to pay for product quality has been in the trade literature at least since Linder (1961). See also Markusen (1986); Flam and Helpman (1987); and Hallak (2006). We believe that Verhoogen (2008) was the first to formalize the idea that an individual firm would choose to sell higher-quality varieties in richer destination markets than poorer ones in a heterogeneous firms model.

[4] The foregoing list of explanations is not exhaustive. Matsuyama (2007) formalizes the idea that exporting requires expenditures on marketing and distribution that are not required on domestic markets, suggesting that the volume of exports rather than destination characteristics should matter for firms' decisions. A number of authors have highlighted learning-by-exporting effects, although the extent to which such effects depend on characteristics of destination markets is typically not specified. An argument that learning-by-exporting effects are particularly strong when exporting to richer foreign markets, for instance because of stricter standards or more demanding buyers, is very much in the spirit of the income-based quality-choice story described above (see, e.g., De Loecker 2007).

[5] Bastos and Silva (2008, 2010) use "free on board" (FOB) prices (which do not include transport costs) and also find a positive correlation between price and distance, consistent with the "Washington apples" hypothesis.

between quality and destination income even in the absence of a causal effect of exporting on firm behavior.

In this paper, we use a rich combination of customs and firm-product-level price data from Portugal to further examine the income-based quality-choice channel, using exchange-rate movements as a source of exogenous variation in the destination of Portuguese firms' sales. Our approach is motivated by two theoretical ideas. First, as mentioned above, countries are asymmetric in income and in consumers' willingness to pay for product quality, and individual firms choose to sell higher-quality varieties in richer markets. Second, firm productivity and input quality are complements in producing output quality, as in Verhoogen (2008) and Kugler and Verhoogen (2012); in equilibrium, more-productive firms use higher-quality inputs to produce higher-quality products. The implication is that an exogenous shift in the destination of exports toward a richer market will lead a firm not only to produce higher-quality products, but also to use higher-quality inputs on average.

While this prediction is conceptually straightforward, taking it to the data presents a challenge. Direct measures of product quality are not available in the Portuguese data, nor in any other nationally representative data we are aware of. Our strategy in this paper is to draw inferences about quality from detailed information about prices at the firm-product (and firm-product-destination) level. But as mentioned above, prices may reflect markups rather than product quality; a large literature has documented not only that markups vary within firms across destinations, but also that markups respond within firm-product-destination over time in response to exchange-rate movements.[6] Our key contention is that while endogenous markups may confound attempts to draw inferences about product quality from *output* prices, they are not expected to influence the *input* prices paid by Portuguese firms. In the absence of effects on product quality, we would not expect a systematic relationship between destination-market income and input prices, controlling for the scale of output and other observable factors.

To organize our thinking about the empirical work, we develop a model of output and input quality choice by heterogeneous firms with variable markups, extending the framework of Atkeson and Burstein (2008). Following Amiti, Itskhoki, and Konings (2014), we focus on the variant of the Atkeson-Burstein model with Bertrand competition, and take as given the entry decisions of firms into destination markets. The model provides a formal justification for the intuitive statement above: while endogenous markups influence the choice of output price, they are not expected to influence the input prices paid by firms. The model employs a specific demand system and has a number of other special characteristics, but we believe that the same implication would follow in a variety of frameworks commonly used in the trade literature.

In the empirical section, we relate average input prices at the firm level to the average income of a firm's destination markets. Simple OLS regressions indicate a robust, positive association between destination income and input prices, controlling for the average distance of the firm's destinations, its share of revenues from exports,

[6] This fact has been extensively documented in the literature on pass-through: see, e.g., Goldberg and Knetter (1997); Nakamura and Zerom (2010); Goldberg and Hellerstein (2008, 2013); Berman, Martin, and Mayer (2012); Chatterjee, Dix-Carneiro, and Vichyanond (2013); and Amiti, Itskhoki, and Konings (2014).

and its overall sales. One might plausibly worry about various forms of endogeneity, discussed in more detail below, and we also implement an instrumental variable (IV) strategy, instrumenting average destination income with real-exchange-rate changes interacted with indicators of whether firms had positive exports to each destination in an initial year. In our preferred IV specification, we include instruments only for non-eurozone export destinations, which represent a minority of Portuguese exports, and there is reason to be concerned that the first stage of the IV procedure is weak. But both weak-instrument-robust statistics and arguments about the direction of the weak-instrument bias lead us to the conclusion that there is an economically significant, positive relationship between average destination income and average input prices. As a robustness check, we implement an alternative IV strategy using firm-specific average real-exchange-rate changes for income groups as instruments, and the results are similar. We also consider the possibility that different types of market power in input markets could be generating the price effects even in the absence of effects on quality choice, but it does not appear that these mechanisms can completely explain our baseline results. Overall, we interpret both the OLS and the IV results as supportive of the hypothesis that an increase in average destination income leads firms to raise the average quality of goods they produce and to purchase higher-quality inputs.

This paper is perhaps most closely related to a recent study by Brambilla, Lederman, and Porto (2012). Using Argentinian data, the authors show that the Brazilian devaluation of 1999 led Argentinian firms to increase the share of exports to other destinations—principally the United States and Europe—and they find that increased exports to richer countries led to higher skill composition and higher wages at the firm level, while increased exports per se had no such effect.[7] Relative to that paper, the main advantage of the current paper is that we have access to data on material input prices; arm's length supplier relationships are arguably less subject to the concern that prices are determined by particular factor-market institutions (e.g., collective bargaining, or fair/efficiency wages, which may be particularly relevant in Argentina).[8] In addition, we control for the average distance of export destinations. The fact that in the Portuguese case richer destinations (e.g., United Kingdom, Sweden) tend to be nearer and poorer destinations (e.g., Brazil, Angola) tend to be further away—in contrast to the Argentinian case, where destination income and distance tend to be positively correlated—helps to strengthen our argument that the positive destination income-input price relationship is due to income-based quality choice and not distance. Overall, however, our findings remain quite consistent with the broader argument in Brambilla, Lederman, and Porto (2012), as well as in Verhoogen (2008). In addition to the papers cited above, our paper is related to a growing recent literature on the role of product quality in trade, including Schott (2004); Hummels and Klenow (2005); Sutton (2007); Choi, Hummels, and Xiang (2009); Hallak and Schott (2011); Baldwin and Harrigan (2011); Fajgelbaum, Grossman, and Helpman (2011); Fieler (2011);

[7] In related papers, Brambilla, Lederman, and Porto (2016) find consistent evidence that Chilean exporters hire more engineers when they increase exports and Brambilla and Porto (2016) show that the relationship between destination income and wages holds in a large set of countries.

[8] We also have output prices, which were not available in the previous study.

Eckel et al. (2015); Crozet, Head, and Mayer (2012); Johnson (2012); Hallak and Sivadasan (2013); Amiti and Khandelwal (2013); Markusen (2013); Caron, Fally, and Markusen (2014); Di Comite, Thisse, and Vandenbussche (2014); Iacovone and Javorcik (2012); Harrigan, Ma, and Shlychkov (2015); Gervais (2015); Fan, Li, and Yeaple (2015); Bas and Strauss-Kahn (2015); Demir (2016); Blaum, Lelarge, and Peters (2017); and Fieler, Eslava, and Xu (2018).

Although we focus on Portugal, a middle-income country, we believe that our findings have implications for our understanding of the upgrading process in developing countries as well. In particular, the results reinforce the idea that increasing exports to high income destinations may require quality upgrading of entire complexes of suppliers and downstream producers, not just of particular exporters (Kugler and Verhoogen 2012). The particular empirical setting has the advantage that it allows us to identify cleanly a causal relationship between destination income and material input prices, but the basic findings seem likely to apply more broadly.

I. Theoretical Framework

In this section we develop a model of input and output quality choice by heterogeneous firms with endogenous markups. The framework builds on the model of Atkeson and Burstein (2008), adding differences in willingness to pay for quality across countries (similar to Hallak 2006; Verhoogen 2008; and Hallak and Schott 2011), and a complementarity between firm productivity and input quality in producing output quality (as in Verhoogen 2008 and Kugler and Verhoogen 2012). Following Amiti, Itskhoki, and Konings (2014), we use the variant of the Atkeson-Burstein model where pricing is Bertrand, and we take the entry decision of firms into different markets as given.[9] Because of the latter, the model is very "partial-equilibrium." On the other hand, in the empirical application we look at short-run responses to exchange-rate movements, and it is plausible that there is limited reshuffling of firms across markets over the time horizons we consider.

There are K countries, each with a continuum of sectors, with each sector populated by an exogenously given, finite set of heterogeneous firms. Firms are indexed by i, sectors by s, and years by t. In the model, we assume firms are active in just one sector; hence i identifies sector as well as firm. We suppress the time subscript until we consider the response to exchange-rate movements in Section ID. Each firm is assumed to sell one product in each country. We use j to index production locations and k to index destination markets. We will be focusing on producers in one country, call it home, and will suppress the index for location when the meaning is clear. Let ϵ_{jk} be the nominal exchange rate between the production location j and destination market k, defined as units of j currency over units of k currency.

[9] While Amiti, Itskhoki, and Konings (2014) allow for endogenous choice of input origin, we abstract from this decision, in the interests of tractability, and treat all inputs as sourced domestically. In the empirical work, we take into account the fact that firms differ in their sourcing strategies, and allow exchange-rate changes to affect directly the input prices paid by firms.

A. *Demand*

In each country, there is a representative consumer with nested constant elasticity of substitution (CES) preferences. The upper nest is given by

$$(1) \qquad U_k = \left[\int_{s\in S_k} (X_{sk})^{\frac{\eta-1}{\eta}} ds\right]^{\frac{\eta}{\eta-1}},$$

where X_{sk} is a sector-level aggregate that depends in part on product quality:

$$(2) \qquad X_{sk} = \left[\sum_{i\in I_{sk}} \left({q_{ik}}^{\zeta(y_k)} x_{ik}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}.$$

Here I_{sk} is the set of firms selling in sector s in country k; q_{ik} is product quality; x_{ik} is consumption and; $\zeta(y_k)$ captures the representative consumer's valuation of quality, which we assume is strictly increasing in the country's income level, y_k, which we take as exogenous.[10] To reduce clutter, we will write $\zeta_k = \zeta(y_k)$. We assume that $\zeta_k > 1/2$ for all k, which will ensure an interior solution for the choice of quality. Following Atkeson and Burstein (2008), we assume that goods are more substitutable within sectors than across sectors, and that both are greater than 1: $\rho > \eta > 1$.

We adopt the convention of reporting monetary values principally in destination-market currency; values in producer currency are indicated by an asterisk. The exact price index corresponding to (1)–(2) is

$$(3) \qquad P_k = \left[\int_{s\in S_k} (P_{sk})^{1-\eta} ds\right]^{\frac{1}{1-\eta}},$$

where P_{sk} is a sector-level quality-adjusted price index:

$$(4) \qquad P_{sk} = \left[\sum_{i\in I_{sk}} \left(\frac{p_{ik}}{q_{ik}^{\zeta_k}}\right)^{1-\rho}\right]^{\frac{1}{1-\rho}},$$

and p_{ik} is the output price charged by firm i in market k.

Given the preferences of the representative consumer, demand for the output of firm i in sector s in market k is

$$(5) \qquad x_{ik} = \left(U_k P_k^{\eta}\right) P_{sk}^{\rho-\eta} p_{ik}^{-\rho} q_{ik}^{\zeta_k(\rho-1)}.$$

[10] Comin, Lashkari, and Mestieri (2015), building on Hanoch (1975), have recently developed a nonhomethetic CES framework that can rationalize such an increase in willingness to pay for quality with income.

The corresponding market share is

$$(6)\qquad S_{ik} \equiv \frac{p_{ik}x_{ik}}{\sum_{i' \in I_{sk}} p_{i'k}x_{i'k}} = \left[\frac{\left(\frac{p_{ik}}{q_{ik}^{\zeta_k}}\right)}{P_{sk}}\right]^{1-\rho}.$$

The price elasticity of demand is

$$(7)\qquad \sigma_{ik} \equiv -\frac{p_{ik}}{x_{ik}}\frac{dx_{ik}}{dp_{ik}} = \rho(1 - S_{ik}) + \eta S_{ik}.$$

A key difference between this Atkeson-Burstein-type framework and the Melitz (2003) model is that firms are not assumed to be vanishingly small relative to their sector. The greater a firm's market share in a sector, the greater is the weight that is placed on the between-sector elasticity of demand, η, as opposed to the within-sector elasticity, ρ. Since $\eta < \rho$ by assumption, firms with greater market share face a lower elasticity of demand. Each sector is small relative to the economy as a whole, and firms will ignore the effect of their pricing decisions on the economy-level aggregate $U_k P_k^{\eta}$ in (5).

