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Exchange Rate Pass-Through in a Competitive Model of Pricing-to-Market*

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Abstract

This paper extends the Mussa and Rosen (1978) model of quality-pricing under perfect competition. Exporters sell goods of different qualities to consumers who have heterogeneous preferences for quality. Production is subject to decreasing returns to scale and, therefore, supply and the toughness of competition react to cost changes brought about by exchange rate fluctuations. First, we predict that exchange rate shocks are imperfectly passed through into prices. Second, prices of low quality goods are more sensitive to exchange rate shocks than prices of high quality goods. Third, in response to an exchange rate appreciation, the composition of exports shifts towards higher quality and more expensive goods. We test these predictions using highly disaggregated price and quantity U.S. import data. We find evidence that in response to an exchange rate appreciation, the composition of exports shifts towards high unit price goods. Therefore, exchange rate pass-through rates that are measured using aggregate data will tend to overstate the actual extent of pass-through.

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1 Introduction

Why are the movements of relative costs brought about by exchange rate fluctuations passed through to consumers only partially?

This paper develops a model of pricing-to-market under perfect competition and flexible prices. We build on the Mussa and Rosen (1978) model of quality-pricing. Exporters sell goods of different qualities to consumers who have heterogeneous preferences for quality. We depart from the work of Mussa and Rosen in two important dimensions. First, we consider a perfectly competitive setting, as opposed to their original monopoly setting. Second, we introduce decreasing returns to scale at the firm level. In the resulting equilibrium of the economy, higher quality goods are matched with higher valuation consumers. The price schedule relating good quality to market price depends on the valuations of consumers who are matched with these goods. Prices are higher when the valuations of consumers in the market are higher. Second, price differentials between goods of different qualities are the larger the higher consumer valuations.

We next analyze how our model can account for incomplete pass-through of cost shocks into consumer prices. The main insight of the model is that pass-through can be incomplete and heterogeneous across different firms even within a narrowly defined competitive industry. The crucial ingredient of our model is the heterogeneity of consumers: all consumers value quality, but they do so at different rates. In the absence of this heterogeneity in valuations, relative good prices are fixed by the representative consumer's valuation for quality, leading in equilibrium to equal pass-through rates across all goods in the industry. Relative prices in our model are determined by differences in quality and by differences in the valuations the respective qualities are matched with. Because the equilibrium matching of qualities and valuations responds to cost changes, pass-through rates differ across different firms.

We consider a purely real model of international price setting. Exchange rate shocks are assumed to be real productivity shocks so that there is no price stickiness, hence no money illusion, and no role for monetary policy. We derive three predictions for the rate of cost pass-through.

First, exchange rate shocks are only partially passed through to consumers. When an exporting country is hit by an appreciation of the real exchange rate, exporting firms scale down their exports. The relative scarcity of goods forces the lowest valuation consumers out of the market. As a consequence, exporters are matched with higher valuation consumers, thereby leading to higher prices. In equilibrium, only a part of the cost shock is passed through to consumers.

Second, we predict that there is more pass-through for low quality goods than for high quality goods. This prediction relies on a subtle argument. After an appreciation of the exporter's exchange rate, two forces drive up prices. First, the exit of low quality firms shrinks the total supply of goods and forces the lowest valuation consumers out of the market. The average valuation of the remaining consumers increases and consequently, also prices increase. Second, all firms scale down their production, which also shrinks the total supply of goods and pushes up all prices. The relative strength of the second effect is larger for higher quality goods.

Following an appreciation of the exchange rate, equivalent to a negative productivity shock for exporters, low quality firms exit. Since the set of competing exporters changes substantially when the exchange moves, prices move almost one for one with the exchange rate for low quality exporters.[1] The price of higher quality goods, on the other hand, depends on the overall tightness of the market, which determines which consumer is matched with which good. In the limit, infinitely high quality goods prices are, in relative terms, not at all affected by the exit of low quality firms. Their price increases only because all firms scale down their production. The pass-through of exchange rate shocks is thus higher for low quality goods than for high quality goods.

Third, we predict that in response to an exchange rate appreciation, the composition of exports shifts towards high quality, high price goods. This prediction is due to the endogenous selection of exporters: in the presence of a fixed cost to enter foreign markets, only the highest quality firms are able to export. When hit by a negative exchange rate shock, the lowest quality firms – which charge the lowest prices – pull out of the export market. The exit of low quality, low price exporters has an effect on individual prices and an additional effect on aggregate prices. First, the exit of low quality exporters shrinks the total supply of goods, driving out low valuation consumers. The remaining firms are matched with higher valuation consumers so that each individual price increases further. Second, since only the low quality, low price exporters pull out, the composition of exports shifts towards high price goods. Since the composition of firms shifts towards high quality, high price firms when the exchange rate appreciates, our results imply that aggregate price indices tend to overestimate the actual extent of pass-through.

We next test these predictions using highly disaggregated price and quantity US import data.

[1] Since all costs occur in importer currency, the price for the lowest observed exporter price moves exactly one for one with the exchange rate. However, following an appreciation of the exchange rate, low quality firms leave the export sector. The good that becomes the lowest quality good exported after the exchange rate appreciation was strictly above the lowest quality before the exchange rate shock. Therefore, its price increases less than one-for-one with the exchange rate.

First, we confirm the widely documented finding that exchange rate shocks are only partially passed through into export prices. This finding holds not only at the aggregate level, as it is commonly described, but also at the highest level of disaggregation allowed by the data. Second, we find no evidence that higher quality goods, proxied as high unit value goods, are more sensitive to exchange rate movements. Third, however, we find evidence that in response to an exchange rate appreciation, the composition of exports shifts towards high unit price goods. This last finding suggests that estimates of the degree of pass-through of exchange rate shocks into export prices performed at the aggregate level tend to be overestimated.

Our approach is motivated by recent findings on exchange rate pass-through. Campa and Goldberg (2005) give an up-to-date review of the evidence on incomplete pass-through. Even though there is almost full pass-through of exchange rate shocks for prices at the dock, there is much more limited pass-through for consumer prices. The order of magnitude is 40% in the short run and 60% in the long run. The empirical literature has stressed the importance of distribution margins in explaining this fact. Burstein, Neves, and Rebelo (2003), Burstein, Eichenbaum, and Rebelo (2005), and Campa and Goldberg (2006) argue that non-tradable inputs such as distribution costs play a key role. Burstein et al. (2003) note that for a typical consumption good in the US, distribution margins account for more than 40% of the final price. Finally, and most related to our model, Campa and Goldberg (2006) note that distribution margins do not remain stable during real exchange rate fluctuations. A 1% real exchange rate depreciation leads to a 0.47% reduction in distribution margins. This response of local distribution margins to the exchange rate has also been documented for the case of the beer industry by Hellerstein (forthcoming).

To capture these facts, we introduce a two-tiered production function similar to Bacchetta and van Wincoop (2003). While transportation costs are linear, we assume that the production capacity of a firm is fixed so that supply to any foreign market is subject to decreasing returns to scale. One possible interpretation of this fixed capacity is that firms have a fixed distribution network. Under this assumption, our model gives rise to incomplete pass-through of exchange rate shocks despite full pass-through at the dock, and to fluctuations in the distribution margin in response to exchange rate movements. One important point is that in our model, all costs are paid in the exporters' currency, not in the local currency. We make this assumption to stress the fact that decreasing returns to scale matter, even if no part of this cost is paid in the importer's currency. If part of the distribution costs were paid in foreign currency, our results would be reinforced.

We point out the potential importance of composition effects in estimating exchange rate pass-through. Burstein, Eichenbaum and Rebelo (2005) suggest one specific composition effect, flight from quality. They point out that following a large devaluation, consumers stop buying high quality goods. Our predictions regarding this flight from quality are ambiguous. Indeed, following a devaluation, we predict that overall, since fewer quality goods are imported, many consumers switch from quality goods to generic goods produced at home. However, the consumers who still buy quality-differentiated goods will typically buy higher quality goods at a higher price.[2]

The importance of heterogeneity in product quality for export selection has been emphasized by Baldwin and Harrigan (2007). Building on the empirical observations of Schott (2004), Hummels and Klenow (2005), Hallak (2006), and Hallak and Schott (2008), the authors argue that selection into the export sector occurs along the dimension of product quality rather than physical productivity. This insight has been extended by Johnson (2008), who predicts that firms with heterogeneous productivity in equilibrium produce output of heterogeneous quality.

In this paper, we explore the implications of export selection along the dimension of product quality for exchange rate pass through. In this respect, the predictions of our model are similar to the work of Verhoogen (2008), who analyzes the effect of exchange rate fluctuations on wage inequality in an economy where high quality workers are employed by firms producing high quality exports. Rather than analyzing the relationship between product quality and relative wages, we analyze relationship between quality and relative pass-through rates.

Despite the growing literature on measuring the quality of exports, there is to our knowledge little evidence on the degree of exchange rate pass-through for exports of different qualities. Gagnon and Knetter (1995) study the exchange rate pass-through for car exports from three main automobiles exporters and find that pass-through rates differ across cars of different classes.

In addition to examining the quality dimension of cost pass-through, we also highlight that incomplete pass-through can arise under perfect competition and flexible prices. The existing theoretical literature on exchange rate pass-through and pricing-to-market has so far relied on two alternative assumptions: either price stickiness or imperfect competition.

[2] Note that we do not consider the impact of exchange rate fluctuations on disposable income, so that consumers in our model are never prevented from buying quality goods because of their budget constraint. Although we believe that this model describes normal exchange rate movements well enough, it is likely to mispredict the flight from quality that occurs during large devaluations.

For example, Betts and Devreux (1996), Taylor (2001), and Bacchetta and van Wincoop (2003) show why pass-through is incomplete and staggered when prices are sticky. Undoubtedly, sticky prices matter for limited pass-through. Gopinath and Rigobon (2008) document that even though exchange rates fluctuate daily, prices at the dock adjust only rarely. However, Gopinath and Rigobon also document that pass-through rates are less than a fourth within the set of firms adjusting prices. While menu costs can explain why actual prices are changed infrequently, they cannot directly explain why the optimal price responds very little when costs change. Our paper rationalizes the latter aspect.[3]

Our model is related to a second strand of literature arguing that the response of the optimal price to the exchange rate is low. The seminal papers of Krugman (1987) and Dornbusch (1987) have been followed by more elaborate models, such as Yang (1997), Corsetti, Dedola, and Leduc (2005), and Atkeson and Burstein (forthcoming). These models rely on the fact that, when firms adjust their prices, they move along the demand curve and face a different demand elasticity. Under some conditions on the shape of the demand curve, exporters will adjust their markups and dampen price fluctuations, leading to pricing-to-market and incomplete pass-through of exchange rate shocks.

