Understanding Markups in the Open Economy

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This draft: 15 October 2013

Abstract

This paper presents a new, transparent model of heterogeneous firms in the open economy where the macroeconomic distribution of markups responds to changes in market structure, such as the degree of trade openness. To achieve this goal, we generalize a canonical model of trade from a class of models commonly used to analyze market power and pass-through in the open economy. The model's simple reduced-form distributions for markups and pricing yield predictions that coincide with a number of stylized facts from the empirical literature on markups, pass-through, and trade openness which previously could be illustrated only through numerical simulations.

Keywords: Ricardian model, heterogeneous firms, endogenous markups, pass-through

JEL Classification: F12, F15, F4, L11

The authors thank seminar and conference participants at the 2010 American Economics Association winter meetings; the Banco do Portugal; the 2011 European Economics Association/Econometrics Society Meetings; the 2010 European Trade Study Group; DEGIT XV at Goethe University of Frankfurt; the Federal Reserve Banks of Dallas, Richmond, and St. Louis; the German Institute for Economic Research (DIW); the 2011 NBER International Trade and Investment Group spring meeting; the 2012 International Finance and Macroeconomics Summer Meeting; Princeton University; Stanford University; the 2012 West Coast Trade Workshop; and the 2012 Western Economics Association International meetings. They are indebted to Andrew Bernard, Ariel Burstein, Jeffrey Campbell, Robert Feenstra, Stefania Garetto, Yingyao Hu, Oleg Itskhoki, Konstantin Kucheryavyy, Karen Lewis, Anthony Landry, Marc Melitz, Virgiliu Midrigan, Kanda Naknoi, Maurice Obstfeld, David Richardson, Barbara Spencer, Jonathan Vogel, and Nick Zolas for detailed comments in early stages of the project, and especially John Leahy and two anonymous referees. Beatriz de Blas acknowledges financial support from the ECO2008-04073 project of the Spanish MEC, and the CCG08-UAM/HUM-4438. This paper circulated in an earlier form under the title "Teams of Rivals: Endogenous Markups in a Ricardian World."

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1 Introduction

Ricardian trade models– in particular, Bernard, Eaton, Jensen, and Kortum (2003, hereafter BEJK) and Atkeson and Burstein (2008) have been used intensively in recent years to understand micro- and macroeconomic outcomes such as aggregate trade flows, pass-through, and aggregate volatility in traded goods prices when heterogenous firms strategically set prices. The models have yielded many insights, but require computationally intensive numerical simulation to understand the behavior of markups and prices in the open economy. This paper presents a new, transparent generalization of BEJK's model of strategic pricing by heterogeneous firms in the open economy—one where the macroeconomic distribution of markups responds to changes in market structure, such as the degree of trade openness. Our purpose is to create tractable analytic expressions for endogenous markups that shed light on the nature of pricing-to-market and price rigidity arising not from nominal rigidities, but from strategic complementarities[1] in a multi-country setting.

In Ricardian models of goods trade with heterogeneous manufacturing firms and endogenous markups, more efficient firms enjoy market power over less efficient firms.[2] Market power refers to the way firms exploit their cost advantage, setting prices or quantities that result in a higher markup than less efficient firms can charge. The degree to which firms can do this depends not only on their efficiency relative to rivals in the industry, but on the substitutability of the goods they produce with those of their rivals. BEJK design a model of Bertrand competition where goods within an industry are perfect substitutes, allowing them to focus exclusively on relative cost efficiency as a source of market power. In this context, the economist can measure the level of competition as how likely a country is to produce a particular good for

[1]See Gopinath and Itskhoki (2011) for a discussion of strategic complementarities in a closed economy setting.

[2]Other examples of models that generate endogenous markups from the demand side include the translog expenditure function, preferences with a constant elasticity of substitution and a finite number of goods, quadratic preferences with love of variety, non-homothetic preferences with love of variety, and a broad treatment of preferences with a variable elasticity of substitution between goods.

a particular market, and market power by how tightly a firm's price setting behavior is likely to be constrained by its next best rival for a market. BEJK achieve this result in a general equilibrium model, while generating Ricardian patterns of trade flows– countries where firms are more productive on average are richer, but all countries export according to their comparative advantage. Their results are rich compared with representative firm models, as greater gains from comparative advantage emerge when firms are more disperse in their efficiency levels.