B. *Production*

As in Kugler and Verhoogen (2012), we assume that there is a perfectly competitive constant-returns-to-scale intermediate-input sector with quality differences. The intermediate sector transforms homogeneous units of labor into intermediate inputs of different qualities.[11] The production function in this sector (in all countries) is assumed to be simply $F(\ell, c) = \ell/c$, where c is the quality of the input produced and ℓ is units of labor. We assume that inputs are sourced domestically.[12] Let the wage level be w_j^* in production location j, denominated in units of producer currency (indicated by the asterisk). The production cost of an intermediate input of quality c in country j will then be $w_j^* c$.

It is convenient to think of firms as producing on a separate production line for each destination, indexed by ik. (Recall that we are focusing on firms in "home" for now.) Let v_{ik}^* be the price paid for inputs on the ik production line, in producer currency. Given perfect competition in the intermediate-input sector, the input price will be equal to the cost of producing the input: $v_{ik}^* = w_j^* c_{ik}$. Given the definition of the nominal exchange rate, ϵ_{jk}, $w_j = w_j^*/\epsilon_{jk}$ and $v_{ik} = v_{ik}^*/\epsilon_{jk} = w_j^* c_{ik}/\epsilon_{jk} = w_j c_{ik}$.

Final-good producers have a "capability" λ_i, which we take as given, along with entry decisions.[13] There is a fixed cost every period to sell in any destination

[11] The intermediate-inputs sector can also be thought of an education sector, which transforms homogeneous unskilled labor into skilled labor.

[12] Thinking of the inputs as labor, this is consistent with the idea that workers cannot move freely between countries. Alternatively, fixed costs of importing inputs and/or variable trade costs may make it more costly to import than to source domestically. While we assume away imports of inputs in the theory, we allow for them in the empirics and consider how exchange-rate movements affect the prices firms pay for inputs.

[13] Following Sutton (2007) and Kugler and Verhoogen (2012), we use the term "capability" to refer to the Melitz productivity draw in order to avoid confusion below, where we allow the parameter to affect both production costs and quality.

market, f_{ik}.[14] There is an iceberg trade cost for shipping to another country: $\tau_{jk} > 1$ for $j \neq k$ and $\tau_{jj} = 1$. In each country, production of physical units in the final-good sector is given by $F(n) = n\lambda_i^a$, where n is the number of units of inputs used and $a > 0$ is a parameter reflecting the extent to which capability lowers unit costs. The marginal cost of each unit of output delivered to the destination (in destination currency) is then $mc_{ik} = v_{ik}\tau_{jk}/\lambda_i^a$.

Following the first variant of Kugler and Verhoogen (2012), the production of quality in the final-good sector is assumed to be governed by a CES combination of firm capability and input quality:[15]

$$q_{ik} = \left[\frac{1}{2}\left(\lambda_i^b\right)^\theta + \frac{1}{2}\left(c_{ik}^2\right)^\theta\right]^{\frac{1}{\theta}}. \tag{8}$$

We assume $\theta < 0$, which guarantees that firm capability, λ, and input quality, c, are complements in generating output quality. The parameter b captures the technological potential for improving quality with increased capability, which we refer to as the scope for quality differentiation. We assume that producing quality does not require fixed investments.

C. *Firms' Optimization*

A firm's profit on a given production line can be written as

$$\pi_{ik}(p_{ik}, c_{ik}; \lambda_i) = \left(p_{ik} - \frac{w_j c_{ik}\tau_{jk}}{\lambda_i^a}\right)\epsilon_{jk}x_{ik} - f_{ik}. \tag{9}$$

Optimizing over the choice of p_{ik} and c_{ik} on each line, we have

$$c_{ik} = (2\zeta_k - 1)^{-\frac{1}{2\theta}}\lambda_i^{\frac{b}{2}}, \tag{10a}$$

$$v_{ik} = w_j(2\zeta_k - 1)^{-\frac{1}{2\theta}}\lambda_i^{\frac{b}{2}}, \tag{10b}$$

$$q_{ik} = \left(2 - \frac{1}{\zeta_k}\right)^{-\frac{1}{\theta}}\lambda_i^b, \tag{10c}$$

$$\mu_{ik} = \frac{\sigma_{ik}}{\sigma_{ik} - 1}, \tag{10d}$$

$$p_{ik} = \mu_{ik}mc_{ik} = \mu_{ik}w_j\tau_{jk}(2\zeta_k - 1)^{-\frac{1}{2\theta}}\lambda_i^{\frac{b}{2}-a}, \tag{10e}$$

$$x_{ik} = \Gamma_k P_{sk}^{\rho-\eta}(2\zeta_k - 1)^{\frac{1}{2\theta}}\left(\mu_{ik}w_j\tau_{jk}\right)^{-\rho}\lambda_i^{(\rho-1)\left[b\left(\zeta_k - \frac{1}{2}\right)+a\right]-\left(\frac{b}{2}-a\right)}, \tag{10f}$$

$$r_{ik} = p_{ik}x_{ik} = \Gamma_k P_{sk}^{\rho-\eta}\left(\mu_{ik}w_j\tau_{jk}\right)^{1-\rho}\lambda_i^{(\rho-1)\left[b\left(\zeta_k - \frac{1}{2}\right)+a\right]}, \tag{10g}$$

[14] We think of the fixed cost of selling in the firm's home market as including any fixed cost of being in business at all; we assume that all firms enter the domestic market.

[15] The multiplicative factor $1/2$ and the 2 in the exponent on c are convenient but not crucial. See Kugler and Verhoogen (2012, fn 30).

where μ_{ik} is the (multiplicative) markup; σ_{ik} is the firm-specific elasticity of demand, defined in (7); mc_{ik} is marginal cost, defined above; r_{ik} is revenues; and $\Gamma_k \equiv U_k P_k^{\eta} \zeta_k^{\frac{\zeta_k(\rho-1)}{\theta}} (2\zeta_k - 1)^{-\frac{(2\zeta_k-1)(\rho-1)}{2\theta}}$, which varies only at the destination level.

Consider first how these choices vary in cross section across firms in home selling in destination market k. It follows from (10a)–(10c) that more capable firms purchase higher-quality inputs, pay higher input prices, and produce higher-quality outputs. Using (10d) and (10g), it is straightforward to show that revenues, r_{ik}, and markups, μ_{ik}, also increase in capability, λ.[16] As in Kugler and Verhoogen (2012), whether output prices are increasing or decreasing in capability (or revenues) depends on the parameters characterizing how capability reduces costs per unit and increases product quality, a and b; if the scope-for-quality-differentiation parameter, b, is sufficiently large then output prices also increase in λ.

Now consider how the choices vary within firms, across production lines producing for different markets. It follows from (10a)–(10c) (recalling that $\theta < 0$) that firms use higher-quality inputs, pay higher input prices, and produce higher-quality outputs for goods destined for richer markets, with higher values of the willingness-to-pay parameter, ζ_k. We have not taken a stand on which firms are active in which markets and hence we cannot draw conclusions about how market shares, markups, and output prices vary across destinations within firms. We can say, however, that in the limit as market shares go to zero ($S_{ik} \rightarrow 0$ and hence $\mu_{ik} \rightarrow \frac{\rho}{\rho - 1}$ for all k) the model predicts that output prices are higher in richer markets (with higher ζ_k), holding trade costs (τ_{jk}) equal.

D. *Production-Line Responses to Real-Exchange-Rate Movements*

Define the real-exchange-rate (RER) between j and k as

$$RER_{jkt} = \frac{\epsilon_{jkt}}{w_{jt}^*/w_{kt}^*}, \tag{12}$$

the nominal exchange rate normalized by the ratio of price levels in j and k. We now reintroduce time subscripts. Consider an increase in the nominal exchange rate between home and destination k, ϵ_{hkt}, holding wages in producer currency unchanged. Such an increase generates an increase in the real-exchange-rate between home and destination k, RER_{hkt}, reflecting a real appreciation in country k relative to home. (Recall that the asterisk denotes monetary values in producer currency.)

What effect does this real-exchange-rate change have on prices and markups of products of home firms destined for k? Consider a production line in continuous

[16] To see this, rewrite (10g):

$$r_{ik}\mu^{\rho-1} = \Gamma_k P_{sk}^{\rho-\eta} (w_j \tau_{jk})^{1-\rho} \lambda_i^{(\rho-1)\left[b\left(\zeta_k - \frac{1}{2}\right)+a\right]}. \tag{11}$$

Note from (7) that σ_{ik} is decreasing in S_{ik} and hence r_{ik}. Hence, from (10d), μ_{ik} is increasing in r_{ik} and the left-hand side of (11) is strictly increasing in r_{ik}. Since $\zeta_k > 1/2$ by assumption, the right-hand side of (11) is increasing in λ. It follows that r_{ik} and hence μ_{ik} are increasing in λ.

operation before and after the RER change (i.e., no change on the extensive margin). Note that (10b) implies

$$v_{ikt}^* = \epsilon_{hkt} v_{ikt} = \epsilon_{hkt} w_{ht} (2\zeta_k - 1)^{-\frac{1}{2\theta}} \lambda_i^{\frac{b}{2}} = w_{ht}^* (2\zeta_k - 1)^{-\frac{1}{2\theta}} \lambda_i^{\frac{b}{2}}$$

and hence that, conditional on w_{ht}^*, the nominal exchange rate does not enter the producer-currency input price. That is, conditional on the domestic wage level (which is constant across firms in a given location), the producer-currency input price on a given production line, v_{ikt}^*, and hence the quality produced on a given production line, q_{ikt}, are *unaffected* by the RER movement.

In contrast, note from (10e) that the producer-currency output price, p_{ikt}^*, can be written as

$$p_{ikt}^* = p_{ikt}\epsilon_{hkt} = \mu_{ikt} w_{ht} \epsilon_{hkt} \tau_{hk} (2\zeta_k - 1)^{-\frac{1}{2\theta}} \lambda_i^{\frac{b}{2}-a} = \mu_{ikt} w_{ht}^* \tau_{hk} (2\zeta_k - 1)^{-\frac{1}{2\theta}} \lambda_i^{\frac{b}{2}-a}.$$

This output price is affected by the RER movement through its effect on the markup term, μ_{ikt}. Intuitively, the foreign appreciation increases the home producer's competitiveness (i.e., reduces its costs in destination-currency terms) and increases its market share in the foreign market. This is turn leads the home producer to pay more attention to the intersectoral demand elasticity, η, relative to the (higher) intrasectoral elasticity, ρ, and hence to charge a higher markup. Using (6) and (7), we can derive the elasticities of the markup and prices with respect to the nominal exchange-rate change (holding wage rates constant in producer currency terms):

$$\text{(13a)} \quad \frac{d\log p_{ikt}^*}{d\log \epsilon_{hkt}} = \frac{d\log \mu_{ikt}}{d\log \epsilon_{hkt}} = \frac{S_{ikt}(1 - S_{ikt})}{\left(\frac{\rho}{\rho-\eta} - S_{ikt}\right)\left(1 - \frac{\rho-\eta}{\rho-1} S_{ikt}\right) + S_{ikt}(1 - S_{ikt})},$$

$$\text{(13b)} \quad \frac{d\log p_{ikt}}{d\log \epsilon_{hkt}} = -\frac{\left(\frac{\rho}{\rho-\eta} - S_{ikt}\right)\left(1 - \frac{\rho-\eta}{\rho-1} S_{ikt}\right)}{\left(\frac{\rho}{\rho-\eta} - S_{ikt}\right)\left(1 - \frac{\rho-\eta}{\rho-1} S_{ikt}\right) + S_{ikt}(1 - S_{ikt})},$$

where the first equality in (13a) follows from the facts that $p_{ikt}^* = \mu_{ikt} v_{ikt}^* \tau_{hk} \lambda_i^{-a}$ and v_{ikt}^*, τ_{hk}, and λ_i^{-a} are unaffected by ϵ_{hkt}. Note that $0 < \frac{d\log p_{ikt}^*}{d\log \epsilon_{hkt}} = \frac{d\log \mu_{ikt}}{d\log \epsilon_{hkt}} < 1$ and $-1 < \frac{d\log p_{ikt}}{d\log \epsilon_{hkt}} < 0$ for positive market shares. The markup rises and in producer-currency terms the price rises but by proportionally less than the RER appreciation in the destination. In destination-currency terms, the producer-country price falls but pass-through is incomplete.[17]

[17] Note in addition that as $S_{ikt} \to 0$, $\frac{d\log p_{ikt}^*}{d\log \epsilon_{hkt}}$ and $\frac{d\log \mu_{ikt}}{d\log \epsilon_{hkt}}$ approach 0, and $\frac{d\log p_{ikt}}{d\log \epsilon_{hkt}}$ approaches -1. That is, in the limit as market shares go to 0, markups are constant and pass-through is complete (as it would be, for instance, in the standard Melitz 2003 setting). Note also from (13a) that $\frac{d\log p_{ikt}^*}{d\log \epsilon_{hkt}}$ and $\frac{d\log \mu_{ikt}}{d\log \epsilon_{hkt}}$ are increasing in S_{ikt} and hence that product prices (in producer currency) and markups respond more to a given RER change for product lines with greater market share. This is consistent with the findings of Berman, Martin, and Mayer (2012)