We depart from this assumption by assuming perfect competition, and our framework is thus more applicable in industries with a large set of competitors. In the above-mentioned literature, as the number of firms competing in a sector increases, the pricing-to-market predictions quickly become negligible. In contrast, we consider the extreme case of a competitive industry with an infinite number of firms that still exhibits imperfect cost pass-through.

An alternative branch of the literature – for example, Melitz and Ottaviano (2008), Gust, Leduc and Vifgusson (2006), and Chen, Imbs, and Scott (2006) – directly assumes that prices are complement in the utility function. We propose another explanation where the matching of firms and consumers generates this complementarity in equilibrium.

The remainder of the paper is organized as follows. In section 2, we present the general setup of our model of quality-pricing. In section 3, we analyze a specific example and provide closed-form solutions. In section 4, we derive the predictions of our model for exchange rate pass-through. Section 5 presents empirical evidence. Section 6 concludes.

[3] Kleshchelski and Vincent (2007) argue that firms and customers form long-term relationships because consumers incur costs to switch sellers. Therefore, firms may decide to keep prices perfectly stable also in the absence of menu costs.

2 Model

In this section, we develop a model of quality-pricing and international trade.

There are two countries, home and foreign. The two countries are respectively populated by a mass L_H and L_F of consumers who share the same preferences. There are three sectors, $\mathcal{A}$, Q_F, and Q_H. The $\mathcal{A}$ sector produces a homogeneous good, which may be freely traded. We will only consider equilibria where all consumers in each country consume some of this numeraire good. We can therefore normalize the price of this good to unity. In each country, the Q sector produces a continuum of goods that differ in terms of quality. For simplicity, we assume that Q goods are differentiated by the country of origin, i.e., each country has a monopoly in its Q good.

There is a continuum of competitive firms producing each type of good. Firms in each of the Q sectors are heterogeneous in terms of the quality of the good they produce. They face a decreasing returns-to-scale technology due to the presence of a fixed production capacity. In addition, in order to enter the foreign market, they must pay a fixed entry cost. There is a continuum of (heterogeneous) consumers buying those goods. Both firms and consumers are price takers.

The timing of the economy is the following: first, firms receive their quality draw; second, they decide whether or not to enter each market, home and foreign; third, given the prices that they expect, they decide how much output to produce; and finally, prices are determined so as to clear all markets.

The strategies of firms and consumers are the following: 1) firms maximize expected profits, given their expectation for prices; and 2) consumers maximize their utility given the set of goods available and the prices they observe.

Preferences

Consumers can consume a continuum of $\mathcal{A}$ goods. For the consumption of each of the Q goods, we consider a discrete choice model. Consumers can consume either zero or one unit of domestic Q goods, and either zero or one unit of foreign Q goods. Different Q goods have different qualities, and different consumers have different valuation for quality. A consumer with the valuation v for quality, who consumes one unit of home good with quality q_H and one unit of foreign good with quality q_F, and A units of the homogenous good, derives a utility

$$U_v\left(q_H, q_F, A\right) = v\left(q_H + q_F\right) + A \tag{1}$$

For simplicity of notation, if a consumer does not consume one of the Q goods, we set its quality to zero.

Valuations for quality, v, are distributed over all consumers according to

$$v \sim F_v(v) \tag{2}$$

where F_v is the cumulative distribution of the v's and $f_v(v)$ the density. Valuations are distributed over the interval $[\bar{v}, v^{\max}]$.[4] We assume that there is a strictly positive density over the entire domain: $f_v(v) > 0$ for $v \in [\bar{v}, v_{\max}]$. We also assume that the distribution of income is such that consumers can always afford to buy one unit of Q good.[5]

The main property of these preferences is that valuation and quality are complementary; the higher a consumer's valuation, the more she values quality, and the more she will be willing to pay for quality. This property allows us to derive two important results. First, there is assortative matching between consumers and goods, i.e., higher valuation consumers buy higher quality goods. Second, the pace at which prices increase with quality is exactly determined by the valuation of consumers. We state and prove these two results formally in the following two propositions.

Proposition 1 (assortative matching) *If an equilibrium exists, consumers' valuations and goods' qualities are matched assortative:*

$$v_1 > v_2 \Rightarrow q_1 \geq q_2$$

where consumer $i = 1, 2$ with valuation v_i is matched with a good of quality q_i.

Proof. Assume there is an equilibrium such that,

$$v_1 > v_2 \text{ and } q_1 < q_2$$

In such a case, consumer 1 with a valuation for quality v_1 is willing to upgrade quality by exchanging his good of quality q_1 against consumer 2's good of quality q_2 and in addition pay her as much as $v_1(q_2 - q_1)$ units of the $\mathcal{A}$ good. Consumer 2, on the other hand, is willing to downgrade her quality by exchanging his good q_2 against good q_1 in exchange for at least $v_2(q_2 - q_1)$ units of the $\mathcal{A}$ good. Note that

$$v_1 > v_2 \text{ and } q_2 > q_1 \Rightarrow v_1(q_2 - q_1) > v_2(q_2 - q_1)$$

[4] We allow for $v^{\max} = +\infty$. In our closed form example in section 3, we consider a support that is unbounded from above for the distribution of valuation draws.

[5] Implicitly, we assume that high valuation consumers also have a high income, so that they can afford the high price for the Q good they buy in equilibrium.

so that both consumers will agree to exchange their goods and at least one of them will be strictly better off. This cannot be an equilibrium. Hence, in any equilibrium, it must be that

$$v_1 > v_2 \Rightarrow q_1 \geq q_2$$

■

Given the complementarity between quality and valuation built into the preferences, assortative matching is a very intuitive result. High valuation consumer gain more from quality. It would not be optimal to allocate high quality goods to low valuation consumers, and hence any market equilibrium must allocate higher quality goods to higher valuation consumers.

A direct corollary of this assortative matching is that, locally, relative prices are pinned down by a no-arbitrage condition on the consumer side. Higher quality goods are more expensive. Moreover, prices increase with quality exactly according to the valuation of the consumers. The following proposition states this result formally.

Proposition 2 *If an equilibrium exists, the mapping from a good quality to prices is continuously differentiable. The prices are determined locally by the valuation of consumers in the following way:*

$$p'(q) = v(q)$$

where $v(q)$ is the valuation of the consumer matched with a good of quality q, $p(q)$ is the price of this good, and $p'(q)$ is the derivative of this price schedule.

Proof. Suppose that an equilibrium exists. Take any two consumers with a valuation $v_1 > v_2$, who are matched, respectively, with goods of quality q_1 and q_2, with prices p_1 and p_2. Given those prices, consumer 1 would strictly prefer to buy q_2 instead of q_1 if $v_1(q_1 - q_2) > (p_1 - p_2)$. In the same way, consumer 2 would strictly prefer to buy q_1 instead of q_2 if $v_2(q_1 - q_2) < (p_1 - p_2)$. In equilibrium, given prices, consumers must not be willing to change their consumption bundles. So it must be that $v_2 \leq \frac{p_1 - p_2}{q_1 - q_2} \leq v_1$.
These inequalities must hold for any q_1 and q_2, which implies that for any $q_0 \in \left[q^{\min}, q^{\max}\right]$,

$$\lim_{q \to q_0^+} \frac{p(q) - p(q_0)}{q - q_0} = \lim_{q \to q_0^-} \frac{p(q) - p(q_0)}{q - q_0} = p'(q) = v(q)$$

where $q^{\min}$ is the lowest quality actually consumed in equilibrium, with the left derivative only for $q_0 = q^{\min}$, and the right derivative only for $q_0 = q^{\max}$. ■

Prices increase with quality. The price schedule mapping qualities to prices is continuous and continuously differentiable and the derivative of the price schedule is exactly equal to the valuation for quality, denominated in units of marginal utility of the $\mathcal{A}$ good.

It is straightforward to see from the previous two propositions that prices are increasing and convex in quality. This property of prices is reminiscent of the Mussa and Rosen (1978) model of quality-pricing. Whether goods are supplied by a single monopolist, as in Mussa and Rosen (1978), by oligopolists as in Champsaur and Rochet (1989), or by atomistic price taking firms as in this model, prices must increase at an accelerating pace in order to prevent low valuation consumers from buying high quality goods.

In our setup, prices depend not only on quality itself, but also on which consumers buy which product. This result follows the same logic as the result of Gabaix and Landier (2008) relating managerial pay to manager skills as well as to the size of the project a manager is matched with. If a highly talented manager works on a tiny project, her marginal product is low. Similarly, if a high quality good is matched with a consumer who has a low valuation for quality, its price is low.

Production

Production in the $\mathcal{A}$ sector is made under constant returns to scale. The labor productivity at home (abroad) is Z_H (Z_F). We will only consider equilibria in which both countries produce the $\mathcal{A}$ good. Labor can freely move between sectors. Thus, the wage w_H (w_F) of domestic (foreign) workers, in units of the $\mathcal{A}$ numeraire good, is simply equal to Z_H (Z_F).

Goods' quality: In the Q sector, there is a continuum of mass M_H (M_F) of firms in the home (foreign) country. Each of these firms produces a good of a specific quality. Firms randomly draw a quality shock from a stochastic distribution given by

$$q \sim F_q(q) \tag{3}$$

where F_q is the cumulative distribution of the q's, and f_q is the corresponding density. Qualities are distributed over the interval $[\bar{q}, q_{\max}]$.[6]

Technology: Despite their differences in quality, all firms face the same technology for producing Q goods. They are subject to decreasing returns to scale. The cost for supplying S units of Q goods is given by $w_H C(S)$, with $C(\cdot)$ increasing and convex. We denote the marginal cost

[6] As for valuations, we allow for an unbounded positive support for the distribution of quality shocks.

of supplying the S^{th} unit of good by $w_H c(S) = w_H C'(S)$, $c'(S) > 0$. We assume that the cost function applies to each market separately. This allows us to independently study the domestic production decision and the foreign production decision.