However, this canonical model embodies a tradeoff: the average markup remains the same under trade and autarky. More specifically, the overall ('macroeconomic') distribution of markups is impervious to any characteristic of market structure, other than the dispersion of firm efficiency levels— including the level of trade openness. So the market power of firms from a particular country does not vary by destination and is not sensitive to policy. This prediction is somewhat at odds with the data. At the micro level, trade liberalization is associated with domestic firms charging lower markups over marginal costs when setting prices.[3] Moreover, firms often set prices reflecting different markups across destination markets ('pricing to market'). These competitive pressures generate a source of price rigidity specific to (and quite *common* among) exporters, as they do not fully pass on changes in marginal costs and exchange rates in the prices they charge overseas, especially in markets where they have less market power.[4]

The authors show that within the BEJK model, selection effects neutralize any effect of changes in market structure on the macroeconomic distribution of markups, but this appears not to be the case in the data, as rigidity in export prices manifests itself in measured aggregates. At the macro level, these micro-level behaviors emerge in two ways. First, the terms of trade— the ratio of export prices to import prices— are less volatile relative to the

[3]See Levinsohn (1993), Harrison (1994), Roberts and Supina (1996), Bottasso and Sembenelli (2001), Novy (2010), and Feenstra and Weinstein (2010).

[4]See for example Baxter and Landry (2010), Berman, Martin, and Mayer (2012), Fitzgerald and Haller (2013), Schoenle (2010), Gopinath, Itshoki, and Rigobon (2010), and Gopinath and Itshoki (2010).

real exchange rate— the ratio of a foreign aggregate price level to the home aggregate price level.[5] This means that traded goods prices are less volatile than prices for domestic goods, suggesting that firms may be more constrained in their price setting when exporting than when selling in their home market. The difference between the behavior of markups for domestic versus export sales even for the same firm (see Fitzgerald and Haller (2013)) suggests that trade costs are likely to be at play in these competitive pressures.

Second, export prices from countries with lower levels of available technology exhibit less pass-through-related volatility, while export prices from high-tech countries exhibit more.[6] In Ricardian models with endogenous markups, market power and the ability to pass relative cost shocks into prices arises from a firm's cost advantage over its rivals. So intuitively, it is not surprising the data suggest that the degree of this rigidity in traded goods prices is, on average, likely to vary with the level of available technology in the exporter's country relative to the destination market. Yet this pattern has eluded a reduced-form presentation in aggregated distributions of markups in any Ricardian model. We are able to fill this gap.

In this paper, we explain two reasons why the disconnect between micro structure and macro distributions may occur and relax the related assumptions in order to bring market structure back into the macroeconomic outcomes in BEJK's model of strategic pricing. The disconnect can occur when the number of rivals is either infinitely large or Poisson distributed across industries.[7] In

[5]Corsetti, Dedola, and Leduc (2008), Atkeson and Burstein (2007 and 2008) and Alessandria (2009).

[6]Using country- and industry-level data, Feenstra and Weinstein (2010), Bergin and Feenstra (2009) and Gust, Leduc, and Vigfusson (2010) show that markups are lower and pass-through is particularly limited for exporters from developing countries to the U.S. market. More generally, a number of studies document that pass-through is greater for exports to developing countries than to industrialized countries, including Calvo and Reinhart (2002), Ca'Zorzi, Hahn, and Sanchez (2007), Frankel, Parsley, and Wei (2012), and Bussiere, Chiaie, and Peltonen (2013). Garetto (2012) uses firm-level data for the auto industry, obtaining very similar findings: pass-through is smaller when countries export to more technologically advanced trading partners.