E. *Implications for Firm-Level Average Prices*

Although it is convenient to think in terms of destination-specific production lines, we do not observe input prices at the production-line level, even in the uncommonly detailed Portuguese data. What we observe is an output-weighted average of input prices across all product lines. In the model, the output-weighted average input price in producer-currency terms can be expressed as

$$\bar{v}^*_{it} = \sum_{k \in K} \omega_{ikt} v^*_{ikt}, \tag{14}$$

where the weights are defined as $\omega_{ikt} = \frac{x_{ikt}}{\sum_{k\in K} x_{ikt}}$. Plugging in (10b), recalling that $v_{ikt} = v^*_{ikt}/\epsilon_{hkt}$ and $\zeta_k = \zeta(y_k)$, and letting $g(y_k) = [2\zeta(y_k) - 1]^{-\frac{1}{2\theta}}$, we have

$$\bar{v}^*_{it} = w^*_{ht} \lambda_i^{\frac{b}{2}} \sum_{k \in K} \omega_{ikt} g(y_k). \tag{15}$$

Note that $g(y_k)$ is monotonically increasing in $\zeta(y_k)$, which we have assumed is monotonically increasing in y_k. Hence, average input prices vary with the domestic wage level (which does not vary across firms), firm capability (which does not vary over time), and a firm-specific weighted average of a monotonic nonlinear transformation of destination income. Importantly, conditional on the domestic wage level, firm capability, and the average $g(y_k)$ term, *average input prices do not depend on a firm's markup in any market.* Nor do they depend on trade costs. The only mechanism linking RER changes and input prices in our model is shifts among production lines producing different quality products for different destinations. Equation (15) implies that, in response to a real-exchange-rate change, *average input prices will move*, *to a first-order approximation*, *proportionally to the average income of their destination markets.* If we were to "turn off" the income-based quality channel in our model—if, for instance, we set $\zeta_k = \zeta$ for all k, regardless of income—then there would be no systematic relationship between destination income and input prices.

Although in the Portuguese customs data we observe output prices at the firm-destination level, in many settings output prices are not available separately by destination market. A firm's output-weighted average output price is a function of markups, destination income, and trade costs. Using (10e)

$$\bar{p}^*_{it} = \sum_{k \in K} \omega_{ikt} p^*_{ikt} = w^*_{ht} \lambda_i^{\frac{b}{2} - a} \sum_{k \in K} [\omega_{ikt} \mu_{ikt} \tau_{hk} g(y_k)], \tag{16}$$

where ω_{ikt} and $g(y_k)$ are as defined above. Equation (16) highlights the difficulties of drawing inferences about product quality from firm-level output prices. There are a number of channels through which an exchange-rate change of the sort we

that higher-performance firms raise markups more than lower performance ones in response to a domestic real depreciation, and of Chatterjee, Dix-Carneiro, and Vichyanond (2013) that, within multi-product firms, firms do the same for products closer to the their core competence.

have considered will affect average output prices. The markup, μ_{ikt}, will change within destination, as discussed in Section ID. In addition, the weights, ω_{ikt}, will shift across destination markets with different levels of markups, transport costs, τ_{hk}, and incomes (and hence valuation of quality). If we observe a movement in average output prices, we cannot attribute the movement to only one of these channels.

F. *Discussion*

In our model, while variable markups may confound attempts to draw inferences about product quality from output prices, they do not confound inferences based on *input* prices in the same way. This result depends in part on the assumption that input markets are competitive. A potential concern is that firms or their suppliers may enjoy market power in input markets. For instance, Halpern and Koren (2007) develop a model in which suppliers charge higher markups to firms that face lower elasticities of demand (and themselves charge higher markups), a phenomenon they call "pricing to firm." Another possibility is that downstream firms have monopsony power in input markets and face upward-sloping supply curves for inputs. While developing a formal model with these features is beyond the scope of the current paper, we consider these possibilities at some length in the empirical analysis below and find that market power in input markets does not appear to be driving our findings.

Our model has imposed a number of other restrictive assumptions, for instance CES demand and a CES complementarity between firm capability and input quality in producing output quality. These functional forms are analytically convenient and have allowed us to derive closed-form solutions, but we do not believe that they are crucial. We believe that the basic insight would hold under a variety of demand systems and production functions, as long as they share the (in our view, natural) feature that producing higher-quality outputs requires higher-quality inputs.

II. Data

The analysis in this paper draws on two main datasets, both collected by *Instituto Nacional de Estatística de Portugal* (INE), the Portuguese national statistical agency:

(i) Customs data on firm-level international trade transactions, which are collected separately for European Union (EU) partner countries (*Estatísticas Correntes do Comércio Intracomunitário*, Current Statistics on Intra-Community Trade) and non-EU partners (*Estatísticas Correntes do Comércio Extracomunitário*, Current Statistics on Extra-Community Trade).[18]

(ii) *Inquérito Anual à Produção Industrial* (IAPI, Annual Survey of Industrial Production), a special survey that solicits information on values and physical

[18] The extra-community trade statistics capture the universe of external trade transactions. The intra-community statistics capture shipments from firms registered in the value-added tax system whose value of annual shipments exceed a cut-off that has changed over time. In 2005, for instance, the cut-off was 85,000 euros. See Bastos and Silva (2010) for further details. The customs data are reported at the Combined Nomenclature (CN) 8-digit level (the European extension of the Harmonized System trade classification).

> quantities of outputs, material inputs, and energy sources of firms. The product-level information is reported using a 12-digit PRODCOM classification, with approximately 5,300 different products, 3,300 different material inputs, and 17 different energy sources appearing in the data. The IAPI data are available for the period 1997–2005, with 6,800–8,300 manufacturing firms covered during 1997–2001 and a reduced number (2,300–3,900 manufacturing firms) covered in 2002–2005.[19,20]

We supplement these data with information from the *Sistema de Contas Integradas das Empresas* (SCIE, Enterprise Integrated Accounts System), a census of firms in 2005, and with information on country characteristics from the World Bank's World Development Indicators as well as with CPI and nominal exchange rate information from the IMF's International Financial Statistics.

Our firm-level baseline estimation sample consists of manufacturing firms in the IAPI survey with information on input purchases and quantities and output sales and quantities at the product level. If a firm appears in the IAPI survey but not in the export or import customs data, we assume that it had zero exports or imports. Table 1 reports summary statistics on our estimation sample and the full set of exporters and importers in the customs data in 1997. Firms in our estimation sample tend to have larger export revenues per year, serve more destinations, export in more different product categories, source inputs from more countries, and source more different types of inputs than firms in the full customs dataset. Table 2 displays further descriptive statistics on our estimation sample for 2005 and the census of firms for the same year. We see that firms in our estimation sample are larger, older, higher-wage, and more likely to be an exporter or importer than the typical manufacturing firm. Our empirical analysis should be interpreted as shedding light on the behavior of large manufacturing firms, which typically account for the bulk of trade flows in each country (Bernard and Jensen 1999; Bernard et al. 2007; Freund and Pierola 2015).

Online Appendix Table A1 presents descriptive statistics on export destinations and import sources of Portuguese firms in 1997, both in the full customs data and in our estimation sample. We exclude petroleum trade, as we will do throughout the paper. The final two columns indicate the income rank and level of the country, using 1996 GDP/capita from the World Development Indicators;[21] if Portugal were included, its income rank would be 41. The leading destinations and source

[19] From 1997 to 2001, the IAPI sampling procedure ranked firms in descending order of sales and included them until 90 percent of total sales were covered, with some minor qualifications: all firms with 20 or more employees were included, all firms in sectors with fewer than 5 firms were included, and once included in the sample firms were followed in subsequent years. In 2002–2005, for budgetary reasons, the set of sectors covered by the survey was reduced. These sampling procedures make it difficult to make cross-sectional comparisons by firm size (in contrast to Kugler and Verhoogen 2012 who had access to data with wider and more consistent coverage). Our main focus in this paper is on within-firm changes over time, conditional on the firm being sampled.

[20] To reduce the influence of outliers in the IAPI unit values data, we followed a suggestion of Angrist and Krueger (1999) and winsorized the unit values within product category, pooling across years, mapping observations below the first percentile of the distribution of real unit values to the first percentile and observations above the ninety-ninth percentile to the ninety-ninth. The results reported below are robust to not winsorizing, or to winsorizing by product-year.

[21] In five cases (Anguila, Estonia, Libya, Qatar, Timor-Leste) GDP/capita is not available in 1996 and we use the first available subsequent year.

Table 1—Summary Statistics, International Transactions: Firm Level, 1997

	All exporters (1)	All importers (2)	Estimation sample (3)
Exports per firm	1.34		5.06
	(0.13)		(0.72)
Share of exports to richer nations	0.61		0.79
	(0.00)		(0.01)
Number of export destinations	3.78		7.71
	(0.05)		(0.15)
Number of export categories	8.47		10.03
	(0.19)		(0.28)
Imports per firm		1.29	3.44
		(0.06)	(0.37)
Share of imports from richer nations		0.88	0.90
		(0.00)	(0.00)
Number of import source countries		3.66	5.63
		(0.02)	(0.08)
Number of import categories		16.93	21.74
		(0.23)	(0.65)
Fraction exporter			0.45
Fraction importer			0.49
Fraction exporter and importer			0.35
N (firms)	12,661	20,280	6,585

Notes: Table reports averages across firms using customs data from 1997, weighting firms equally. First four rows are conditional on being an exporter (i.e., having positive exports), and next four rows are conditional on being an importer (i.e., having positive imports). Values of exports and imports in millions of 2000 euros. Petroleum exports and imports excluded. Standard errors of means in parentheses.

Table 2—Summary Statistics: Firm Level, 2005

	All manufacturing (1)	Estimation sample (2)
Revenues	1.36	13.32
	(0.15)	(1.27)
Average annual earnings/worker	7.06	10.01
	(0.14)	(0.09)
Employment	17.38	108.59
	(0.29)	(7.51)
Age of firm	15.74	25.08
	(0.32)	(0.86)
Number of establishments in Portugal	1.17	1.83
	(0.01)	(0.11)
Fraction exporter	0.15	0.62
Fraction importer	0.14	0.61
N (firms)	45,031	2,522

Notes: Table reports averages across firms using the 2005 economic census (SCIE), weighting firms equally. Values of revenues (sales plus income from provision of subcontracting and other services) are in millions of 2000 euros. Average annual earnings per worker are in thousands of 2000 euros. Standard errors of means in parentheses. The estimation sample contains 2,639 firms in 2005, not all of which could be linked to the manufacturing census; those that could not be linked are omitted in column 2.

countries include several richer nations that adopted the euro during our study period (Germany, Spain, France, Netherlands, Belgium, and Italy) but also include non-eurozone countries such as the United Kingdom, United States, Sweden, and Switzerland.[22] Among the main destination and source countries are several lower income nations such as Angola, Brazil, Cape Verde, Turkey, Morocco, and Russia. For the vast majority of export destinations and source countries, bilateral export and import shares in the estimation sample are relatively similar to those in the full customs data. Online Appendix Table A2 provides summary statistics on firms in the estimation sample for each year of the period under analysis. For most indicators of interest, averages across firms remain fairly stable over time, despite the reduction in sample size observed after 2001.

III. Empirical Methodology

We are interested in the effect of the income level of export destinations on input prices. The ideal dataset would report input prices separately for products destined for different destinations, but we are not aware of any such dataset. Our strategy instead is to relate average input prices at the firm level to average destination income at the firm level. We describe the way we calculate average input prices at the firm level at the end of this section. Motivated by the theoretical relationship in equation (15), we are interested in estimating a model of the following form:

$$\log \bar{v}_{it} = \log(inc_{it})\beta + A_i + B_t + X_{it}\alpha + \varepsilon_{it}, \tag{17}$$

where i and t index firms and years, respectively; $\log \bar{v}_{it}$ is a firm-level average log input price; inc_{it} is a measure of the average GDP per capita of firm i's export destinations in year t (calculated using incomes at the beginning of the period of study only, as described below); A_i is a firm fixed effect; B_t is a year effect; X_{it} are other time-varying firm characteristics, including export share of sales, log average destination distance, and log total sales; and ε_{it} is a conditional-mean-zero error term.