Trade barriers: In order to export abroad domestic firms must overcome both a variable cost for shipping each unit of good abroad, and a fixed cost of entering the foreign market. The variable cost takes the traditional form of iceberg transportation costs, with a fraction $(\tau - 1)$ of all shipments melting on the way $(\tau > 1)$. The fixed cost of entry is equal to $\tau w_H f^E$, which is paid in units of the $\mathcal{A}$ numeraire good.

We now consider the decision of a domestic firm that decides to export abroad. Leaving aside for the moment the question of whether or not it is profitable to pay the fixed entry cost, we characterize the quantity an exporter would supply abroad. Firms are price takers, so they decide to increase their supply of goods until their marginal cost equals the price of their good. In equilibrium, a firm that expects a price p for its good supplies $S(p)$ units abroad. $S(p)$ is defined by $\tau w_H c(S(p)) = p$. We can rewrite this optimality condition as

$$S(p) = c^{-1}\left(\frac{p}{\tau w_H}\right) \tag{4}$$

where c^{-1} is the inverse of the cost function. Note that the marginal cost of selling the S^{th} unit of a good abroad is the marginal cost of production multiplied by τ. To sell one unit abroad, a firm must export τ units, each at a cost of $w_H c(S)$. The marginal cost is strictly increasing in the quantity supplied, so that the quantity supplied S is strictly increasing in the price p. All firms follow the same strategy and supply a quantity which depends on the price they expect to receive for their quality.

Foreign market entry decision: Firms must decide whether or not to pay the fixed entry cost into the foreign market. They compare the profits they would earn from exporting to the fixed entry cost. Only those firms whose gross profits are above the entry cost export. There is a minimum price $p_{\min}$ below which it is not profitable to export. The minimum price is given by the zero profit cutoff condition:

$$p_{\min} S(p_{\min}) - \int_0^{S(p_{\min})} \tau w_H c(s)\, ds - \tau w_H f^E = 0 \tag{5}$$

The net profit from exporting if the price abroad is $p_{\min}$ is exactly zero. Since $c(\cdot)$ and $S(\cdot)$ are strictly increasing, $p_{\min}$ is uniquely determined by Equation (5).

Note that for the moment, we know the price of the lowest quality exported, but we still have not determined the actual level of the lowest quality exported. It is determined in equilibrium, which we define in the next section.

Equilibrium

An equilibrium consists of a price schedule such that the goods market clears if consumers optimally chose which good to consume, if any, and if firms optimally chose how much to produce and whether or not to enter the foreign market. We will construct the equilibrium in the following way. First, we match goods to consumers. Given this matching, we define the price schedule matching quality to price, up to a constant. We then identify the quality of the good matched with the lowest valuation consumer. Finally, we determine production amounts.

First, note that there are potentially three possible types of equilibrium: a sellers' market where there are more consumers than goods, a buyers' market where there are more goods than consumers, or a third case where neither all exporting firms sell their good, nor all consumers buy a Q good (because they have negative valuations for quality). We will consider the case of a sellers' market, where all exporting firms sell their goods, but not all consumers buy a Q good.

We can rewrite the matching implied by proposition 1 and define formally the matching between quality and consumers. A good of quality q will be matched to a consumer with quality $v(q)$, according to

$$N_H \int_q^{q_{\max}} S(p(\chi)) f_q(\chi) \, d\chi = L_F \int_{v(q)}^{q_{\max}} f_v(v) \, dv \tag{6}$$

for any $q \in [q_{\min}, \ q_{\max}]$, where $q_{\min}$ is the lowest quality exported, and $S(p(\chi))$ is the quantity being supplied by the firm with quality χ. The left hand side of (6) is the number of goods with quality q and above, whereas the right hand side is the number of consumers with the valuation $v(q)$ and above. For any level of quality q, these two must be equal.

Given the matching between goods and consumers, we can derive prices from proposition 2. Integrating prices over quality, we get the price $p(q)$ of a good of quality q

$$p(q) = \int_{q_{\min}}^{q} v(\chi) \, d\chi + p_{\min} \tag{7}$$

for any $q \in [q_{\min}, \ q_{\max}]$, where $v(\chi)$ is the valuation of the consumer matched with the quality χ given in Equation (6), and $p_{\min}$ is the price of the lowest quality exported, given by the zero cutoff profit condition (5).

We now have to determine the quality of the good matched with the lowest valuation consumer. Since we are in a sellers' market, some consumers will not buy any Q goods. The last consumer must be indifferent between buying and not buying good $q_{\min}$, or in other words, she must be indifferent between buying $q_{\min}$ or buying $\mathcal{A}$ goods instead. The lowest quality exported $q_{\min}$ is defined by,

$$v\left(q_{\min}\right) q_{\min} = p_{\min} \tag{8}$$

where $v\left(q_{\min}\right)$ is the valuation of the consumer matched with quality $q_{\min}$ given in Equation (6), and $p_{\min}$ is the price of the lowest quality exported, given by the zero cutoff profit condition (5).

An equilibrium price schedule will be the solution to the zero cutoff profit condition (5), to the matching equation (6), to the pricing equation (7), and to equation (8) defining the lowest quality exported. The following proposition states the existence of such an equilibrium.[7]

Proposition 3 *There exists a* $(p(\cdot),\ v(\cdot),\ p_{\min},\ q_{\min})$ *solution to Equations (5), (6), (7) and (8), not necessarily unique.*

Proof. *See Unpublished Technical Appendix, page 32.* ■

In order to derive precise predictions for the pass-through of exchange rate shocks of different goods, we introduce a specific functional form for the distribution of valuation and quality draws. We present this example in the next section.

3 A closed-form example

First, we assume that both valuation shocks and quality shocks are Pareto distributed. The distribution of both shocks are as follows:

$$\begin{cases} F_v\left(v\right) = 1 - \left(\frac{v}{\bar{v}}\right)^{-\lambda_v} \\ F_q\left(q\right) = 1 - \left(\frac{q}{\bar{q}}\right)^{-\lambda_q} \end{cases} \tag{9}$$

Production takes place under decreasing returns to scale. We assume that the marginal cost function takes the following form,

$$c\left(S\right) = \tau w_H \left(1 + S^{1/\eta}\right) \tag{10}$$

This simple functional form for the marginal cost ensures that, in equilibrium, the supply elasticity will be constant and equal to η for all firms. Along with the assumption that both qualities and

[7] The proofs of some of the following propositions are available on the website of this journal in an unpublished technical appendix.

valuations for quality are distributed Pareto, this generates simple analytical solutions for the equilibrium matching and pricing functions.

Under perfect competition, firms equalize their marginal cost to the price they face, so that we have the following expression for the supply of each Q good as a function of its price,

$$S(p) = \left(\frac{p}{\tau w_H} - 1 \right)^{\eta} \tag{11}$$

We are now able to solve for the equilibrium price schedule.

Proposition 4 *If the entry cost is such that* $f^E = \left(\frac{\lambda_q - \eta}{(1+\eta)(\lambda_q + \lambda_v)} \right)^{1+\eta}$, *then there exists a unique equilibrium price schedule, lowest quality exported, and lowest price, defined as*

$$\begin{cases} p(q) = \gamma \left(\tau w_H \right)^{\eta/(\lambda_v+\eta)} q^{(\lambda_v+\lambda_q)/(\lambda_v+\eta)} + \tau w_H \\ q_{\min} = \gamma' \left(\tau w_H \right)^{\lambda_v/(\lambda_v+\lambda_q)} \\ p_{\min} = \left(\frac{\lambda_q+\lambda_v}{\lambda_q-\eta} \right) \tau w_H \end{cases}$$

where γ and γ' are constants.[8]

Proof. See Unpublished Technical Appendix, page 34. ■

We impose the knife-edged condition $f^E = \left(\frac{\lambda_q - \eta}{(1+\eta)(\lambda_q + \lambda_v)} \right)^{1+\eta}$ for the sole purpose of deriving closed-form solutions. In that specific case, we are able to describe precisely how both individual prices and quantities of each exported good, as well as aggregate prices respond to marginal cost shocks.

Asymptotically, the elasticity of the price with respect to quality converges to $\frac{\lambda_v+\lambda_q}{\lambda_v+\eta} > 1$. The more elastic the supply of goods by each individual exporter, that is, the larger η, the less responsive are prices to changes in quality. If the technology of production is such that large changes in the quantity supplied are needed to generate a given change in the marginal cost of production (η high), then firms with a higher quality will supply much larger quantities compared to firms with low quality. Moreover, when η is high, firm output responds strongly to cost fluctuations.

The other two key parameters that determine how responsive prices are to changes in quality are the measures of the fatness of the tails of the distributions of quality and valuation for quality, λ_q and λ_v. If the quality of firms is more homogenous (λ_q high), or if the valuation of consumers

[8] $\gamma = \left(a^{\lambda_v} \frac{\lambda_v \bar{v}^{\lambda_v}}{\lambda_q \bar{q}^{\lambda_q}} \left(\frac{\lambda_v+\eta}{\lambda_v+\lambda_q} \right)^{\lambda_v} \frac{\lambda_q-\eta}{\lambda_q+\lambda_v} \frac{L_F}{N_H} \right)^{1/(\lambda_v+\eta)}$ and $\gamma' = \left(\frac{\lambda_v+\eta}{\lambda_q-\eta} \right)^{(\lambda_v+\eta)/(\lambda_v+\lambda_q)}$.

is more heterogeneous (λ_v small), prices will be more responsive to changes in quality. This is entirely driven by the sensitivity of either supply or demand to changes in prices. If firms are very homogenous, that is, if most of the mass of firms is concentrated around the bottom of the distribution, higher qualities are very scarce. The price of those higher qualities will therefore be high. By the same token, if the distribution of consumers' valuations is very dispersed, there is a relatively large mass of consumers who have a high valuation for quality, and who are, therefore, willing to pay a high price for higher qualities. The price of higher quality goods will therefore be high.