[7]Their results nest within ours and within those of Holmes, Hsu, and Li (2011) if the number of rivals is infinite. However, in the statistics literature, it is known that a Poisson-distributed number of draws from the Weibull can be integrated out to focus on other

contrast, we generalize their approach by explicitly allowing for a finite number of entrants that compete in each industry. When the number of competitors is infinitely large, our distribution of markups converges to that of BEJK. In particular, in this limiting case, there are no anti- or pro-competitive effects from trade, allowing Bertrand competition to fit within a gravity framework. In addition, our macroeconomic distribution of markups— the distribution of markups across all industries in the economy— preserves characteristics of the market structure that are sensitive to the degree of trade openness and differences in technological development across countries. Because we explicitly include a finite number of rivals, we see that the distribution of markups is directly affected by the number of firms competing to be the low-cost supplier in the closed economy or in the case when both of the best potential suppliers to a market are in the same source country. We use these new, closed-form distributions to draw out the effects of Ricardian differences in countries' available technology on markups, as well as the impact of multi- versus bilateral trade liberalization on price volatility that have been observed empirically (Flach and Cao 2011) but not yet integrated into the theoretical literature on pass-through.

In doing so, we deliver two sets of findings. First, we demonstrate with concise functional forms exactly when lowering barriers to trade in goods produces pro-competitive effects, versus when it does the opposite. In the context of Ricardian models with heterogeneous firms and endogenous markups, a pro-competitive effect occurs when a firm must lower its markup due to exposure to very efficient rival suppliers, or rival suppliers with marginal costs that fall relative to incumbent firms when trade costs fall. It is well known that pro-competitive effects emerge among domestic producers when their native market opens to trade under any circumstances, as new competition from foreign rivals forces them to reduce markups.[8] However, under bilateral liberaliza-

parameters (Raftery 1987). Unpublished teaching notes suggest that the distribution was derived using the Poisson assumption. We show in the Appendix A that the number of rivals also drops out of the autarkic distribution of markups in a special case discussed below if the underlying distribution of efficiency levels is Pareto.

[8]There is ample empirical evidence from the trade literature that these pro-competitive

tion, a drop in trade costs lowers the marginal cost for exporters relative to both domestic firms and firms from less-favored countries who are not granted lower trade barriers. Therefore, exporters can respond to trade liberalization by charging higher markups, resulting in increased volatility. We call this an anti-competitive effect. Arkolakis, Costinot, Donaldson, and Rodríguez-Clare (2012) make this point using several different classes of trade models, suggesting that endogenous markup behavior reduces gains from trade. Simulations of two-country models are likely to find little in the way of pro-competitive effects among exporters from trade liberalization, since any liberalization is necessarily bilateral. We use our markup distributions to argue that the anti-competitive effect of bilateral liberalization among exporters can be reversed in many cases by multilateral liberalization. Thus, reducing tariff barriers has a different effect from expanding the set of partners in a trade agreement.

Second, we outline empirical predictions regarding the effects of technological disparities across countries on the prices of traded goods shipped to different destinations. In particular, we argue that firms, on average, charge lower markups when exporting to technologically more advanced countries, which reduces their ability to pass through shocks to marginal costs into prices. In this sense, Ricardian productivity differentials can drive differences in markups, not just trade flows. Further, by eliminating anti-competitive effects from bilateral liberalization, accession into multilateral trade agreements can reduce pass-through and volatility in the prices of goods exported to developing countries from industrialized countries. We discuss existing evidence in support of these predictions in Section 5.

In short, our more generalized approach to the BEJK model of Bertrand competition provides reduced-form distributions for markups, enabling us to illustrate for the first time patterns evident in the data but which currently require simulation to observe in theory. The new distributions shed light on the behavior of traded goods prices and their aggregates.

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effects from trade exist and can be large. Among these are Levinsohn (1993), Harrison (1994), Roberts and Supina (1996), Bottasso and Sembenelli (2001), Novy (2010), and Feenstra and Weinstein (2010), Edmond, Midrigan, and Xu (2012), and de Loecker, Goldberg, Khandelwal, and Pavcnik (2012).

The paper is organized as follows. In Section 2, we briefly discuss the relationship of our model with recent theoretical studies. Section 3 presents a simple closed economy model with analytical solutions for the macroeconomic distribution of markups and prices which include the number of rivals. Section 4 considers the implications of trade in goods for these distributions given asymmetric trading partners. In Section 5, we present empirical implications of the model for understanding price volatility. Section 6 concludes and discusses paths for future research.