As a measure of the income level of each destination market, we use GDP per capita in the year prior to the beginning of our sample, 1996, to avoid possible endogeneity of contemporaneous income.[23] Average destination income for firm i in year t can then be written as

$$inc_{it} = \sum_{k \in K} s_{ikt} \cdot gdppc_{k,1996}, \tag{18}$$

[22] The currencies of the initial set of countries in the eurozone were fixed in relation to one another on January 1, 1999, and the euro bills and coins were introduced on January 1, 2002. The original members of the eurozone are France, Belgium, Luxembourg, Netherlands, Germany, Italy, Ireland, Spain, Finland, and Austria. Greece and Denmark joined the European Exchange Rate Mechanism (ERM II) in 1999, and Greece adopted the euro in 2001. The Danish krone remained pegged to the euro. We treat Greece and Denmark as part of the eurozone for our purposes. We also include several smaller countries (or administrative regions) that use the euro as their currency: Andorra, Malta, San Marino, Slovenia, Réunion, Mayotte, Guadalupe, and Guyana.

[23] In a small number of destinations, GDP per capita is not observed in 1996. In these cases, we use GDP per capita in the first subsequent year in which it is observed.

where the set of all destinations, K, includes the home market.[24] The inc_{it} term is an empirical analogue to the $\sum_{k \in K} \omega_{ikt}\, g(y_k)$ term on the right-hand side of equation (15), to which average input prices are hypothesized to respond. Note that *average destination income as we have defined it does not respond to changes in measured GDP per capita within destination.* The inc_{it} term varies only to the extent that the firm i's revenue shares shift across destination markets.

We begin the discussion of the main results with simple OLS regressions of (17) and find a robust, positive, significant estimate of β. (See Section IVB.) This correlation is consistent with our theoretical predictions, and supports the income-based quality-choice channel.

At the same time, one might worry about endogeneity of average destination income, even defined using initial GDP per capita as in (18). A key concern is that input-cost shocks at the firm level may affect both observed input prices and where firms export.[25] In principle, the bias in $\hat{\beta}_{OLS}$ from such shocks could be positive or negative. One possible response is on the intensive margin: if richer consumers are less price-sensitive than poorer ones, then we would expect positive input cost shocks to lead firms to increase the share of their sales to richer countries, conditional on entry decisions, and $\hat{\beta}_{OLS}$ will be biased upward.[26] But the extensive margin may be just as important. Although not considered in our own theoretical model, an established body of research has shown that sunk costs of export entry are substantial, and that the larger are such costs, the less likely firms will enter initially and the greater the lengths they will go to continue exporting to a destination, to avoid having to reestablish themselves in the future (Roberts and Tybout 1997; Das, Roberts, and Tybout 2007). In addition, Morales, Sheu, and Zahler (2015) estimate that the sunk costs are significantly higher for destinations that are further away geographically, linguistically, or in terms of average income. In the Portuguese case, this would imply that sunk costs are higher among poorer, more distant destinations. This in turn would predict less entry to those destinations in response to favorable (negative) cost shocks and less exit in response to unfavorable (positive) cost shocks than to richer destinations. These responses would generate negative correlation between input cost shocks and average destination income and hence a *negative* bias in $\hat{\beta}_{OLS}$. Below, we present simple reduced-form regression results that support the idea that the extensive-margin channel is important. In addition, we would expect measurement error in average destination income to generate the standard attenuation bias; the less signal in this measure relative to noise, the more

[24] Domestic sales are not observed in the customs data, but we observe domestic sales in the IAPI data. The baseline estimation sample includes firms with zero exports, for which average destination income corresponds to Portuguese GDP per capita in 1996. The main results in the paper remain qualitatively similar when restricting the sample to include only firms with positive exports in 1997.

[25] Possible pass-through of such input cost shocks is a reason to be skeptical that cross-sectional correlations between input prices and output prices at the firm level can be interpreted as evidence that high-quality inputs are used to produce high-quality outputs, as in Manova and Zhang (2012). As Khandelwal (2010), Kugler and Verhoogen (2012), and others have argued, one needs additional information on sales (and ideally measures of market power in input markets) to justify inferences about product quality in cross-sectional data.

[26] Although this idea is intuitive, economic theory is also consistent with an effect in the opposite direction. In our model, if Portuguese firms have smaller market shares in richer countries than in poorer ones, they will face more elastic demand there. Similarly, in the multisector model with additively separable utility recently explored by Caron, Fally, and Markusen (2014), price elasticities are higher for more income-elastic goods, and richer countries tend to consume more income-elastic goods. Both of these possibilities would generate a negative bias in OLS arising from the intensive margin.

severe the attenuation bias. We fully acknowledge that average destination income is a very rough measure of the theoretical quantity we would like to measure, the willingness of the consumers a firm faces to pay for product quality, and the attenuation bias (negative in this case) could therefore be substantial. Other forms of bias are also possible.[27]

To address the endogeneity concerns, we supplement the OLS results with an instrumental-variables strategy, using real-exchange-rate movements to construct instruments for average destination income. A key challenge in constructing the instruments is to identify a source of variation at the firm level. Our strategy relies on the fact that a real-exchange-rate movement in a particular destination market does not matter equally for all Portuguese firms; it matters particularly for Portuguese firms that have already developed relationships with buyers in that destination. Using this fact, we construct instruments by interacting the real-exchange-rate in a destination with an indicator for whether a firm had positive exports to the destination in the initial year of our sample.[28]

As a first step in explaining the IV strategy, consider the following empirical model for sales of Portuguese firms in each destination:

$$s_{ikt} = F_{ik} + \log(RER_{kt})\gamma_k + (\log(RER_{kt}) \times C_{ik,1997})\delta_k + u_{ikt}, \tag{19}$$

where i, k, and t index firms, destinations, and years; s_{ikt} denotes the share of firm i's total sales in year t from exports to destination k; F_{ik} is a firm-destination fixed effect; $C_{ik,1997}$ is an indicator for whether firm i had any exports to destination k in the initial year of our sample, 1997; and $\log(RER_{kt})$ is the log real-exchange-rate of destination k in year t, defined (following (12)) as

$$\log(RER_{kt}) = \log\left[\frac{\epsilon_{hkt}}{CPI_{ht}/CPI_{kt}}\right], \tag{20}$$

where h indicates Home (Portugal) and ϵ_{hkt} is the nominal exchange rate, defined as units of home currency per unit of k currency. Given this definition, a real appreciation of, for instance, the British pound will be reflected in an increase of $\log(RER_{kt})$ for the United Kingdom. Hence, both γ_k and δ_k in (19) are expected to be positive.

In principle, a valid IV strategy would be to estimate (19), recover the predicted values $\hat{s}_{ikt}$, and plug them into the expression (18) to generate predicted values of log average destination income to use as an instrument for $\log(inc_{it})$. But estimating (19) by OLS would generate many negative values, especially given the large number of firm-destination pairs with zero exports, and the generated instrument would be a poor predictor of inc_{it}, exacerbating the weak-instrument problem we discuss

[27] For instance, our theoretical model suggests that a positive productivity shock will lead firms to purchase higher-quality inputs, produce higher-quality outputs, and expand sales relatively more in richer countries. This would generate a positive bias in $\hat{\beta}_{OLS}$.

[28] Similar instruments based on real-exchange-rates have been used at the sector level by Revenga (1992) and Bertrand (2004), and at the firm level by Park et al. (2010), Brambilla, Lederman, and Porto (2012), and Hummels et al. (2014), among others.

below. Estimating a nonlinear model such as a Tobit would be challenging because of the presence of the large number of incidental parameters, F_{ik}. Instead, we take a more reduced-form approach that avoids the need to estimate (19) in a preliminary step. Combining (18) and (19), we can write

$$inc_{it} \;=\; G_t + H_i + \sum_{k \in K} (\log(RER_{kt}) \cdot C_{ik,1997})\phi_k + \nu_{it}\,, \tag{21}$$

where $G_t = \sum_{k \in K} \log(RER_{kt})\, gdppc_{k,1996}$, $H_i = \sum_{k \in K} F_{ik}\, gdppc_{k,1996}$, $\phi_k = \delta_k\, gdppc_{k,1996}$, and $\nu_{it} = \sum_{k \in K} u_{ikt}\, gdppc_{k,1996}$. Equation (21) suggests that the full set of RER interaction terms, $\log(RER_{kt}) \cdot C_{ik,1997}$, can serve as instruments for $\log(inc_{it})$ in an IV estimation of (17). These are the instruments we will use in our baseline IV specification.

Given the large number of instruments (one for every export destination; we limit the number to 100 in our preferred specification), the coefficient estimates $\hat{\phi}_k$ can be difficult to interpret. In an alternative IV procedure, we construct a second set of instruments, by calculating the average RER for groups of countries determined by income rank, using firms' initial sales shares as weights. We divide destinations into income groups indexed by g and define

$$\overline{RER}_{igt} \;=\; \sum_{k \in g} s_{ik,1997} \cdot RER_{kt}\,. \tag{22}$$

This aggregation has the disadvantage that we lose some variation in the instruments, but the advantage that the coefficients on them are more interpretable. We will see below that the results are broadly similar to the baseline specification.

It is important to recognize that the movements of real-exchange-rates may have an effect not only on the destination of exports of Portuguese firms but also on the prices that Portuguese firms pay for imported inputs.[29] If such movements matter for input prices especially for firms that have initial *importing* relationships with the relevant *source* country, and initial importing relationships are correlated with initial exporting relationships, then the IV exclusion restriction for a model of the form of (17) will be violated. To absorb these direct effects, we construct interactions of (the log of) RERs with indicators for whether a firm has positive imports from a particular source country, $\log(RER_{kt}) \cdot D_{ik,1997}$, where $D_{ik,1997} = 1$ if firm i has positive imports from country k in 1997, and equals zero otherwise. We include these RER-initial importer interactions directly as covariates in the main outcome equation. Thus, our main estimating equation is

$$\log \bar{v}_{it} \;=\; \log(inc_{it})\beta + X_{it}\alpha + a_i + b_t + \sum_{k \in K} \big[\log(RER_{kt}) \cdot D_{ik,1997}\big]\chi_k + \varepsilon_{it} \tag{23}$$

[29] A large literature on exchange-rate pass-through investigates the relationship between exchange-rate-driven movements in input prices (as well as output prices) at the firm level. Although pass-through is typically found to be less than complete, it is also typically found to be greater than zero. See Goldberg and Knetter (1997) and more recent work by Nakamura and Zerom (2010), Goldberg and Hellerstein (2008, 2013), and Amiti, Itskhoki, and Konings (2014).

where $\log(inc_{it})$ is instrumented by the terms $\log(RER_{kt}) \cdot C_{ik,1997}$ (or, in an alternative procedure, the $\overline{RER}_{igt}$ as defined in (22)). In the cases of firms that initially import from and export to the same set of countries, the effect of the RER movements will be captured by the RER-importer interactions. The coefficient on average destination income will be identified by differences between the initial sets of import sources and export destinations, and the differential response to RER movements that result from them. The exclusion restriction is that the interaction terms $\log(RER_{kt}) \cdot C_{ik,1997}$ are uncorrelated with the error term ε_{it} in (23), conditional on the other covariates. Intuitively, once the direct effect of RER movements on imports have been controlled for, we need the $\log(RER_{kt}) \cdot C_{ik,1997}$ terms to affect the input prices paid by Portuguese firms only through their effect on average destination income, captured by $\log(inc_{it})$.

In our baseline specification, we drop some destinations from the instrument set. Portugal is a member of the eurozone, and since 1999 has shared the euro with a number of its main trading partners. For these partners, the only changes in the real-exchange-rate over the 1999–2005 period were due to differential rates of inflation. One might worry that omitted variables such as firm-level productivity shocks in Portuguese firms might contribute to inflation rates in the eurozone. For this reason, in our baseline specification we omit the eurozone states from our set of instruments. We also limit the number of countries in the instrument set to 100, by descending order of export share. (The qualitative results are robust to including the eurozone countries in the instrument set and to including 50, 75, or 125 destinations instead of 100.)

As noted above, in the set of covariates represented by X_{it} we include the export share of sales at the firm level, log average destination distance (adding 1 kilometer to distance, to avoid dropping firms with only domestic sales), and log total sales. One might worry that export share and average distance are also endogenous, for reasons similar to those discussed in connection to average destination income. Conveniently, the same set of RER interactions are also plausible instruments for these two covariates. That is, because the RER movements interacted with the initial export indicator affect sales to each destination, they also affect the export share of sales and average destination distance. Below we present IV specifications in which we treat these covariates as endogenous.