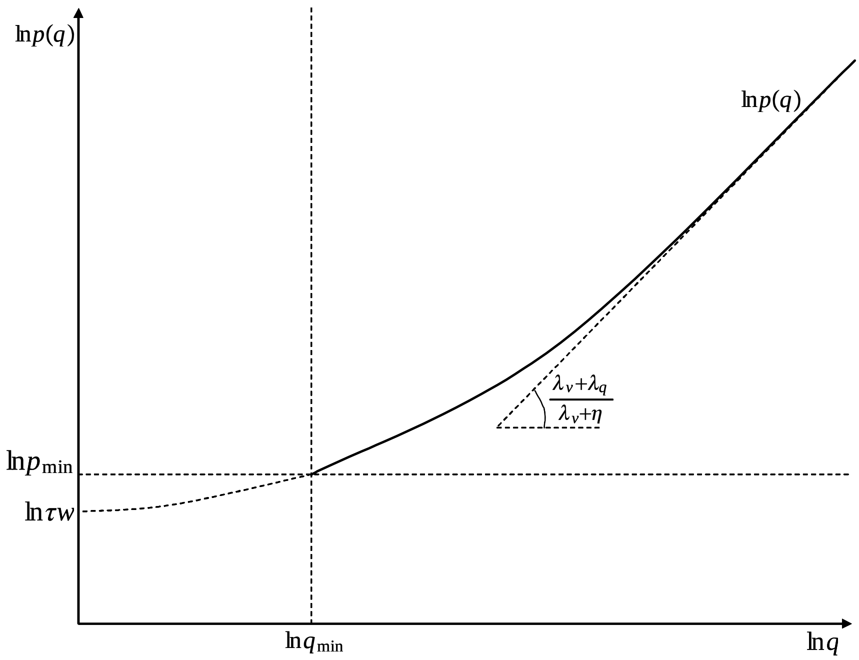

Figure 1: Equilibrium price-quality schedule.

The equilibrium price schedule is presented on Figure 1, which plots the log of quality versus the log of price. $\ln \tau w_H$ is the marginal cost of producing the first unit of output to be sold abroad. Because of the existence of a fixed entry cost, firms must sell more than one unit in order to generate enough profit to recover this entry cost. There is a minimum quality, $q_{\min}$, that commands a minimum price $p_{\min}$, and this minimum price is strictly above $\ln \tau w_H$. Below that price, no firm is willing to export. Consequently, any firm with a quality below $q_{\min}$ will not export its good abroad. The equilibrium price schedule starts at $p_{\min}$ and is then increasing and convex, and it converges asymptotically to a log-linear relationship.

Now that we have characterized the equilibrium price schedule, we can describe the impact of marginal cost shocks on prices.

4 Exchange rate pass-through

In this section, we describe the impact of exchange rate shocks on prices. We first define exchange rate shocks as shocks to real wages arising from productivity shocks. We then characterize the effect of those shocks on individual prices, on the composition of exporters, and on aggregate prices. Note that we call such shocks exchange rate shocks only for simplicity, and to be able to easily relate our theoretical model to the empirical evidence presented in the next section. In essence, those shocks could be any shock affecting the marginal cost of production faced by exporters.

Formally, we define a shock to the exchange rate of the home country as a shock to the domestic wage in terms of the international numeraire $\mathcal{A}$ good. When the domestic productivity in the $\mathcal{A}$ sector Z_H increases, as long as some labor is employed in each sector, the domestic wages will have to increase proportionally with productivity. For firms in the Q sector, this amounts to a negative productivity shock; in units of the numeraire, firms must pay their workers a higher wage. In this section, we will, therefore, define an appreciation of the domestic exchange rate as an increase in the real wage w_H.

What is the response of export prices to such an exchange rate shock? There are two margins that will adjust. First, firms face a higher marginal cost and, consequently, scale down their production and export smaller quantities abroad. This is the intensive margin of adjustment. Second, facing this higher cost, some low quality firms stop exporting altogether. This is the extensive margin of adjustment. Those two margins lead to an overall reduction of the total quantity of Q goods exported and a relative scarcity of home Q goods abroad. Low valuation consumers are pushed out of the market and stop buying Q goods altogether. Overall, goods are matched with higher valuation consumers, so that prices increase. This is the source of exchange rate pass-through into prices in our model. As fewer goods are exported, prices increase. Because supply responds to changes in marginal cost with some finite elasticity, the pass-through is incomplete.

The response of prices to an exchange rate shock is depicted on Figure 2, which plots the log of quality versus the log of price for two levels of the exchange rate. The exchange rate

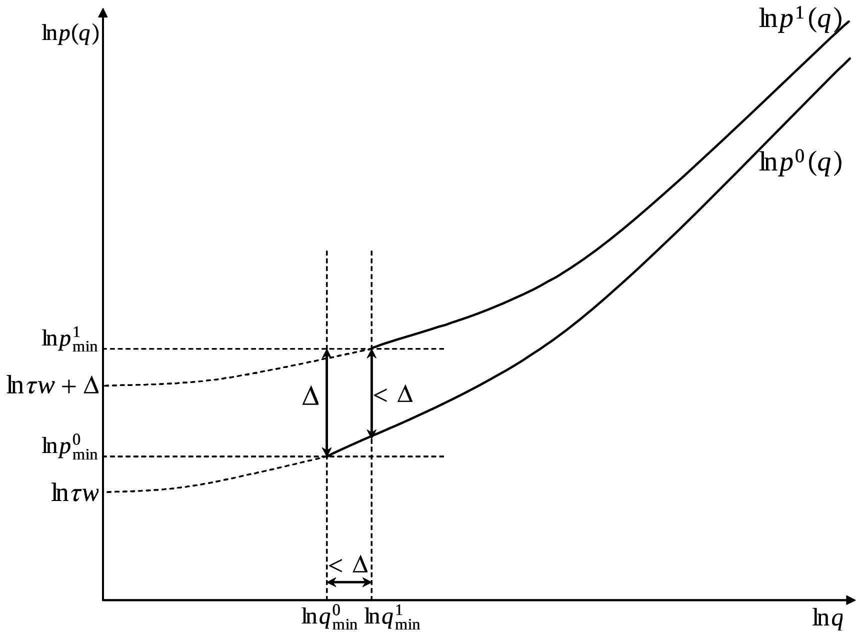

Figure 2: Exchange rate pass-through.

appreciates from τw at date $t = 0$, to $\tau w \times \Delta$ at date $t = 1$, with the constant $\Delta > 1$. Following an appreciation of the exchange rate, the price of the lowest quality exported, $p_{\min}$, increases proportionally with the exchange rate. However, the lowest quality firms pull out of the export market, so that the lowest quality exported, $q_{\min}$, increases. This exit of firms, as well as the reduction in the quantities exported by all firms, leads to an increase of the prices charged for exports. For every level of quality, the price increase is less than proportional to the exchange rate. Moreover, the relative price increase is lower for higher quality goods.

In the remainder of this section, we formally describe the response of individual prices to exchange rate shocks, the composition effect of exchange rate shocks, and the response of aggregate prices. We define the rate of exchange rate pass-through as the elasticity of the price of a good of quality q with respect to the exchange rate.

Definition 1 *Define $\sigma_{p(q)}$ as the elasticity of the price $p(q)$ of a quality q good with respect to the exchange rate,*

$$\sigma_{p(q)} \equiv \frac{\partial \ln p(q)}{\partial \ln \tau w_H}$$

Proposition 5 (exchange rate pass through) *There is incomplete pass-through of exchange rate shocks into the price of individual goods. The lower the quality of a good, the higher the pass-through.*

Proof. *See Unpublished Technical Appendix, page 34.* ■

When the exchange rate appreciates, firms scale down their production and some low quality exporters exit the export market altogether. There are two forces that drive all prices up. First, the lowest quality exported is now higher. The valuation of the consumer buying the lowest quality good increases. Since this consumer is willing to pay a higher price for the Q good she buys, the price of the low quality goods increase. Second, the overall supply of Q goods abroad shrinks, so that goods are now matched with higher valuation consumers. The price schedule steepens and all prices increase. Prices of goods at different level of quality are affected by these two forces in different ways. For very high quality goods, the exit of low quality firms and the effect this has on prices is negligible. Only the second force, the overall tightening of the market, matters. For low quality goods, on the other hand, both the change in the lowest quality exported and the overall tightening of the supply matter. In relative terms, low quality goods prices increase more than high quality goods prices. There is more pass-through for low quality goods.

In order to understand the composition effect due to the endogenous selection of firms into the export market, we have to characterize precisely the response of the extensive and intensive margins of trade to exchange rate fluctuations. How does the lowest exported quality $q_{\min}$ and its price change with the exchange rate?

Definition 2 *Define $\sigma_{q_{\min}}$ as the elasticity of the lowest quality exported ($q_{\min}$) with respect to the exchange rate, and $\sigma_{p_{\min}}$ as the elasticity of the lowest price ($p_{\min}$) with respect to the exchange rate*

$$\sigma_{p_{\min}} \equiv \frac{\partial \ln p_{\min}}{\partial \ln \tau w_H} \quad \textit{and} \quad \sigma_{q_{\min}} \equiv \frac{\partial \ln q_{\min}}{\partial \ln \tau w_H}$$

It is important to note that $\sigma_{p_{\min}}$ is not a pass-through elasticity of a good of fixed quality $q = q_{\min}$, but rather, the elasticity measuring how the lowest observed price moves with the exchange rate. The following proposition describes how both this lowest price and the lowest quality exported respond to exchange rate shocks.

Proposition 6 *The price of the lowest quality exported moves one for one with the exchange rate. The price of the lowest quality exported increases less than proportionally with the exchange rate.*

Proof. *From the definition of the equilibrium price schedule in proposition 4,*

$$q_{\min} = \gamma' \left(\tau w_H\right)^{\lambda_v/(\lambda_v+\lambda_q)} \quad \textit{and} \quad p_{\min} = \left(\tfrac{\lambda_q+\lambda_v}{\lambda_q-\eta}\right)\tau w_H$$

and differentiating with respect to τw_H *solves to equlibirum elasticities of*

$$\sigma_{q_{\min}} = \tfrac{\lambda_v}{\lambda_v+\lambda_q} < 1 \quad \textit{and} \quad \sigma_{p_{\min}} = 1$$

■

As the exchange rate appreciates, both the price of the lowest quality exported, $p_{\min}$, and the actual lowest quality exported, $q_{\min}$, increase. Mechanically, since the fixed entry cost is paid in foreign labor, $p_{\min}$ goes up one for one with the exchange rate. The lowest minimum price at which any firm is willing to export increases one for one with the exchange rate. However, because of the increase in the marginal cost of production, some firms exit the export market altogether, so that the lowest quality exported increases. Therefore, even for the lowest quality exporter, the price charged abroad increases less than one for one with the exchange rate. After an appreciation of the exchange rate, the new lowest quality exporter has a quality higher than that of the lowest quality exporter prior to the exchange rate shock. Since the price strictly increases with the quality, the new lowest quality good exported experiences an increase in its price that is less than proportional to the exchange rate shock. In addition, in response to an exchange rate appreciation, the share of high quality exports compared to low quality exports increases.