2 Related literature

Our central contribution lies in analytical expressions summarizing markup behavior for an arbitrary number of countries with differing market structures. Numerical studies by Atkeson and Burstein (2007 and 2008), Garetto (2012), and de Blas and Russ (2013) start with a Fréchet or lognormal distribution of firm efficiency levels, then build on BEJK by computing markups under Bertrand competition (also Cournot in the case of Atkeson and Burstein (2008)). Collectively, they note that the size of the markup shrinks under trade and that trade costs make firms less able to pass on shocks to marginal costs by raising export prices.[9] They also note that the number of competitors within each industry affects both the size of the average markup and the degree or frequency of pass-through. This is where our model fills a hole in the literature, with analytic distributions of markups that explicitly allow for an arbitrary finite number of rivals.

Claessens and Laeven (2004) and de Blas and Russ (2013) refer to this rivalry as "contestability," a phenomenon with roots in the industrial organiza-

[9]Rodriguez (2011) uses a translog expenditure function to achieve similar results. A number of recent papers also make advances using nominal rigidities to achieve the stickier export prices behind the low relative volatility of the terms of trade. These include Corsetti, Dedola, and Leduc (2008), Gopinath and Itshoki (2010), and Schoenle (2010). Alessandria (2009) and Drodz and Nosal (2012) use consumer-oriented frictions in distribution and marketing. In Section 5, we discuss nominal rigidities as complementary to the real rigidities arising from market structure.

tion literature attributed in particular to Baumol, Panzar and Willig (1982).[10] The key is that unlike models using Chamberlinian monopolistic competition or limit pricing, such as Melitz (2003) and Melitz and Ottaviano (2008), the degree of entry embodied in the number of rivals changes the shape of the entire distribution of markups, costs, and firm size. The particular number of rivals is not critical for our qualitative results, as long as it is finite instead of infinite or Poisson-distributed across industries. A finite number allows other elements of market structure– including trade costs and differences in technology and wages across countries– to influence the distribution of markups, too.

In the Ricardian setting, trade and trade costs affect both the number of rivals for a particular market and how close the best two competitors are in terms of marginal cost. Edmond, Midrigan, and Xu (2012, hereafter EMX) in an important contribution extend our understanding of and rigorously quantify the degree of gains from trade due to pro-competitive effects based on the model of Cournot (quantity-based) competition in Atkeson and Burstein (2008). Because they work within a two-country framework, EMX find anti-competitive effects in their simulations: highly efficient exporters exploit reductions in trade costs by absorbing them as higher markups, reducing gains from trade relative to models with constant markups.[11] In a two-country setting, our model would have a similar outcome. However, our multi-country setting provides a distinct and nontrivial result: this anti-competitive effect is only likely if trade costs are lowered for one trade partner and not others— thus, in bilateral, versus multilateral trade liberalization.

[10] One can conceptualize the number of rivals as an exogenous policy parameter, as in the numerical analyses by Atkeson and Burstein (2007 and 2008) and de Blas and Russ (2013). Alternatively, one can endogenize it using a free entry condition as Holmes, Hsu, and Li (2011) have recently done, so that markups are sensitive to market size and structure, in line with findings in the closed-economy literature such as those by Campbell and Hopenhayn (2005).

[11] This is the result in their experiment where productivity draws are independent across countries. The logic behind can be best understood in the context Arkolakis, Costinot, Donaldson, and Rodríguez-Clare (2012), who show the same effect in a large class of trade models with endogenous markups.

3 Autarky

The heart of the model lies in the production of intermediate goods by heterogeneous firms. For simplicity, we assume that producers of the final good are perfectly competitive and assemble the intermediate goods, with no additional capital or labor necessary. The continuum of intermediate goods j spans the fixed interval [0,1]. The assembly process uses a technology involving a constant elasticity of substitution across inputs, with aggregate output given by

$$Y = \left[\int_0^1 Y(j)^{\frac{\sigma-1}{\sigma}} dj \right]^{\frac{\sigma}{\sigma-1}} .$$