It remains to explain how we construct the firm-level average log input prices, represented by $\log \bar{v}_{it}$ in (17) and (23). We first run the following regression:

$$\log(uv_{i\ell t}) = \theta_{it} + \kappa_{\ell t} + \xi_{i\ell t}, \tag{24}$$

where i indexes firms, ℓ indexes products, t indexes years; $uv_{i\ell t}$ is the unit value for product ℓ in firm i in year t, calculated as expenditures divided by units of physical quantity; θ_{it} is a firm-year fixed effect; $\kappa_{\ell t}$ is a product-year fixed effect; and $\xi_{i\ell t}$ is a mean-zero error term. We use information only on manufactured inputs. The product-year effects, $\kappa_{\ell t}$, capture all common factors that affect the price of a particular input across firms. The firm-year effects, θ_{it}, are thus identified by comparisons with other firms purchasing the same input in the same year. The OLS estimates, $\hat{\theta}_{it}$, reflect average prices at the firm level purged of effects due to the composition of

Table 3—Destination Characteristics and Export Prices in Cross Section, 1997

	Dependent variable: Firm-product log export price			
	(1)	(2)	(3)	(4)
Richer than Portugal	0.092	0.089		
	(0.030)	(0.026)		
log GDP/cap.			0.029	0.032
			(0.011)	(0.010)
log GDP	0.008	0.003	0.006	0.001
	(0.004)	(0.005)	(0.005)	(0.006)
European Union	0.053	0.021	0.062	0.026
	(0.029)	(0.022)	(0.027)	(0.020)
Landlocked	0.020	0.028	0.006	0.020
	(0.026)	(0.018)	(0.033)	(0.020)
log distance	0.072	0.064	0.069	0.062
	(0.013)	(0.011)	(0.012)	(0.009)
Product effects	Yes	No	Yes	No
Firm-product effects	No	Yes	No	Yes
R^2	0.75	0.93	0.75	0.93
Observations	71,490	71,490	71,490	71,490

Notes: Sample is all firm-product-destination observations in 1997 for firms in estimation sample, including eurozone destinations. Results when excluding eurozone destinations are similar (see online Appendix Table A4). "Richer than Portugal" defined using 1996 GDP/capita, consistent with our use of 1996 values elsewhere; log GDP/cap. variable is from 1997. Robust standard errors, clustered by destination, in parentheses.

products. We define the firm-level average input prices to be equal to these OLS estimates (setting $\bar{v}_{it} = \hat{\theta}_{it}$).[30]

For completeness, we will also estimate a model similar to (23) with firm-level average *output* prices on the left-hand side. The estimation of average output prices is analogous to the estimation of average input prices, with output unit values on the left-hand side of (24). As noted above, caution is warranted in interpreting these results, as any effects on output prices may reflect markups as well as quality.

IV. Results

A. *Preliminaries*

Before turning to our main estimates, we present a descriptive analysis of several key empirical relationships underlying our approach. We first confirm the cross-sectional finding from Bastos and Silva (2010) that firms charge higher prices to richer destinations in the same narrow product category in the same year. Table 3 presents regressions of log export unit values at the firm-product level on indicators

[30] Instead of calculating firm-level average prices, an alternative approach would be to regress the firm-product-level output or input unit values ($\log(uv_{ikt})$ in (24)) directly on the covariates in (23), using the same instruments as described above. Using a particular choice of weights, such a "one-step" approach would be numerically equivalent to the "two-step" approach that we employ (first estimating the $\hat{\theta}_{it}$ from (24) and then estimating (23)) (Amemiya 1978; Donald and Lang 2007). Using different weights, Kugler and Verhoogen (2012) report both one-step and two-step estimates and show that they are similar. Here we focus on the two-step estimates to reduce the computational burden of the estimation.

Table 4—Sales Response to Real-Exchange-Rate Movements

	Dependent variable: Percent of firm's total sales			
	(1)	(2)	(3)	(4)
log(RER)	0.006	0.007	0.003	0.004
	(0.001)	(0.001)	(0.000)	(0.001)
log(RER) · 1(any exports in 1997)			0.864	
			(0.095)	
log(RER) · (sales share in 1997)				0.274
				(0.068)
Firm effects	Yes			
Destination effects	Yes			
Firm-destination effects	No	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
R^2	0.04	0.85	0.85	0.85
Observations	6,666,214	6,666,214	6,666,214	6,666,214

Notes: Data are at firm-destination-year level. Eurozone destinations excluded. Log real exchange rate (log(RER)) defined as in equation (20). Variables **1**(any exports in 1997) and sales share in 1997 defined at firm-destination level. Zeros included for any firm-destination for which firm is in estimation sample in given year (for destinations with positive exports by any firm in the sample in any year). Robust standard errors, clustered at firm-year level, in parentheses.

of destination income per capita and a number of other destination characteristics (standard in gravity regressions), for firms in our estimation sample in the initial year (1997). Consistent with Bastos and Silva (2010), firms charge higher prices in richer countries, on average, even controlling for firm-product fixed effects.[31]

We now consider the effects of real-exchange-rate movements on sales of Portuguese firms. To provide a visual sense of the variation underlying the fluctuations in the firm-specific exchange rates, online Appendix Figures A1 and A2 illustrate the movements in the RERs of Portugal's principal non-eurozone trading partners, for countries richer and poorer than Portugal, respectively. At first blush, the swings in RERs appear large enough to have been economically significant.

Table 4 analyzes the response of Portuguese firms' sales to the RER movements at the firm-destination-year level (including zeros for any destination with no exports for which the firm is in the estimation sample in a given year). An increase in the real-exchange-rate in a destination is associated with a modest but statistically significant increase in the share of a firm's total sales sold in that destination, controlling for either firm and destination or firm-destination fixed effects (columns 1–2). Column 3 includes an interaction of the RER with an indicator for whether the firm had positive exports to the destination in 1997, and shows that the response to RER movements is much larger for firms with initial attachment to the destination. The message is similar when we interact the RER movements with the firm's initial share of sales in the destination (column 4). To check robustness,

[31] Online Appendix Table A3 shows that an analogous pattern holds for imports: within narrow product categories, imports from richer nations tend to carry higher prices, in line with prior findings in the literature (Schott 2004; Hummels and Klenow 2005; Kugler and Verhoogen 2009; Hallak and Schott 2011). Online Appendix Table A4 shows that the pattern for exports in Table 3 is robust to excluding eurozone countries.

online Appendix Table A5 reports similar regressions with the inverse hyperbolic sine of sales (an approximation of the logarithm that does not require throwing out zeros) as dependent variable, in place of sales percentage. The patterns are qualitatively similar: the sales response is much greater for firms with initial attachment to the destination.

One might wonder whether the sales response in Table 4 is mainly a mechanical effect of changes in prices. Online Appendix Table A6 sheds light on this question by looking at the intensive margin within firm-product-destinations and relating export quantities and prices to log RERs (and their lags), using the physical quantities (in kilograms) reported in the trade-transactions data. A first point to note is that all variables respond quickly to exchange rate changes; it is the contemporaneous RERs, not lags, that matter for quantities, prices, and sales. But the more important point is that the lion's share of the overall sales response is accounted for by the *quantity* response. The price elasticity (0.040 in column 4) is relatively small.[32] Overall, it does not appear that the sales response in Table 4 is generated mechanically by price changes.

As discussed in Section III, our baseline IV specification (see equation (23)) requires differences between the initial sets of import sources and export destinations at the firm level in order to identify the coefficients of interest. Considering firms in our estimation sample that export to one or more of the top 100 non-eurozone export destinations in 1997, the top panel of online Appendix Figure A3 plots the average number of non-eurozone source countries (hollow bars) and the average number of non-eurozone source countries that are also destinations (gray bars) against the number of non-eurozone export destinations in 1997. The bottom panel presents a simple histogram of firms' number of non-eurozone destinations. The figure reveals that the overlap between destinations and source countries is modest. Averaging over all firms in 1997, 18 percent of export destinations were also source countries for imports at the firm level. The overlap between export destinations and import sources at the firm level does not appear to be prohibitively large in our setting.

B. *OLS Estimates: Destination Income and Input Prices*

We now turn to the main focus of the paper: the relationship between average destination income and firm-level average input prices. Table 5 presents OLS estimates of average log input prices on log average destination income, successively adding more covariates: log(1 + average destination distance), the firm-level share of sales from exports, and log sales of the firm. In all specifications, there is a positive and significant relationship between destination income and input prices within firms, and the coefficient estimate is stable across specifications.[33] The coefficient of interest indicates that a 10 percent increase in log average destination GDP/cap

[32] Although we do not observe invoicing currencies, it is likely that many Portuguese exporters invoice in euros, which may explain the relatively small price elasticity (corresponding to high pass-through) we observe.

[33] Table 5 includes interactions between RERs and dummy variables for whether firms sourced inputs from the corresponding country in 1997, to control for potential direct effects of exchange rate movements on input prices. Online Appendix Table A11 shows that the OLS estimates remain similar when excluding these initial source interactions, while online Appendix Table A13 reveals that the OLS estimates also remain unaffected when including interactions between current-year (as opposed to initial-year) import dummies and the RER of the corresponding country.

TABLE 5—DESTINATION INCOME AND FIRM-AVERAGE INPUT PRICES, OLS ESTIMATES

	Dependent variable: Firm-average log real input price			
	(1)	(2)	(3)	(4)
log average destination GDP/cap	0.065	0.074	0.075	0.070
	(0.023)	(0.025)	(0.028)	(0.028)
log(1 + average destination distance)		−0.003	−0.003	−0.003
		(0.002)	(0.002)	(0.002)
Export share of sales			−0.004	−0.002
			(0.031)	(0.031)
log sales				0.024
				(0.007)
Initial source interactions	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
R^2	0.80	0.80	0.80	0.80
Observations	45,659	45,659	45,659	45,659

Notes: Table reports OLS estimates of equation (23) in text, using baseline estimation sample. Average destination GDP/capita defined as in equation (18). Robust standard errors in parentheses.

is associated with approximately a 0.7 percent increase in average input prices at the firm level. This correlation is consistent with the theoretical prediction that firms use higher-quality, higher-priced inputs for goods shipped to richer countries. The correlation is robust to controlling for distance, the share of exports, and log sales.

A question that may arise in this context is whether the association between destination income and input prices is driven by changes on the extensive margin (i.e., firms exporting to new destinations) or on the intensive margin (i.e., firms changing intensity of exports to existing destinations). To investigate this, online Appendix Table A7 regresses firm-average input prices on separate terms capturing changes in destination income on the intensive and extensive margins.[34] Both variables are positively associated with firms' input prices, but the *intensive* margin appears to be playing a more important role, accounting for more than two-thirds of the overall destination income-input price correlation.

As discussed above, there are reasons for concern about bias in the OLS estimates. We argued that differential responses on the extensive margin in richer and

[34]To construct the terms capturing the intensive and extensive margins, we note first that (given the definition of inc_{it} in (18)) changes in average destination income can be written as

$$\Delta inc_{it} = \sum_{k \in K^I} \Delta s_{ikt} \cdot gdppc_{k,1996} + \sum_{k \in K^E} \Delta s_{ikt} \cdot gdppc_{k,1996}, \tag{25}$$

where K^I is the set of destinations that the firm served in both t and $t-1$, K^E is the set of destinations for which the firm's export status changed between the two periods, and Δ indicates the difference between years $t-1$ and t. To recover the level of inc_{it}, we can write

$$inc_{it} = inc_{i0} + \sum_{t'=1}^{t} \Delta inc_{it'} = inc_{i0} + \sum_{t'=1}^{t} \sum_{k \in K^I} \Delta s_{ikt'} \cdot gdppc_{k,1996} + \sum_{t'=1}^{t} \sum_{k \in K^E} \Delta s_{ikt'} \cdot gdppc_{k,1996}, \tag{26}$$

where inc_{i0} is firm i's average destination income in the first year it is in the sample. The second term in (26) measures changes in average destination income within firms driven by the intensive margin, and the third captures the extensive margin. Online Appendix Table A7 includes (logs of) the second and third terms. (Since inc_{i0} is time-invariant within firms, it is absorbed by the firm fixed effects.)

poorer destinations may lead to a downward bias in the OLS coefficient on average destination income. Is this mechanism realistic? Full estimation of a structural model of endogenous entry is beyond the scope of this paper, but as a simple first step we estimate a reduced-form linear-probability model, separately for destinations richer and poorer than Portugal. Rather than using initial export interactions as instruments with input price on the left-hand side, as in equation (23), we use the initial import interactions as instruments for input price, with an indicator for whether a firm has any exports to a given destination on the left-hand side. The estimating equation is

$$(27)\qquad Z_{ikt} \;=\; \log \bar{v}_{it}\alpha + a_i + b_{kt} + \sum_{k \in K} \left[\log\left(RER_{kt}\right) \cdot C_{ik,1997}\right]\chi_k + \varepsilon_{ikt}\,,$$

where Z_{ikt} is a $0/1$ indicator for whether firm i has positive exports to destination k in year t, a_i is a firm effect, b_{kt} is a destination-year effect, the other notation is as in Section III, and firm-average log real input price, $\log \bar{v}_{it}$, is instrumented by the terms $\log(RER_{kt}) \times D_{ik,1997}$ (interactions of initial source indicators and log RERs). Online Appendix Table A8 presents the results. The table indicates that the responsiveness of entry/exit decisions to cost shocks to Portuguese firms is greater in destinations richer than Portugal (column 1) than in destinations poorer than Portugal (column 2).[35] Consistent with our story about differences in sunk costs between richer and poorer destinations, the results suggest that a positive input cost shock will tend to lead to more exit from richer destinations than poorer ones, and hence (other things equal) a negative correlation between input cost shocks and average destination income, biasing the OLS estimate downward.[36] This finding underlines the advantages of the IV approach we turn to next.