Despite the fact that all prices increase less than proportionally with the exchange rate, we prove that in the specific closed-form example considered here, aggregate prices increase exactly proportionally with the exchange rate. This is due to the composition effect of low quality exporters pulling out of the export market and because the ouput share of higher quality goods increases compared to the share of low quality goods. Since low quality exporters charge the lowest price, the reduction in the share of those goods drives up aggregate prices. Generically, the reshuffling of exports towards higher quality goods will induce a larger response to exchange rate shocks of aggregate prices than of individual prices. The following proposition states this result formally.

Proposition 7 (aggregate pass through) *Aggregate prices are proportional to the exchange rate, where aggregate prices are defined as a weighted average of individual prices, with consumer expenditure shares used as weights.*

Proof. *Formally, define the Consumer Price Index as the weighted average of individual prices, where the weights are the aggregate consumer expenditure shares,*

$$CPI = \frac{\int_{q_{\min}}^{\infty} f_q(q)\, S(q) \times p(q)\, dq}{\int_{q_{\min}}^{\infty} f_q(q)\, S(q)\, dq}$$

Some simple algebra, and using the of the expression for the price schedule and for the lowest quality exported from proposition 4 yields

$$CPI = \frac{(\lambda_q - \eta)(\lambda_v - 1)}{(\lambda_q - \eta)(\lambda_v - 1) - (\lambda_v - \eta)} \gamma \tau w_H$$

Thus, aggregate prices are exactly proportional to the exchange rate. ■

In this section, we have proved three main results. First, following a shock to the real exchange rate, there is only incomplete pass-through into prices for all goods. Second, the pass-through of exchange rate shocks is higher for lower quality goods. Third, the composition effect due to the exit of low quality exporters implies that, in response to an exchange rate appreciation, the composition of exports shifts towards high quality/high price goods. In the next section, we test those predictions using highly disaggregated US import data on prices and quantities.

5 Empirical evidence

In this section, we test the three predictions of our theoretical model using disaggregated US import data on prices and quantities. We find some evidence in support of our theoretical model. First, we confirm the widely documented fact that exchange rate shocks are only partially passed through into export prices, even at a high level of disaggregation. Second, we test whether high quality exports, as proxied by high unit value goods, experience less exchange rate pass-through, but find no statistical evidence for this. Third, we document that in response to an exchange rate appreciation, there is evidence of a composition effect in that the share of high price goods increases.

We use a panel of highly disaggregated annual price and quantity data for US imports from 1991 to 2001. Goods are disaggregated at the 10-digit Harmonized System, and in some instances grouped into 6, 7, or 8-digit sectors. We use nominal bilateral exchange rates with the US trading partners.[9]

Our approach to approximate quality with unit values is motivated by Schott (2004), Hummels and Klenow (2005), and Hallak (2006). Schott (2004) finds that exporter GDP per capita is positively correlated to the average unit value of 10-digit Harmonized System sold to the United States. This empirical finding is confirmed by Hummels and Klenow (2005), who document the strong empirical correlation between exporter GDP per capita and export unit value. Hallak (2006), in turn, finds that the demand for quality is related to importer GDP per capita. These authors conclude that variation in quality is an important determinant of trade flows.

Hallak and Schott (2008) emphasize that unit prices may differ for reasons other than quality. They, therefore, develop a new method to disentangle price and quality variation in unit value data. Among their findings is a confirmation that the level of quality is correlated with the level of development, but the relationship is weaker than suggested by earlier research.

To test the predictions of the theoretical model, we measure the response of US prices of goods imported from a given country to a shock of the bilateral nominal exchange rate of the US vis à vis this country. We control for local demand shocks in the US by including the current US GDP as a control. We also control for the marginal cost of production in the exporting country as well as for the overall level of inflation in the exporting country. We are interested in both the response of individual good prices to exchange rate shocks and the response of aggregate prices to the same shocks.

5.1 Exchange rate pass-through

In this section, we run exchange rate pass-through regressions for individual goods. We find that for most goods, exchange rate shocks are only partially passed through into export prices. There is, however, a large degree of heterogeneity in the response of the export price of an individual good to exchange rate shocks.

We define a good (denoted ω) as a 10-digit Harmonized System category. This is the highest

[9] The data used in this section comes from the following sources. US import data is from the Center for International Data at UC Davis. Unit value is calculated as the total value of exports, including freight and insurance cost, excluding duty, and divided by quantity. Exchange rates are from the International Financial Statistics of the IMF. Real unit labor costs, consumer price index, and US GDP growth are from the OECD. All variables are winsorized and changes are expressed as the year-to-year differences of the logarithm of a variable. We provide a more detailed discussion of the data in an unpublished appendix, which is available on the website of this journal.

level of disaggregation available for most goods imported by the US. Each good ω belongs to a sector Ω, where we use different levels of disaggregation for those Ω sectors: 6, 7, or 8-digit Harmonized System categories. As will become clear in the results below, there is a trade-off between using a coarse definition of sectors, so that there are many observations per sector, but goods within a sector are only weakly comparable, or using a finer definition of sectors, so that goods are closer substitutes, but the number of observations per sector is smaller.

Following Campa and Goldberg (2005), we adopt the following specification for estimating the degree of exchange rate pass-through for each HS-10 good ω.

$$\Delta \ln P_t^c(\omega) = \alpha(\Omega) + \beta(\Omega)\Delta \ln RGDP_t^{US} + \delta(\Omega)\Delta \ln W_t^c + \gamma(\Omega)\Delta \ln CPI_t^c + \lambda(\Omega)\Delta \ln E_t^c + \varepsilon_t^c(\omega) \tag{12}$$

where the price $P_t^c(\omega)$ is the unit value of good ω imported form country c at time t, expressed in US dollars. $RGDP_t^{US}$ is the real US GDP, W_t^c is a measure of labor cost in country c, CPI_t^c is the consumption price index in country c, and E_t^c is the bilateral exchange rate between country c and the US, expressed as the price in US dollars of the foreign currency (so that an increase in E corresponds to an appreciation of the foreign currency).

Table 1: Exchange rate pass-through.

	DLog Unit Value			
	(1)	(2)	(3)	(4)
DLog Exch. Rate	.26***	.36***	.35***	.35***
	(25.03)	(28.84)	(27.09)	(26.88)
DLog CPI		.21***	.20***	.17***
		(4.35)	(4.18)	(3.42)
DLog Labor Cost			.04	.00
			(1.37)	(.02)
DLog GDP				-.01***
				(5.39)
Constant	.01***	.00*	.00*	.02***
	(6.67)	(1.85)	(1.88)	(5.66)
Observations	814,460	776,172	738,432	738,432

Notes: This table explains the change in individual prices in response to exchange rate shocks. The dependent variable is the log difference in unit values. The explanatory variables are: the log change in the bilateral exchange rate, the log change in the CPI of the exporting country, the log change in the US GDP, the log change in the exporting country's labor cost. *, **, and *** means statistically different from zero at 10, 5 and 1% level of significance. (absolute values of T-stats in parenthesis).

We first run this regression for all goods together (estimating a single λ). As documented

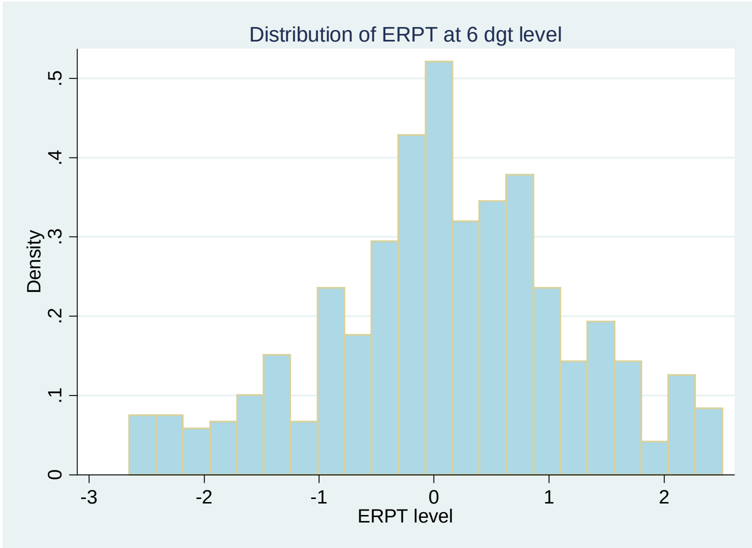

Figure 3: Distribution of exchange rate pass-through across 6-digit sectors (the exchange rate pass-through is estimated from Eq. (12); it measures the percentage change of export prices to a 1% appreciation of the exporting country's currency vis à vis the USD; the top and bottom 5% observations have been trimmed).

in the literature, there is strong evidence of incomplete pass-through of exchange rate shocks into import prices. This result holds even when using the finest level of disaggregation of prices available for all US exports. Table 1 shows the results of this regression. Depending on the set of controls included, pass-through ranges between 26% and 36%.

We then run this regression separately and estimate the parameter $\lambda(\Omega)$ for each individual 6-digit sector Ω. This parameter is a simple measure of the elasticity of individual prices to exchange rate shocks within sector Ω. The most salient feature of the data is the very large degree of heterogeneity in the degree of exchange rate pass-through across different goods.