C. *Baseline IV Estimates: Destination Income and Input Prices*

Table 6 presents our baseline instrumental-variable estimates of equation (23), using the interactions of RER movements and indicators for positive initial sales in a destination as excluded instruments. Columns 1–4 treat only log average destination income as endogenous; column 5 adds log(1 + average destination distance) and column 6 adds the share of sales from exports to the set of endogenous covariates.[37] The first stage of the IV estimation is reported in online Appendix Table B1.[38]

It is important to acknowledge two possible concerns about the first stage of the IV estimation. First, although including the (initial exporter × log(RER)) interaction

[35] The IV procedure in online Appendix Table A8 suffers from the same weak-instruments issue discussed below in reference to our baseline IV results. Since the results are only meant to be suggestive of the direction of bias in OLS, and since our responses to the concern are the same as in the baseline IV, we postpone discussion of the weak-instruments issue to the next section.

[36] This result is fully consistent with the result in online Appendix Table A7 that the destination-income/input price correlation is mainly driven by firms changing the composition of exports among continuing destinations. The sunk-cost story indicates simply that poor destinations are more likely to continue as destinations in response to a positive cost shock; these destinations will then be captured by the intensive-margin term in online Appendix Table A7.

[37] Results are similar when log sales is also treated as an endogenous covariate.

[38] Column 4 of Table 6 corresponds to column 1 of online Appendix Table B1; column 5 to columns 2 and 4; and column 6 to columns 3, 5, and 6.

TABLE 6—DESTINATION INCOME AND FIRM-AVERAGE INPUT PRICES, BASELINE IV ESTIMATES

	Dependent variable: Firm-average log real input price					
	(1)	(2)	(3)	(4)	(5)	(6)
log average destination GDP/cap	0.66	0.61	0.73	0.71	0.77	0.68
	(0.21)	(0.21)	(0.25)	(0.25)	(0.26)	(0.26)
log(1 + average destination distance)		−0.01	−0.00	−0.00	0.05	0.06
		(0.00)	(0.00)	(0.00)	(0.03)	(0.03)
Export share of sales			−0.34	−0.33	−0.66	−0.22
			(0.13)	(0.13)	(0.23)	(0.32)
log sales				0.02	0.01	0.01
				(0.01)	(0.01)	(0.01)
Initial source interactions	Yes	Yes	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	45,659	45,659	45,659	45,659	45,659	45,659
Kleibergen-Paap LM statistic (under-identification)	264.22	269.91	249.61	248.92	245.01	232.20
Kleibergen-Paap LM p-value	0.00	0.00	0.00	0.00	0.00	0.00
Kleibergen-Paap Wald rk F-stat (weak instruments)	3.11	3.11	2.67	2.65	2.53	2.32
Anderson-Rubin Wald test F-stat	2.20	2.20	2.19	2.17	2.17	2.18
Anderson-Rubin Wald test p-value	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Table reports IV estimates of equation (23) in text, where instruments are interactions of indicators for positive exports to destination in 1997 and log RERs for Portugal's top 100 non-eurozone export destinations; first-stage results are in online Appendix Table B1. Average destination GDP/capita defined as in equation (18). Columns 1 to 4 treat only log average destination GDP/cap as endogenous; column 5 adds log(1 + average destination distance) and column 6 adds export share of sales to endogenous set. Robust standard errors in parentheses.

terms directly avoids the difficulties of estimating a nonlinear relationship between sales share and real-exchange-rates discussed above, it also makes the first-stage coefficients more difficult to interpret. Based on the fact that increases in firm-level sales shares are positively affected by the interaction of the initial export indicator and RER for a destination (Table 4), on average we would expect to see a positive effect of the instrument on average destination income for richer destinations and a negative effect for poorer destinations. The estimates largely conform to this pattern but there are many exceptions. These exceptions appear to be driven by the fact that in several destinations initial non-exporters reacted more to the RER movements than initial exporters. The alternative IV procedure in Section IVD will address this concern. In the alternative procedure, the first stage is more straightforward to interpret, and we will see that the results are largely as expected.

Second, there is reason to be concerned that the instruments are weakly correlated with average destination income and the other potentially endogenous covariates. Table 6 reports a number of diagnostic statistics. Because we have no particular reason to believe that errors are homoskedastic, we use the heteroskedasticity-robust Kleibergen and Paap (2006) test statistics for under-identification and weak instruments. The Kleibergen-Paap LM statistic indicates that we can reject the null hypothesis that the model is unidentified. This leaves open the possibility that the instruments are only weakly correlated with the endogenous regressors, however. Stock and Yogo (2005) tabulate critical values for the Cragg-Donald (1993) F-statistic to use in testing the null that instruments are weak in the homoskedastic case. Again, because we are reluctant to assume homoskedasticity, we instead report the heteroskedasticity-robust Kleibergen-Paap (2006) Wald rk *F*-statistic. Although the appropriate critical values in the heteroskedastic case have not been tabulated in the literature (Mikusheva 2013), common practice is to compare this statistic to the Stock-Yogo critical values. This comparison suggests that we *cannot* reject the null of weak instruments. For this reason, below we report weak-instrument-robust test statistics and consider further the consequences of weakness of the instruments.

Keeping these caveats in mind, we now turn back to the IV estimates in Table 6. The estimates of the coefficient on the destination-income term are significantly positive and significantly greater than the OLS estimates in Table 5. Because of the weak-instruments concern, we also report an Anderson-Rubin (1949) Wald test, which is robust to weakness of the instruments. This is a test of the null that the coefficients on the excluded instruments are jointly zero when they are included in place of the endogenous covariates in the outcome equation. In the specifications of columns 1 to 4, this is equivalent to a test of the hypothesis that the coefficient on the destination-income term is zero. The test decisively rejects the null. In columns 5 and 6, where there are multiple endogenous covariates, the Anderson-Rubin test corresponds to the null hypothesis that the coefficients on the endogenous covariates are jointly zero. Tests for subsets of endogenous regressors in weakly identified IV models are a frontier of research in econometric theory (Mikusheva 2013), and the literature has not converged on a standard test in this setting. Here we satisfy ourselves with two simple observations. First, it is reassuring that the IV estimates of the destination-income coefficient are reasonably robust across specifications (and using the country-income-group level instruments in Section IVD). Second, in settings with weak instruments, IV estimates are "biased toward" the corresponding OLS estimates (see, e.g., Angrist and Pischke 2009, ch. 4 for discussion). Given that the corresponding OLS estimate in column 4 of Table 5 is significantly smaller than the IV estimates in columns 4–6, this suggests that the IV estimates are likely to be *underestimates* of the true relationships. As an additional check, we also follow a suggestion of Angrist and Pischke (2009, Section 4.6.4) and report limited-information maximum likelihood (LIML) estimates of the same model, since LIML estimates tend to be more robust to weakness of the instruments than IV. These appear in online Appendix Table A9. Reassuringly, the results are similar to those for IV and are a bit larger, consistent with the idea that the IV estimates are more biased toward OLS than the LIML estimates.

The main take-away from Table 6 is that the positive relationship between destination income and input prices we found with OLS is robust, consistent with the hypothesis that exogenous shifts in exporting toward richer destinations lead to an increase in average input quality within firms. The magnitudes are larger than in OLS, plausibly because of the biases due to heterogeneity in sunk costs and measurement error discussed above. Although there is some evidence that exogenous increases in average distance are associated with higher average input prices (columns 5 and 6 of Table 6), the relationships between within-firm changes in prices and within-firm changes in average distance, export share, and total sales do not appear to be robust. This is not to argue that there is no relationship; the standard errors are large enough that it is not possible to rule out economically significant positive effects.

D. *Alternative IV Estimates: Instruments at Income-Group Level*

As discussed in Section III and the previous subsection, we have implemented an alternative IV procedure in which we first aggregate the country-level instruments by income group. This approach does not fully exploit the underlying destination-specific exchange-rate variation, and is less able to estimate the separate contributions of the various covariates than the approach above, but has the advantage that the first-stage estimates are more straightforward to interpret.

The instruments are (logs of) firm-specific weighted averages of real-exchange-rates within the corresponding income group, with the weights given by the firm's initial export shares to each destination in 1997, as defined in equation (22). In our preferred specification for the alternative IV, we divide destinations into 16 income groups, with 15 groups of 10 destinations per group by income rank (as reported in online Appendix Table A1) and a remainder category of the poorest countries.[39] Note that we have defined the income bins using all destinations; in our main specifications, eurozone destinations and destinations outside of the top 100 by export volume in 1997 are subsequently excluded when constructing the instruments.

Table 7 presents the first stage for this IV model. In columns 1–5, log average destination income is the dependent variable, with different combinations of the other covariates (distance, export share, sales) treated as exogenous (corresponding to the specifications in columns 1–5 of Table 6 and Table 8 below). To provide a visual illustration of these results, online Appendix Figure A4 plots the coefficients from column 5 for the 16 income groups, with 90 percent confidence intervals. Although there is some nonmonotonicity in the estimates, the coefficients have largely the expected signs, with positive and significant estimates for the richest two groups (which account for a disproportionately large share of exports), and negative and significant estimates for the sixth group (which includes former colony Brazil, Turkey, Hungary, and Poland), the ninth group (which includes Russia, Tunisia, and Algeria), and the thirteenth group (which includes former colony Angola). (Recall that Portugal's income would put it in the fourth income group if it were included.)

In column 6 of Table 7, log(1 + average destination distance) is the dependent variable.[40] The coefficients for poorer income groups are largely positive, consistent with the observation that Portuguese exporters' poorer destinations tend to be further away than richer destinations. The exception is the ninth group, which as noted above happens to include several not particularly distant, poor destinations: Russia, Tunisia, Algeria. In column 7, with export share as the dependent variable, we see that the income-group instruments do not appear to have much explanatory power for firm-level export share. This is a cost of using the aggregated income-group instruments; they do not permit us to estimate a specification in which the export share is treated as endogenous (as in column 6 of Table 6).

Table 8 presents the alternative IV results using the income-group instruments. Similar to Table 6, columns 1–4 treat only log average destination income as endogenous and column 5 adds log(1 + average destination distance) to the set of

[39] Similar results hold if we divide destinations into, for instance, 10 groups, with approximately 15 countries per group and a remainder category.

[40] Results are robust to using the inverse hyperbolic sine of average distance.