Figure 3 describes the distribution of exchange rate pass-through across 6-digit sectors. For the bulk of the sectors, the degree of exchange rate pass-through is between 0 (no sensitivity of export prices to exchange rate movements) and 100% (full pass-through, export prices move one for one with the exchange rate). However, at such a high level of disaggregation, exchange rate pass-through can be above 100%, or even negative in several sectors. As we refine the level of disaggregation of individual sectors to 7 or 8-digit sectors, the dispersion of exchange rate pass-through increases even further. We observe that there is a very wide dispersion in pass-through rates, but to what extent is this related to good quality?

5.2 Pass-through and quality

We next compare pass-through rates across different levels of good quality, proxied by average unit values. In order to ensure that we are indeed measuring quality differences rather than differences in the market structure in different sectors, we only compare pass-through rates for the 10-digit goods *within* each 6-digit sector. We argue that the resulting differences in average unit value can be interpreted as differences in quality.

For example, at the 6-digit level, there are 6 different sectors for plywood (bamboo, outer ply >6mm of tropical woods, outer ply >6mm of non-coniferous wood, outer ply <6mm of tropical hardwood, outer ply <6mm of non-coniferous wood, and softwood).[10] At the 10-digit good level, there are, for example, 15 different goods within the 6-digit sector "softwood." These 15 10-digit goods differ only in small aspects such as the gluing of the ply or whether the ply is made up of several or only one layer(s). We believe that it is reasonable to assume that these specific differences in product attributes within a narrowly defined sector capture mostly differences in good quality rather than differences in the market structure.

In order to ensure comparability of the results *across* 6-digit sectors, we also normalize unit values in terms of standard deviations from the mean within each sector Ω. This normalization is in order, as sectors might differ in the degree of heterogeneity in unit values irrespective of the degree of heterogeneity in quality.

To investigate whether pass-through differs across good quality, we then run a regression for each 6-digit sector Ω of the following form

$$\begin{aligned} \Delta \ln \left(P_t^c(\omega)\right) &= \alpha(\Omega) + \lambda(\Omega)\,\Delta \ln E_t^c + \mu(\Omega)\,\Delta \ln E_t^c \times Q_t^c(\omega) + \nu(\Omega)\,Q_t^c(\omega) \\ &\quad + \beta(\Omega)\,\Delta \ln RGDP_t^{US} + \delta(\Omega)\,\Delta \ln W_t^c + \gamma(\Omega)\,\Delta \ln CPI_t^c + \varepsilon_t^c(\omega) \end{aligned} \tag{13}$$

where $Q_t^c(\omega) = \frac{P_{t-1}^c(\omega) - E_{t-1}[P_t^c(\omega')|\omega' \in \Omega]}{\sigma_{t-1}[P_t^c(\omega')|\omega' \in \Omega]}$ is the normalized unit value (expressed in terms of standard deviations from the mean within sector Ω). The coefficient of interest is $\mu(\Omega)$, the interaction coefficient of quality and the exchange rate. If $\mu(\Omega)$ is negative, this implies that in 6-digit sector Ω, higher quality goods are characterized by a lower degree of pass-through. Table 2 below presents the summary statistics for the coefficients $\lambda(\Omega)$ and $\mu(\Omega)$ across all 6-digit sectors Ω.

In Table 2, the median rate of pass-through is equal to 34.9%. The median interaction of quality and exchange rate changes is estimated at -1.33%. Since quality is standardized, this implies that a good with quality that is 2 standard deviation above the 6-digit sector's median

[10] The 6-digit HS sectors are 441210, 441211, 441212, 441213, 441214, and 441219 respectively.

Table 2: Exchange rate pass-through and quality.

% of Cases w. p-Value:	Median	Negative Coefficient $> 5\%$	Negative Coefficient $< 5\%$ $> 1\%$	Negative Coefficient $< 1\%$	Positive Coefficient $> 5\%$	Positive Coefficient $< 5\%$ $> 1\%$	Positive Coefficient $< 1\%$
Coeff. on Dlog Exch.	.349	10.4%	.6%	.0%	41.4%	14.9%	32.8%
		Total Negative: 10.9%			Total Positive: 89.1%		
Coeff. on Dlog Exch. ×Quality	-.0133	36.8%	6.9%	7.5%	36.8%	4.6%	7.5%
		Total Negative: 51.1%			Total Positive: 48.9%		

Notes: Table 2 presents summary statistics of quality dependent pass-through rates. For Each 6-Digit sector, we estimate Equation (13). Table 2 reports the distribution of p-Values for the coefficients on exchange rate changes ($\lambda(\Omega)$) and for the interaction of exchange rate changes and quality ($\mu(\Omega)$). It lists the frequency with which the p-Value lies above %5, between 5% and 1%, and below 1%. This is done first for the case with negative estimated coefficient, and then for cases with positive estimated coefficient.

has a pass-through rate of 32.2% ($= 34.9\% + 2 * -1.33\%$). This compares to a pass-through rate of 37.3% for a good with quality 2 standard deviations below the sector's median. Thus, economically, these regressions suggests that quality can explain a moderate amount of variation in pass-through rates.

These results are, however, not statistically significant. For example, we list summary statistics for the single coefficients. In total, the interaction coefficient is estimated to be negative in 51.1% sectors and positive in the rest of the sectors. Moreover, when we look at the number of cases in which the interaction coefficient is estimated significantly, the pattern seems to be rather random. For example, while this coefficient is estimated to be negative and significant at the 1% level in 7.5% of the sectors, it is also estimated positive and significant at the 1% level in 7.5% of the sectors. A joint test whether on average, the interaction coefficient is negative *cannot* be reject even at the 10% level.

The variation of pass-through rates across sectors is very large (see Figure 3) and we, therefore, do not find statistical evidence that exchange rate pass-through can be explained by differences in quality, as proxied by unit values.

5.3 Measuring composition effects

In this section, we test our third prediction that exchange rate fluctuations induce a change in the composition of exports. We find evidence that, in response to an appreciation of the exchange rate of the exporter's currency, the composition of goods shifts towards higher quality goods. Since high quality goods are expensive, this leads mechanically to an increase in aggregate prices that is not due to individual firms adjusting their export prices. We argue that conventional measures of exchange rate pass-through that use aggregate prices may overestimate the degree of exchange rate pass-through by up to 10 percentage points.

To test our prediction, we build an index of the average quality of a country's exports to the US. We then measure how the average quality of exports changes in response to exchange rate shocks.

The following describes our procedure. For a given sector Ω (defined at a 6, 7, or 8-digit sector), we define the change in the average quality of exports from country c between time $t-1$ and t as

$$\Delta Quality_t^c(\Omega) = \sum_{\omega \in \Omega_t^c \cap \Omega_{t-1}^c} \left(s_t^c(\omega) - s_{t-1}^c(\omega)\right) \times \ln P_{t-1}^c(\omega) \tag{14}$$

The quality of a good ω in sector Ω is proxied by the unit value of that good in period $t-1$. Note that we are only comparing goods within a relatively narrow sector (6, 7, or 8-digit sectors), so that unit values are a relevant proxy for quality. We only look at the subset of goods that are exported both in period $t-1$ and in period t so that the trade shares $s_t^c(\omega)$'s and $s_{t+1}^c(\omega)$'s both add up to one without the need for any arbitrary normalization. Prices are denominated in US dollars. If this index for the change in the quality of exports from country c towards the US is positive ($\Delta Quality_t^c(\Omega) > 0$), it means that the average quality of goods in sector Ω exported by country c towards the US has increased.

We then test whether exchange rate shocks have any systematic impact on the average quality of exports. We run the following regression separately for each sector Ω.

$$\begin{aligned} \Delta Quality_t^c(\Omega) &= \alpha(\Omega) + \beta(\Omega)\Delta \ln RGDP_t^{US} + \delta(\Omega)\Delta \ln W_t^c \\ &\quad + \gamma(\Omega)\Delta \ln CPI_t^c + \lambda(\Omega)\Delta \ln E_t^c + \varepsilon_t^c(\Omega) \end{aligned} \tag{15}$$

We are interested in the coefficient $\lambda(\Omega)$. Our theoretical model predicts that an appreciation of the exporting country's currency should lead to an increase in the average quality of exports ($\lambda(\Omega) > 0$). If such a composition effect exists, estimates of exchange rate pass-through at the aggregate level will tend to be overestimated.

Table 3 presents the regression results for 6, 7, and 8-digit sectors. We are confronted with a salient feature of the data; at such a fine level of disaggregation, many countries do not export goods in all sectors towards the US. We are therefore faced with very small samples. To get around

Table 3: Measuring quality composition effects.

	ΔQuality		
	(at least 50 obs.)	(at least 100 obs.)	(at least 150 obs.)
ΔLog Exch. Rate			
6-digit	-.0021	-.011	.041
7-digit	.00080	0036	.081
8-digit	-.016	0.041	.097

Notes: This table explains the change in the quality composition of exports in response to exchange rate shocks. The dependent variable is the change in the (log) quality of exports, defined in Eq. (14) as the weighted average of export unit values within a narrow sector. The explanatory variables are: the log change in the bilateral exchange rate, the log change in the CPI of the exporting country, the log change in the US GDP, the log change in the exporting country's labor cost. We present only the average coefficient on the log change in the bilateral exchange rate: $\lambda(\Omega)$ in Eq. (15).

this problem, we consider only regressions with a minimum number of observations. We consider different thresholds for the minimum number of observations: 50, 100, and 150. When we include regressions with relatively few observations (less than 100), we do not find a systematic pattern in the data, and depending on the degree of aggregation, we find that the quality composition effect in response to exchange rate shocks could go either way. However, as we impose a more stringent constraint on the number of observations (at least 100 observations), except at the lowest level of aggregation (6-digit), we find that an appreciation of the exporting country's exchange rate leads to a shift towards higher quality goods. Finally, when restricting the sample to sectors with at least 150 country-good observations, we find that the increase in aggregate prices that is due to such a shift towards higher quality ranges between 4.1% and 9.7%. This mechanically leads to an increase in aggregate export prices, even if no individual price actually changes.[11]

6 Conclusion

We develop a perfectly competitive economy featuring heterogeneity in both good qualities and consumer valuations for quality. In equilibrium, high valuation customers and high quality firms are matched and the relative scarcity of goods of different qualities leads to pricing-to-market, with prices determined by the local tightness of competition.

[11] Since we proxy quality by the period $t-1$ price, by construction, individual prices are fixed and we only allow the composition of exports to change.