Table 7—First Stage for Alternative IV, Using Income-Group Instruments

Instrument	log average destination income (1)	(2)	(3)	(4)	(5)	log (1 + avg. dist.) (6)	Export share (7)
$\log(\overline{RER}_{it})$, including ranks 1–10	0.036	0.037	0.030	0.031	0.031	−0.097	0.013
	(0.020)	(0.019)	(0.016)	(0.016)	(0.016)	(0.135)	(0.018)
$\log(\overline{RER}_{it})$, including ranks 11–20	0.042	0.039	0.055	0.056	0.055	0.315	−0.026
	(0.029)	(0.027)	(0.023)	(0.023)	(0.023)	(0.201)	(0.029)
$\log(\overline{RER}_{it})$, including ranks 21–30	−0.002	−0.006	−0.001	−0.001	−0.001	0.209	−0.001
	(0.016)	(0.016)	(0.012)	(0.012)	(0.012)	(0.137)	(0.018)
$\log(\overline{RER}_{it})$, including ranks 31–40	−0.018	−0.015	−0.019	−0.019	−0.019	−0.154	0.001
	(0.025)	(0.024)	(0.019)	(0.019)	(0.019)	(0.133)	(0.024)
$\log(\overline{RER}_{it})$, including ranks 41–50	0.019	0.017	0.012	0.013	0.013	0.049	0.014
	(0.010)	(0.009)	(0.008)	(0.008)	(0.008)	(0.076)	(0.010)
$\log(\overline{RER}_{it})$, including ranks 51–60	−0.007	−0.004	0.001	0.000	0.000	−0.073	−0.017
	(0.014)	(0.013)	(0.011)	(0.011)	(0.011)	(0.127)	(0.016)
$\log(\overline{RER}_{it})$, including ranks 61–70	−0.036	−0.044	−0.037	−0.037	−0.038	0.422	0.004
	(0.010)	(0.010)	(0.009)	(0.009)	(0.009)	(0.077)	(0.010)
$\log(\overline{RER}_{it})$, including ranks 71–80	0.021	0.015	0.007	0.007	0.007	0.161	0.030
	(0.018)	(0.017)	(0.014)	(0.014)	(0.014)	(0.118)	(0.018)
$\log(\overline{RER}_{it})$, including ranks 81–90	0.024	0.027	0.031	0.032	0.032	−0.051	−0.012
	(0.026)	(0.026)	(0.022)	(0.022)	(0.022)	(0.193)	(0.025)
$\log(\overline{RER}_{it})$, including ranks 91–100	−0.035	−0.034	−0.041	−0.041	−0.041	−0.154	0.011
	(0.015)	(0.015)	(0.014)	(0.014)	(0.014)	(0.068)	(0.012)
$\log(\overline{RER}_{it})$, including ranks 101–110	0.013	0.008	0.004	0.006	0.006	0.197	0.020
	(0.019)	(0.019)	(0.018)	(0.018)	(0.018)	(0.122)	(0.019)
$\log(\overline{RER}_{it})$, including ranks 111–120	−0.095	−0.099	−0.010	−0.010	−0.013	1.212	−0.166
	(0.034)	(0.035)	(0.033)	(0.033)	(0.033)	(0.306)	(0.034)
$\log(\overline{RER}_{it})$, including ranks 121–130	0.052	0.049	0.037	0.035	0.035	−0.023	0.028
	(0.032)	(0.032)	(0.030)	(0.030)	(0.030)	(0.213)	(0.031)
$\log(\overline{RER}_{it})$, including ranks 131–140	−0.019	−0.024	−0.017	−0.017	−0.018	0.282	−0.002
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.058)	(0.005)
$\log(\overline{RER}_{it})$, including ranks 141–150	−0.056	−0.040	−0.058	−0.057	−0.055	−0.844	−0.000
	(0.060)	(0.060)	(0.053)	(0.053)	(0.053)	(0.588)	(0.058)
$\log(\overline{RER}_{it})$, including ranks 151+	−0.010	−0.018	−0.008	−0.008	−0.009	0.421	−0.002
	(0.010)	(0.010)	(0.010)	(0.009)	(0.010)	(0.110)	(0.010)
log(1 + average destination distance)		0.019	−0.002	−0.003			
		(0.001)	(0.001)	(0.001)			
Export share of sales			0.512	0.511	0.495	6.110	
			(0.024)	(0.024)	(0.023)	(0.104)	
log sales				0.008	0.008	0.078	0.006
				(0.002)	(0.003)	(0.016)	(0.002)
Initial source interactions	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.94	0.94	0.95	0.95	0.95	0.95	0.96
Observations	45,659	45,659	45,659	45,659	45,659	45,659	45,659

Notes: Table presents first-stage estimates for alternatve IV model described in Section IVD and reported in Table 8. Instruments are log weighted-average RERs at the country-income-group level, weighting by firm-level initial export shares to destination, as defined in equation (22). Eurozone countries and countries outside of Portugal's top 100 export destinations excluded when constructing instruments. Robust standard errors in parentheses.

TABLE 8—ALTERNATIVE IV ESTIMATES, USING INCOME-GROUP INSTRUMENTS

	Dependent variable: Firm-average log real input price				
	(1)	(2)	(3)	(4)	(5)
log average destination GDP/cap	0.90	0.59	0.84	0.84	1.26
	(0.37)	(0.33)	(0.39)	(0.39)	(0.45)
log(1 + average destination distance)		−0.01	−0.00	−0.00	0.10
		(0.01)	(0.00)	(0.00)	(0.04)
Export share of sales			−0.39	−0.40	−1.23
			(0.20)	(0.20)	(0.38)
log sales				0.02	0.01
				(0.01)	(0.01)
Initial source interactions	Yes	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes
Observations	45,659	45,659	45,659	45,659	45,659
Kleibergen-Paap LM statistic (under-identification)	58.16	70.83	58.88	59.18	65.81
Kleibergen-Paap LM p-value	0.00	0.00	0.00	0.00	0.00
Kleibergen-Paap Wald rk F-stat (weak instruments)	3.72	4.56	3.77	3.79	4.23
Anderson-Rubin Wald test F-stat	2.16	2.17	2.18	2.20	2.17
Anderson-Rubin Wald test p-value	0.00	0.00	0.00	0.00	0.00

Notes: Table reports IV estimates of equation (23) in text, where instruments are log weighted-average RER at the country-income-group level, weighting by firm-level initial export shares to destination, as defined in equation (22). First-stage results are in Table 7 and reduced-form results are in online Appendix Table A10. Eurozone countries and countries outside of Portugal's top 100 export destinations excluded when constructing instruments. Columns 1 to 4 treat only log average destination GDP/cap as endogenous; column 5 adds export log(1 + average destination distance) to endogenous set. Robust standard errors in parentheses.

endogenous covariates. The estimates of the coefficient on average destination income are similar to (and not statistically distinguishable from) those in the baseline IV results in Table 6. In column 5, when distance is instrumented as well, the coefficient on export share changes sharply, and the coefficient on destination income is affected as well. The income-group instruments are less able than the baseline instruments to estimate separately the contributions of destination income, distance, and export share.[41] But the key point is that the estimates are not statistically distinguishable from one another across columns and are robustly distinguishable from zero.

Online Appendix Table A10 presents the reduced form corresponding to the alternative IV model, with log average input price at the firm level regressed directly on the income-group instruments and other covariates. Online Appendix Figure A5 plots the coefficients from column 5 for the 16 income groups, with 90 percent confidence intervals. The pattern is largely as expected, with exchange-rate appreciations in richer destinations generating increases in average input prices (significant for the richest group), and exchange-rate appreciations in poorer destinations generally (although not uniformly) leading to decreases in average input prices. The

[41] This issue is exacerbated by high correlation between the export share and distance (and to a lesser extent average destination income) variables: since many firms have few exports, and since domestic sales enter the average distance calculation as having zero distance, increases in export share at the firm level tend to be accompanied by increases in average distance.

coefficients for the richest income group and the ninth income group are significant at the 95 percent level and robust across specifications. Overall, it is reassuring that the basic patterns are robust to the alternative IV procedure.

V. Additional Results

A. *Robustness*

In this subsection, we conduct a number of checks of the robustness of the IV estimates. Online Appendix Table A11 presents the OLS estimates analogous to Table 5 but excluding the initial source interactions (the $\log(RER_{kt}) \cdot D_{ik,1997}$ terms in (23)) and online Appendix Table A12 presents the corresponding IV model (analogous to Table 6). Reassuringly, the OLS estimates are nearly identical to those in Table 5, and the IV estimates are slightly smaller but not statistically distinguishable from those in Table 6. These results are consistent with our observation in Section IVA that there is relatively little overlap between initial export destinations and import sources. They also address the concern that RERs are primarily operating through direct effects on input prices rather than by affecting the destination of exports as we have hypothesized. If that concern were important, one would expect more of a difference in the estimates including and excluding the initial source interactions. Moreover, the change in the magnitude of the estimates argues against this concern: if the baseline IV estimates were driven by the direct effect of exchange rates on import prices, one would expect the coefficient on average destination income to be smaller when controlling for the initial source interaction terms; in fact, the point estimates are larger (although not statistically significantly so). Online Appendix Table A14 reveals that the baseline IV results also remain fairly similar when using import dummies for the current year rather than 1997.

Since each non-eurozone destination enters the instrument set individually, our estimates might potentially be driven by RER movements in a relatively small subset of rich or poor destinations. To address this concern, online Appendix Tables A15 and A16 examine the extent to which the estimates are sensitive to the exclusion from the instrument set of progressively larger subsets of the richest and poorest destinations, ranked on the basis of their income per capita in 1996. Reassuringly, the magnitude and precision of the IV estimates are quite similar when excluding from the instrument set the richest 5, 10, 15, 20, or 25 non-eurozone export destinations or the poorest 5, 10, 15, 20, or 25 non-eurozone export destinations.[42]

Another potential concern about the IV estimates in Table 6 is that the two-step estimation procedure we adopt might introduce or increase heteroskedasticity in the second step. To address this concern, in online Appendix Table A17 we report estimates weighted for efficiency to correct for arbitrary heteroskedasticity, using a two-step feasible efficient GMM estimator (EGMM). The results remain qualitatively similar.

In unreported results (available from the authors), we have found that the basic patterns in Table 6 survive a number of additional robustness checks: (i) using 50,

[42] The first-stage tables corresponding to each column of online Appendix Tables A15 and A16 are available upon request.

TABLE 9—DESTINATION INCOME AND FIRM-AVERAGE OUTPUT PRICES, OLS ESTIMATES

	Dependent variable: Firm-average log real output price			
	(1)	(2)	(3)	(4)
log average destination GDP/cap	0.077	0.071	0.037	0.027
	(0.063)	(0.065)	(0.076)	(0.075)
log(1 + average destination distance)		0.002	−0.001	−0.001
		(0.005)	(0.005)	(0.005)
Export share of sales			0.087	0.090
			(0.079)	(0.079)
log sales				0.045
				(0.013)
Initial source interactions	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
R^2	0.77	0.77	0.77	0.77
Observations	45,659	45,659	45,659	45,659

Notes: Table is similar to Table 5, but for output prices. Table reports OLS estimates of equation (23) for output prices, using baseline estimation sample. Robust standard errors in parentheses.

75, or 125 instruments instead of 100; (ii) not winsorizing prices, or winsorizing by year; (iii) including nonmanufacturing inputs in the calculation of firm-level average prices; (iv) including eurozone destinations in the instrument set; and (v) instrumenting for log sales as well as average destination income, average destination distance, and export share.

B. *Average Destination Income and Output Prices*

We now briefly turn to the relationship between average destination income and firm-level average *output* prices. As discussed above, this relationship, even if causal, is difficult to interpret, since output prices are expected to reflect markups and distance as well as product quality. Table 9 presents OLS estimates of equation (23) for average output prices, analogous to Table 5. (Average output prices are calculated similarly to average input prices.) The estimates indicate a positive but statistically insignificant relationship between destination income and average output price. As for input prices, there are plausible reasons why the OLS estimate might be biased up or down. Indeed, the arguments above about the direction of bias for β_{OLS} for input price apply to output prices as well. If markups do not vary systematically across richer or poorer destinations (which is the case in our theoretical model if market shares do not vary systematically across destinations within firms), then the relationship between output prices and average destination income will be similar to the relationship between input prices and average destination income. In particular, the differences in sunk costs across destinations hypothesized above, together with input cost shocks, will generate a negative correlation between output prices and average destination income, biasing the OLS estimate downward.

Table 10 reports the IV results for output prices, analogous to Table 6. Qualitatively, the results are similar to the results for input prices: we see a significant, robust

Table 10—Destination Income and Firm-Average Output Prices, IV Estimates

	Dependent variable: Firm-average log real output price					
	(1)	(2)	(3)	(4)	(5)	(6)
log average destination GDP/cap	2.10	2.07	2.09	2.06	2.02	1.75
	(0.53)	(0.54)	(0.63)	(0.64)	(0.64)	(0.66)
log(1 + average destination distance)		−0.03	0.00	0.00	−0.03	0.01
		(0.01)	(0.01)	(0.01)	(0.07)	(0.07)
Export share of sales			−0.96	−0.95	−0.71	0.63
			(0.34)	(0.34)	(0.57)	(0.91)
log sales				0.03	0.03	0.02
				(0.01)	(0.02)	(0.02)
Initial source interactions	Yes	Yes	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	45,659	45,659	45,659	45,659	45,659	45,659
Kleibergen-Paap LM statistic (under-identification)	264.22	269.91	249.61	248.92	245.01	232.20
Kleibergen-Paap LM p-value	0.00	0.00	0.00	0.00	0.00	0.00
Kleibergen-Paap Wald rk F-stat (weak instruments)	3.11	3.11	2.67	2.65	2.53	2.32
Anderson-Rubin Wald test F-stat	3.01	3.00	2.99	2.98	2.98	2.99
Anderson-Rubin Wald test p-value	0.00	0.00	0.00	0.00	0.00	0.00

Notes: Table similar to Table 6 but for output prices. Table reports IV estimates of equation (23), using baseline estimation sample. Instruments are interactions of indicators for positive exports to destination in 1997 and log RERs for Portugal's top 100 non-eurozone export destinations; first-stage results are in online Appendix Table B1. Average destination GDP/capita defined as in equation (18). Columns 1–4 treat only log average destination GDP/cap as endogenous; column 5 adds adds log(1 + average destination distance), and column 6 adds export share of sales to endogenous set. Robust standard errors in parentheses.

positive relationship between average destination income and average output prices at the firm level, and no robust relationship between either the export share of sales or average destination distance and average firm-level prices. The positive sign could reflect an increase in product quality, if there are strong complementarities among inputs it would be natural to expect output quality to increase more than proportionally relative to the quality of particular inputs. But it is important to acknowledge that the output price change may instead reflect a change in markup, and we have no way to separate the quality and markup effects.

VI. Alternative Explanations

The results of the previous section suggest that exogenous increases in average destination income cause an increase in firm-average input prices. In this section we consider a number of possible alternative, non-quality-related explanations for this pattern. As discussed in Kugler and Verhoogen (2012), models with imperfect competition in input markets offer plausible mechanisms linking firm-level outcomes to input prices. First, if suppliers have market power, they may optimally charge higher prices to firms facing a lower elasticity of demand, a phenomenon that Halpern and Koren (2007) call "pricing to firm." If richer destinations have lower price-elasticity of output demand, this could explain the positive relationship between destination income and input prices. Second, and relatedly, if input suppliers have bargaining power and the RER movements lead firms to charge higher markups in richer countries, input suppliers may be able to bargain for higher input prices, capturing part of these increased markups. Third, if a producer has monopsony power in input markets and faces upward-sloping supply curves for inputs, any firm-specific positive demand shock will increase derived demand for inputs, which may in turn make firms move up in the supply curve and pay a higher input price. It is possible that these mechanisms are stronger when exporting to richer countries than when exporting to poorer ones.

Following a similar analysis in Kugler and Verhoogen (2012), we construct measures of market power in intermediate-input markets (in the IAPI data) and examine the extent to which the relationship between average destination income and average input prices is stronger when input suppliers or purchasers have more market power. To measure market power of input suppliers, we construct a Herfindahl index for suppliers of each input category, defined as the sum of squared market shares of domestic producers of the input in the IAPI data. To account for potential monopsony power of downstream producers in input markets, we construct two measures: (i) a Herfindahl index for purchasers of each input category, defined as the sum of squares of expenditures on the input by producers in the IAPI data; and (ii) the "purchaser share," defined as the share of each firm in total expenditures on a given input. The Herfindahl indices are defined at the input level and the purchaser share is defined at firm-input level. We then average these measures using firms' input expenditure shares in their first year in the sample as weights. These firm-level averages can be interpreted as firm-specific measures of exposure to market power in input markets.[43]

In Table 11, we examine whether the correlation between average destination income and input prices is stronger among firms with greater values of these market power measures. To our baseline IV specification we add interactions of each of these measures with average destination income, using the initial destination interactions (the $\log(RER_{kt}) \cdot C_{ik,1997}$ terms) and their interactions with the market power measures as instruments in the first stage. We deviate the market power measures from the means across all firms in the sample before interacting, so the coefficient on the uninteracted average destination income term can be interpreted as the estimate for a firm at the average level of market power exposure. (The uninteracted market power terms are invariant within firms and absorbed by the firm fixed effects.) The first point to notice is that the coefficient on average destination income remains robustly positive, and statistically indistinguishable from the baseline IV estimates in Table 6, after controlling for the interactions with observable measures of market power. The second point to notice is that the coefficients on the market power terms are negative, when entered either separately (columns 1–3) or together (column 4). If the market power stories above were explaining our main result, we would expect the destination income-input price relationship to be stronger for firms enjoying more market power, or exposed to more market power of suppliers, in input markets. In fact, the signs on the market power interactions are

[43] Because some firms only use inputs for which no producers were sampled in the IAPI data, there are a few firms in our baseline estimation sample for which the firm-specific Herfindahl supplier index could not be constructed.

Table 11—Interactions with Measures of Market Power

	Dependent variable: Firm-average log real input price			
	(1)	(2)	(3)	(4)
log average destination GDP/cap	0.40	0.45	0.56	0.49
	(0.20)	(0.21)	(0.22)	(0.16)
log(1 + average destination distance)	0.04	0.04	0.03	0.02
	(0.02)	(0.02)	(0.02)	(0.02)
Export share of sales	−0.03	−0.21	−0.11	−0.24
	(0.26)	(0.24)	(0.24)	(0.19)
log sales	0.01	0.01	0.01	0.02
	(0.01)	(0.01)	(0.01)	(0.01)
log average destination GDP/cap · Herfindahl (suppliers)	−1.89			−1.20
	(0.60)			(0.53)
log average destination GDP/cap · Herfindahl (purchasers)		−1.39		−0.64
		(0.71)		(1.17)
log average destination GDP/cap · purchaser share			−1.03	−0.14
			(0.69)	(1.12)
Initial source interactions	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
Observations	43,776	45,659	45,659	43,776
Kleibergen-Paap LM statistic (under-identification)	342.10	368.59	382.69	565.82
Kleibergen-Paap LM p-value	0.00	0.00	0.00	0.00
Kleibergen-Paap Wald rk F-stat (weak instruments)	1.89	1.87	1.99	1.85
Anderson-Rubin Wald test F-stat	2.25	3.04	2.88	3.66
Anderson-Rubin Wald test p-value	0.00	0.00	0.00	0.00

Notes: Specifications similar to Table 6, column 6, but including market power measures and interactions. Instruments are the baseline instruments (interactions of indicators for positive exports to destination in 1997 and log RERs) and their interactions with the corresponding market power measures. Column 4 includes interactions of baseline instruments with all three market-power measures in instrument set; first-stage results are in online Appendix Table B2. Because some firms only use inputs for which no producers were sampled in the IAPI data, there are a few firms in our baseline estimation sample for which the firm-specific Herfindahl index for suppliers could not be constructed, hence the smaller number of observations in columns 1 and 4. See Section VI for details of construction of market-power measures. Robust standard errors in parentheses.

pointing in the other direction, significantly in some cases. It does not appear that market power in input markets can explain our main finding.

To provide further evidence for the income-based quality channel, we consider how the relationship between destination income and input prices varies across sectors with different scopes for quality differentiation. Following Sutton (1998) and Kugler and Verhoogen (2012), we use the ratio of industry-level R&D and advertising expenditures to sales as a proxy for the scope for quality differentiation.[44] In Table 12, we add to our baseline IV specification an interaction term between this measure and average destination income, using the initial destination interactions (the $\log(RER_{kt}) \cdot C_{ik,1997}$ terms) and their interactions with the R&D and advertising intensity measure as instruments in the first stage. We observe that the effect of average destination income on input prices is significantly greater among firms

[44] These data come from the US Federal Trade Commission (FTC) Line of Business Survey and have been widely used by researchers, including Cohen and Klepper (1992); Brainard (1997); Antràs (2003); and Kugler and Verhoogen (2012), in addition to Sutton (1998).

Table 12—Interactions with R&D and Advertising Intensity, IV Estimates

	Dependent variable: Firm-average log real input price		
	(1)	(2)	(3)
log average destination GDP/cap	0.51	0.51	0.46
	(0.21)	(0.21)	(0.21)
log(1 + average destination distance)	−0.04	−0.04	−0.02
	(0.02)	(0.03)	(0.03)
Export share of sales	−0.20	−0.22	0.06
	(0.11)	(0.18)	(0.23)
log sales	0.02	0.02	0.02
	(0.01)	(0.01)	(0.01)
log average destination GDP/cap · R&D + advertising intensity	1.66	1.65	1.42
	(0.66)	(0.67)	(0.69)
Initial source interactions	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes
Year effects	Yes	Yes	Yes
Observations	45,659	45,659	45,659
Kleibergen-Paap LM statistic (under-identification)	367.68	363.46	372.30
Kleibergen-Paap LM *p*-value	0.00	0.00	0.00
Kleibergen-Paap Wald rk *F*-stat (weak instruments)	2.46	2.27	1.88
Anderson-Rubin Wald test *F*-stat	2.37	2.38	2.38
Anderson-Rubin Wald test *p*-value	0.00	0.00	0.00

Notes: Specifications similar to Table 6, columns 4–6, but including interaction of destination income and R&D and advertising intensity for the firm's output sector. Instruments are the baseline instruments (the $\log(RER_{kt}) \cdot C_{ik,1997}$ terms) and the interactions with the R&D and advertising intensity measure; first-stage results are in online Appendix Table B3. Data on advertising and R&D expenditures as a share of total industry sales are from the US FTC 1975 Line of Business Survey, converted from FTC four-digit industry classification to CAE four-digit classification using verbal industry descriptions, then, matched to firms' industries as reported in the firm-level data. Column 1 treats only log average destination GDP/cap and the interaction with the R&D and advertising intensity as endogenous; column 2 adds log(1 + average destination distance), and column 3 adds export share of sales to endogenous set. Robust standard errors in parentheses.

operating in industries with greater scope for quality differentiation, providing further support for the income-based quality-choice channel.

In the same spirit, we conduct a placebo test using a set of inputs for which we are confident that there is no scope for quality differentiation: energy inputs. There are 17 different energy inputs in the IAPI data for which unit values can be constructed.[45] Energy inputs typically do not exhibit meaningful quality differences, but their prices might plausibly reflect the alternative mechanisms discussed above, notably market power of input suppliers or monopsony power of downstream producers. A positive and significant effect of average destination income on energy input prices would suggest that forces other than quality differences are driving this relationship. Table 13 reports OLS and IV estimates of the effect of average destination income on average energy input prices. The estimate of the destination-income coefficient is statistically insignificant and close to zero, consistent with the hypothesis that in the

[45] The energy inputs are: electricity, fuel oil, gasoline, diesel, petroleum, natural gas, derived gas, steam, propane gas, charcoal, wood (purchased), wood (own production), hydrogen, acetylene, coal, coke (from coal), and briquettes/pellets.

Table 13—Destination Income and Firm-Average Energy Input Prices

	Dependent variable: Firm-average log real energy price			
	OLS	IV		
	(1)	(2)	(3)	(4)
log average destination GDP/cap	−0.00	−0.08	−0.06	−0.02
	(0.01)	(0.11)	(0.11)	(0.11)
log(1 + average destination distance)	0.00	0.00	0.01	0.00
	(0.00)	(0.00)	(0.01)	(0.01)
Export share of sales	−0.03	0.01	−0.05	−0.29
	(0.01)	(0.06)	(0.09)	(0.13)
log sales	−0.01	−0.01	−0.01	−0.01
	(0.00)	(0.00)	(0.00)	(0.00)
Initial source interactions	Yes	Yes	Yes	Yes
Firm effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
Observations	42,043	42,043	42,043	42,043
Kleibergen-Paap LM statistic (under-identification)		240.94	247.81	233.09
Kleibergen-Paap LM p-value		0.00	0.00	0.00
Kleibergen-Paap Wald rk F-stat (weak instruments)		2.55	2.51	2.34
Anderson-Rubin Wald test F-stat		1.68	1.68	1.69
Anderson-Rubin Wald test p-value		0.00	0.00	0.00

Notes: Specifications similar to Table 5, column 4 and Table 6, columns 4–6, but using only energy inputs in calculating firm-level average input prices. See list of energy inputs in Section VI. First-stage results are in online Appendix Table B4. Robust standard errors in parentheses.

absence of quality differences we would not observe a positive and significant effect of average destination income on input prices paid by firms.

VII. Conclusion

This paper has developed an approach to estimating the role of the income-based quality-choice channel in shaping firms' behavior in the international economy. Direct measures of product quality are not available, and following a growing literature we seek to draw inferences about product quality from information about prices. Such inferences can be confounded by the fact that prices may reflect markups as well as product quality. Our proposed solution to this problem is to focus on how *input* prices paid at the firm level respond to variation in the income level of a firm's export destinations. While output prices may reflect various forms of pricing-to-market, input prices arguably do not.

We have found a robust, statistically significant, positive relationship between the average income level of destinations to which Portuguese firms export and the prices they pay for their inputs. To address concerns about the endogeneity of average destination income, we have used real-exchange-rate movements, interacted with indicators for firms' initial export presence in particular destinations, as instruments for the average income of destination markets (and other endogenous covariates) at the firm level. Weak-instrument-robust statistical tests reinforce the finding of a positive, robust, statistically and economically significant relationship between average destination income and input prices within firms. The destination income-input price relationship holds when controlling for average destination distance, the export share of sales, and total sales at the firm level.

Alternative explanations of the effects of exporting on firm behavior cannot fully account for the observed patterns. Models based on scale effects suggest that destination income should not matter once we have controlled for the scale of exports and total sales. Models of the "Washington apples" effect suggest that destination income should not matter once we have controlled for distance. We have considered alternative possible explanations for the input-price results based on market power in input markets, but have found little evidence to support them.

Overall, we interpret our findings as supportive of the hypothesis that firms choose to sell higher-quality products in richer countries, that doing so requires purchasing higher-quality inputs, and that this mechanism is part of the explanation for the effects of exporting on firm behavior that have been documented by a number of authors. The empirical findings add to the accumulation of evidence that endogenous quality choice of both outputs and inputs is an important element of firms' behavior in the international economy.

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