The paper's contribution is to explain why pass-through can be incomplete and heterogeneous across different firms within a competitive industry. The crucial ingredient of our model is to introduce heterogeneous consumers who all value quality, but who do so at different rates. In the absence of this heterogeneity in valuations, relative prices are fixed by the representative consumer's valuation for quality, leading in equilibrium to equal pass-through rates across all goods in the economy. In the framework of this paper, different consumers value quality differently, and the equilibrium matching determines the prices in the economy. Relative prices in our setup are determined by differences in quality and by the valuations with which the respective qualities are matched. Because the equilibrium matching of qualities and valuations responds to cost changes, pass-through rates differ across different firms.

Firms accommodate changes in the relative cost brought about by a change in the exchange rate by adjusting the quantity of their exports. Since the quantities supplied decrease when the home currency appreciates, export markets get relatively less crowded, and thus prices measured in foreign currency increase, leading to partial exchange rate pass-through.

Moreover, the range of firms that are actively exporting changes. In the presence of fixed costs of market access, some low quality firms no longer export. While the change in the intensive margin (volume of exports per firm) affects all firms equally, this change in the extensive margin affects low quality firms relatively more. A further consequence of the change in the set of exporters is that the average composition of firms changes.

We test these predictions using highly disaggregated price and quantity US import data. We find evidence that in response to an exchange rate appreciation, the composition of exports shifts towards high unit price goods. Therefore, exchange rate pass-through rates that are measured using aggregate data will tend to overstate the actual extent of pass-through.

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7 Appendix Not For Publication

7.1 Technical Appendix: proofs

7.1.1 Proof of proposition 3

Proposition 3 (reminded) *There exists a* $(p(\cdot),\ v(\cdot),\ p_{\min},\ q_{\min})$ *solution to Equations (5), (6), (7) and (8), not necessarily unique.*

Let us assume for simplicity that the cost function is quadratic, so that $c^{-1}(p) = p$, and that $\tau w_H = 1$. As pointed out by Rochet and Stole (2002, p. 282, footnote 10),[12] this is not a restrictive assumption. As they argue, the cost function could be any strictly convex function: "since the measurement of units of consumers' [valuations] and product qualities are not intrinsic, they can be redefined in such a way that costs are quadratic [...]".

Before turning to the proof of proposition 3, it will be useful to first prove the following lemma.

Lemma 1 *There exists a unique* α *solution to*

$$\begin{cases} \alpha = \frac{p_{\min}}{F_v^{-1}\left[\frac{N}{L}p_{\min}F_q(\beta(\delta(\alpha)))\right]} \\ \beta(\delta) = \frac{p_{\min}}{F_v^{-1}\left[\frac{N}{L}\delta\right]} \\ \delta(\alpha) = \int_{\alpha}^{q_{\max}} F_v^{-1}\left[\frac{N}{L}\int_{\chi}^{q_{\max}} p_{\min} f_q(q)\, dq\right] d\chi + p_{\min} \end{cases}$$

Proof. In the third equation, the function δ is continuously decreasing in α. Since F_v^{-1} is a decreasing function, in the second equation, the denominator is decreasing in α, so that the function β is increasing in $\delta(\alpha)$. In the first equation, the counter-cumulative function F_q is decreasing, while F_v^{-1} is decreasing, so that the denominator is increasing in β. $\beta(\alpha)$ is increasing in α. Consequently, in the first equation, the denominator is increasing in α. Therefore the right-hand side of the first equation continuously decreases in α, crossing the 45° line only once. ■

We can now turn to the proof of the existence of an equilibrium.

Proof. It is straightforward to prove that the zero cutoff profit condition (5) determines a unique price $p_{\min}$. Equation (6) mechanically defines the matching function $v(\cdot)$. We now prove that there exists a solution $(p(\cdot),\ q_{\min})$ to Equations (7) and (8).

Let E be the set of continuous functions from any interval $I \subset [\alpha, \beta]$ to $[\gamma, \delta]$ normed by $\|(p, q_{\min})\| = \sqrt{\sup_q |p(q)|^2 + |q_{\min}|^2}$. α, β, γ and δ are positive real numbers (defined below). Let

[12] see ROCHET, Jean-Charles and Lars STOLE (2002), "Nonlinear Pricing with Random Participation", *The Review of Economic Studies*, Vol. 69, No. 1, pp. 277-311.

Γ be a mapping from $S = E \times [\alpha, \beta]$ into itself (proven below), such that $\Gamma(p_1, q_1) = (p_2, q_2)$ is defined as follows:

$$\begin{cases} p_2(q) = \int_{q_1}^{q} \bar{F}_v^{-1} \left[\frac{N}{L} \int_{\xi}^{q_{\max}} p_1(\chi) f_q(\chi) d\chi \right] d\xi + p_{\min}, \ \forall Q \in [q_1, q_{\max}] \\ q_2 = \frac{p_{\min}}{F_v^{-1}\left[\frac{N}{L} \int_{q_1}^{q_{\max}} p_1(q) f_q(q) dq \right]} \end{cases}$$

α is defined in Lemma 1. δ is defined by $\delta(\alpha)$ as in Lemma 1. $\gamma = p_{\min}$ and β is defined by $\beta(\delta)$ as in Lemma 1.

- S is a Banach space: the set of continuous functions over a closed interval of the real line, normed by the sup norm, is a Banach space; the Cartesian product of this space and a closed interval with the Euclidean norm is a Banach space, too. Since Cauchy sequences converge in both E with the sup norm, and in $[\alpha, \beta]$ with the absolute value norm, then Cauchy sequences converge in S with the conjugated norm.

- Γ maps S into itself, or, if $(p_1, q_1) \in S$, then $\Gamma(p_1, q_1) = (p_2, q_2) \in S$:

  - if $p_1 \in E$, then by construction, $\bar{F}_v^{-1}$ and f_q being continuous, p_2 is continuous.
  - F_v^{-1} takes only positive values, so for $q \in [q_1, q_{\max}]$, $p_2(q) \geq p_{\min} = \gamma$.
  - F_v^{-1} takes only positive values, so for $q \in [q_1, q_{\max}]$, $p_1(q) \geq p_{\min}$. F_v^{-1} is decreasing and takes only non-negative values so that $p_2(q) \leq \int_{\alpha}^{q_{\max}} \bar{F}_v^{-1} \left[\frac{N}{L} \int_{\xi}^{q_{\max}} p_{\min} f_q(\chi) d\chi \right] d\xi + p_{\min} = \delta$.
  - for any $q \in [q_1, q_{\max}]$, $p_1(q) \geq p_{\min}$. Therefore, for $q_1 \in [\alpha, \beta]$, $\int_{q_1}^{q_{\max}} p_1(\chi) f_q(\chi) d\chi \geq p_{\min} F_q(\beta)$. F_v^{-1} is decreasing, so that $q_2 \geq \alpha$.
  - for any $q \in [q_1, q_{\max}]$, $p_1(q) \leq \delta$. Moreover, f_q is a well-defined density function, so that $\int_{q_1}^{q_{\max}} p_1(\chi) f_q(\chi) d\chi \leq \frac{N}{L}\delta$. F_v^{-1} is decreasing so that $q_2 \leq \beta$.
  - We have therefore proven that if $(p_1, q_1) \in S$, then $\Gamma(p_1, q_1) = (p_2, q_2) \in S$: $p_2 \in E$ (it is a continuous function that is from an interval included in $[\alpha, \beta]$ into $[\gamma, \delta]$), and $q_2 \in [\gamma, \delta]$.

- Γ is continuous, or $\forall\, \varepsilon > 0, \ \exists\, \delta > 0$ subject to if $\|(p_1, q_1) - (p_1', q_1')\| \leq \delta$, then $\|\Gamma(p_1, q_1) - \Gamma(p_1', q_1')\| \leq \varepsilon$, for any (p_1, q_1) and (p_1', q_1') in S.

- Applying the Schauder fixed point theorem, there exists a fixed point (not necessarily unique) $(p, q_{\min})$ such that $(p, q_{\min}) = \Gamma(p, q_{\min})$

■

7.1.2 Proof of proposition 4

Proposition 4 (reminded) *If the entry cost is such that* $f^E = \left(\frac{\lambda_q-\eta}{(1+\eta)(\lambda_q+\lambda_v)}\right)^{1+\eta}$*, then there exists a unique equilibrium price schedule, lowest quality exported, and lowest price, defined as*

$$\begin{cases} p\left(q\right) = \gamma\left(\tau w_H\right)^{\eta/(\lambda_v+\eta)} q^{(\lambda_v+\lambda_q)/(\lambda_v+\eta)} + \tau w_H \\ q_{\min} = \gamma'\left(\tau w_H\right)^{\lambda_v/(\lambda_v+\lambda_q)} \\ p_{\min} = \left(\frac{\lambda_q+\lambda_v}{\lambda_q-\eta}\right)\tau w_H \end{cases}$$

where γ *and* γ' *are constants.*[13]

Proof. An equilibrium is defined by the following 4 equations:

$$\begin{cases} v\left(q\right) = \bar{F}_v^{-1}\left(\frac{N_H}{L_F}\int_q^\infty c^{-1}\left(\frac{p(x)}{\tau w_H}\right) f_q\left(x\right)dx\right) \\ p\left(q\right) = \int_{q_{\min}}^q v\left(\chi\right)d\chi + p_{\min} \\ p_{\min} = v\left(q_{\min}\right)q_{\min} \\ \tau w_H f^E = p_{\min} S\left(p_{\min}\right) - \int_0^{S(p_{\min})} \tau w_H c\left(s\right)ds \end{cases}$$

where $\bar{F}_v$ is the "counter cumulative distribution" of the valuations v. In our closed-form example, we have the following functional forms,

$$\begin{cases} \bar{F}_v^{-1}\left(m\right) = \bar{v}m^{-1/\lambda_v} \\ f_q\left(q\right) = \lambda_q\left(\frac{q}{\bar{q}}\right)^{-\lambda_q} q^{-1} \\ c^{-1}\left(\frac{p}{\tau w_H}\right) = \left(\frac{p}{\tau w_H} - 1\right)^\eta \end{cases}$$

We guess that the equilibrium price schedule is of the following form

$$p\left(q\right) = \alpha\tau w_H q^\beta + \tau w_H$$

with α and β being some positive constant to be determined. We have 5 equations and 6 unknowns $\left(v\left(\cdot\right),\ p\left(\cdot\right),\ p_{\min},\ q_{\min},\ \alpha,\ \beta\right)$. The condition guaranteeing a unique equilibrium is the size of the fixed entry cost f^E.

Plugging the equilibrium conditions into our guess for the price schedule, the following simple

[13] $\gamma = \left(a^{\lambda_v}\frac{\lambda_v\bar{v}^{\lambda_v}}{\lambda_q\bar{q}^{\lambda_q}}\left(\frac{\lambda_v+\eta}{\lambda_v+\lambda_q}\right)^{\lambda_v}\frac{\lambda_q-\eta}{\lambda_q+\lambda_v}\frac{L_F}{N_H}\right)^{1/(\lambda_v+\eta)}$ and $\gamma' = \left(\frac{\lambda_v+\eta}{\lambda_q-\eta}\right)^{(\lambda_v+\eta)/\left(\lambda_v+\lambda_q\right)}$.

algebra yields

$$
\begin{aligned}
p(q) &= \int_{q_{\min}}^{q} v(\chi)\, d\chi + p_{\min} \\
&= \int_{q_{\min}}^{q} \bar{F}_v^{-1}\left(\frac{N_H}{L_F}\int_{\chi}^{\infty} c^{-1}\left(\frac{p(x)}{w_H\tau}\right) f_q(x)\, dx\right) d\chi + p_{\min} \\
&= \int_{q_{\min}}^{q} \bar{F}_v^{-1}\left(\frac{N_H}{L_F}\int_{\chi}^{\infty} \left(\frac{p(x)}{\tau w_H} - 1\right)^{\eta} f_q(x)\, dx\right) d\chi + p_{\min} \\
&= \int_{q_{\min}}^{q} \bar{F}_v^{-1}\left(\frac{N_H}{L_F}\int_{\chi}^{\infty} \alpha^{\eta} x^{\beta\eta}\lambda_q \left(\frac{x}{\bar{q}}\right)^{-\lambda_q} x^{-1} dx\right) d\chi + p_{\min} \\
&= \int_{q_{\min}}^{q} \bar{F}_v^{-1}\left(\frac{N_H}{L_F}\frac{\alpha^{\eta}\lambda_q}{\lambda_q - \eta\beta}\chi^{\eta\beta-\lambda_q}\right) d\chi + p_{\min} \\
&= \frac{\bar{v}}{\bar{q}^{\lambda_q/\lambda_v}}\left(\frac{N_H}{L_F}\frac{\alpha^{\eta}\lambda_q}{\lambda_q - \eta\beta}\right)^{-1/\lambda_v} \int_{q_{\min}}^{q} \chi^{(\lambda_q-\eta\beta)/\lambda_v} d\chi + p_{\min} \\
&= \frac{\bar{v}}{\bar{q}^{\lambda_q/\lambda_v}}\left(\frac{N_H}{L_F}\frac{\alpha^{\eta}\lambda_q}{\lambda_q - \eta\beta}\right)^{-1/\lambda_v} \frac{\lambda_v}{\lambda_v + \lambda_q - \eta\beta}\left(q^{(\lambda_q+\lambda_v-\eta\beta)/\lambda_v} - q_{\min}^{(\lambda_q+\lambda_v-\eta\beta)/\lambda_v}\right) + p_{\min}
\end{aligned}
$$

For our guess to be correct for any quality, it must be the case that

$$
\begin{aligned}
\beta &= \frac{\lambda_v + \lambda_q}{\lambda_v + \eta} \\
\tau w_H \alpha &= \left(\frac{\lambda_v \bar{v}^{\lambda_v}}{\lambda_q \bar{q}^{\lambda_q}}\left(\frac{\lambda_v + \eta}{\lambda_v + \lambda_q}\right)^{\lambda_v} \frac{\lambda_q - \eta}{\lambda_q + \lambda_v}\frac{L}{N}\right)^{1/(\lambda_v+\eta)} \times (\tau w_H)^{\eta/(\lambda_v+\eta)}
\end{aligned}
$$

This gives us the following expression for the equilibrium price schedule:

$$
\begin{aligned}
p(q) &= \gamma (\tau w_H)^{\eta/(\lambda_v+\eta)} q^{(\lambda_v+\lambda_q)/(\lambda_v+\eta)} + \tau w_H \\
\text{with } \gamma &= \left(\frac{\lambda_v \bar{v}^{\lambda_v}}{\lambda_q \bar{q}^{\lambda_q}}\left(\frac{\lambda_v + \eta}{\lambda_v + \lambda_q}\right)^{\lambda_v} \frac{\lambda_q - \eta}{\lambda_q + \lambda_v}\frac{L_F}{N_H}\right)^{1/(\lambda_v+\eta)}
\end{aligned}
$$

Note that $\frac{\lambda_v+\lambda_q}{\lambda_v+\eta} > 1$ iif $\lambda_q > \eta$. We need the assumption that $\lambda_q > \eta$, otherwise, there are too many large firms (λ_q small), or large firms are too big (η large), and the integrals would not converge.

If this equilibrium price schedule holds for every quality, it holds for the lowest quality $q_{\min}$ so that

$$
p_{\min} = \gamma (\tau w_H)^{\eta/(\lambda_v+\eta)} q_{\min}^{(\lambda_v+\lambda_q)/(\lambda_v+)} + \tau w_H
$$

This, together with the equation defining the lowest valuation $q_{\min}$, yields a solution for the lowest price and for the lowest valuation

$$\begin{cases} p_{\min} = \left(\frac{\lambda_q+\lambda_v}{\lambda_q-\eta}\right)\tau w_H \\ q_{\min} = \gamma' \left(\tau w_H\right)^{\lambda_v/(\lambda_v+\lambda_q)} \\ \text{with } \gamma' = \left(\frac{\lambda_v+\eta}{\lambda_q-\eta}\right)^{(\lambda_v+\eta)/(\lambda_v+\lambda_q)} \end{cases}$$

However, $p_{\min}$ is independently defined by the zero profit cutoff condition

$$\begin{aligned} \tau w_H f^E &= p_{\min} S\left(p_{\min}\right) - \int_0^{S(p_{\min})} \tau w_H c\left(s\right) ds \\ p_{\min} &= \left(1 + \left(\left(1+\eta\right) f^E\right)^{1/(1+\eta)}\right)\tau w_H \end{aligned}$$

For our guess to be correct, we need that

$$f^E = \left(\frac{\lambda_q - \eta}{\left(1+\eta\right)\left(\lambda_q+\lambda_v\right)}\right)^{1+\eta}$$

■

7.1.3 Proof of proposition 5 (exchange rate pass-through)

Proposition 5 (reminded) *There is incomplete pass-through of exchange rate shocks into the price of individual goods. The lower the quality of a good, the higher the pass-through.*

Proof. Recall the definition of $\sigma_{p(q)}$, the elasticity of the price $p\left(q\right)$ of a quality q good with respect to the exchange rate,

$$\sigma_{p(q)} \equiv \frac{\partial \ln p\left(q\right)}{\partial \ln \tau w_H}$$

From the definition of the equilibrium price schedule in proposition 4,

$$p\left(q\right) = \gamma\left(\tau w_H\right)^{\eta/(\lambda_v+\eta)} q^{(\lambda_v+\lambda_q)/(\lambda_v+\eta)} + \tau w_H$$

Differentiating with respect to τw_H solves to

$$\begin{aligned} \sigma_{p(q)} &= \frac{\partial \ln p\left(q\right)}{\partial \ln \tau w_H} \\ &= 1 - \frac{\lambda_v}{\lambda_v - \eta} \times \frac{1}{1 + \gamma^{-1}\left(\tau w_H\right)^{\lambda_v/(\lambda_v+\eta)} q^{-(\lambda_v+\lambda_q)/(\lambda_v+\eta)}} \end{aligned}$$

From this expression, it is straightforward to prove that

$$\begin{aligned} \frac{\partial \sigma_{p(q)}}{\partial q} &< 0 \\ \lim_{q\to+\infty} \sigma_{p(q)} &= \frac{\eta}{\lambda_v+\eta} \\ \lim_{q\to 0} \sigma_{p(q)} &= 1 \end{aligned}$$

Since the lowest quality is strictly above 0, we know that for any $q \geq q_{\min}$, we have,

$$\frac{\eta}{\lambda_v + \eta} < \sigma_{p(q)} < 1$$

There is incomplete pass-through of exchange rate shocks into the prices of individual goods (the elasticity $\sigma_{p(q)}$ is smaller than 1 for all goods), and the lower the quality of a good, the higher the pass-through (the elasticity $\sigma_{p(q)}$ is increasing with the quality q). ■

7.2 Data Description Appendix

US imports - C.I.D. at UC Davis:

Unit value is calculated as the total value of export, including freight and insurance cost, excluding duty, divided by quantity. Observations are expressed in log change, year over year. All variables are winsorized.

Exchange rates - IMF, International Financial Statistics:

Average nominal exchange rates, USD per foreign currency. For countries adopting the Euro, all exchange rates are expressed in USD per 1 Euros also for years before the fixed parity was established, to insure comparability over time. The conversion has been made at the parity established in 1999 or 2001 (for Greece) (See http://www.ecb.int/bc/intro/html/index.en.html#fix). Data come from International Financial Statistics, IMF). Observations are expressed in log change, year over year. All variable are winsorized.

Real Unit Labor costs – OECD:

This reports the annual labor income share calculated for this database as total labor costs divided by the nominal output. The OECD documentation states that: "The term labour income share [. . .] relates to compensation of employees adjusted for the self employed and thus essentially relates to labour income. The division of total labour costs by nominal output is sometimes also referred to as a real unit labour cost - as it is equivalent to a deflated unit labour cost where the deflator used is the GDP implicit price deflator for the economic activity (i.e. sector) concerned". Observations are expressed in log change, year over year. All variables are winsorized.

Consumer Price Index, All items – OECD:

Observations are expressed in log change, year over year. Variables are winsorized.

US gdp growth – OECD:

Observations are expressed in log change, year over year. Variables are winsorized.