Output of the final good is purchased for immediate use by consumers or as an input into the production of intermediate goods. When used as a production input, it is fully expended– no inventories are carried over into future periods. We consider each intermediate input j as representing a different industry and assume that the price elasticity of substitution between output from different industries σ is greater than one. The demand for an individual input is downward sloping in its price, $Y(j) = \left(\frac{P(j)}{P}\right)^{-\sigma} Y$, and the aggregate price level P is given by

$$P = \left[\int_0^1 P(j)^{1-\sigma} dj \right]^{\frac{1}{1-\sigma}} . \tag{1}$$

Each producer of an intermediate good draws an efficiency parameter z from a cumulative distribution $F(z)$ with positive support over the interval $(0,\infty]$. Eaton and Kortum (2009, Chapter 4) describe a process whereby over time, $F(z)$ can emerge as a frontier distribution representing the efficiency levels associated with the best surviving ideas available to produce a particular good j. Being the distribution of the best surviving ideas, $F(z)$ naturally takes on an extreme value form and under mild assumptions, it can be characterized by a Fréchet distribution. Thus, we assume that a finite number of firms r

each draw an efficiency parameter from a distribution given by

$$F(z) = e^{-Tz^{-\theta}}.$$

We assume that $T > 0$ and also that the shape parameter, θ, is positive. Only the most efficient firm with efficiency level $Z_1(j)$ in any industry supplies the market. This efficiency parameter increases the level of output a firm produces from one unit of a composite input $Q(j)$:[12]

$$Y(j) = Z_1(j)Q(j).$$

Marginal cost for this most efficient firm, $C_1(j)$, is inversely related to the efficiency parameter,

$$C_1(j) = \frac{wd}{Z_1(j)},$$

which accounts for both the cost of the composite input, w, and any frictions involved in sending intermediate goods to the assemblers of the final good, $d \geq 1$. We assume that both labor and the final good are used in the production of intermediate goods with constant cost shares: $w = \omega^{\beta} P^{1-\beta}$, ω being the labor wage rate and P the cost of a bundle of intermediate goods. The distribution of potential marginal costs is given by

$$G(c) = 1 - e^{-T(wd)^{-\theta} c^{\theta}}.$$

Given that some number of rivals r draw an efficiency parameter hoping to be the low-cost supplier of industry j, the distribution of the lowest cost $C_1(j)$

[12] $Q(j)$ is a Cobb-Douglas bundle of labor and the final good used as an intermediate input. Letting L_j represent the amount of labor hired by the firm and Y_j represent the amount of the final good used in production, then $Q(j) = \beta^{-\beta}(1-\beta)^{\beta-1} L_j^{\beta} Y_j^{1-\beta}$, for $0 < \beta \leq 1$.

is[13]

$$G_1(c_1) = 1 - e^{-rT(wd)^{-\theta}c_1^{\theta}}. \tag{2}$$

We assume that $d = 1$ under autarky in this section and for domestic sales in the open economy in Section 3. The limiting distribution– $G_1(c_1)$ given an infinitely large sample r– is well defined for any positive, finite T. (See Castillo (1988, p.116) and Castillo, Hadi, Balakrishnan, and Sarabia (2005, p.207) for the derivation of the limiting distribution of maxima drawn from a Fréchet distribution.) Although the number of rivals appears similar to a scale parameter representing technological advancement in our model, we will see below that it has a more complex effect on the distribution of markups through the joint distribution of the first and second order statistics for marginal costs, representing the marginal costs of the best and second-best firm available to supply a particular market.

3.1 The distribution of markups

Let $C_2(j)$ represent the unit cost of the second-best competitor in industry j, who sits inactive but ready to begin production instantly should the opportunity arise. Given the CES assembly technology for the final good, the lowest-cost firm producing good j would like to set a price using what we call the "unconstrained" markup, where marginal cost equals marginal revenue—the CES markup $\bar{m} \equiv \frac{\sigma}{\sigma-1} > 1$. However, if charging the CES markup results in a price that exceeds the marginal cost of the second-best competitor waiting in the wings, the lowest-cost supplier may find itself undersold. In short, no firm can charge a price that exceeds the unit cost of its next best rival. The low-cost supplier in each industry j takes the prices of the low-cost supplier in

[13] See Rinne (2009), p.237 for derivation. The assumption that BEJK use regarding the number of entrants to simplify their framework is not stated in the published or working-paper version of the text. Their results can be replicated by assuming that it is infinitely large. (See Holmes, Hsu, and Li (2011) for details regarding the derivation of the composite distribution of efficiency draws, or our discussion below with regard to markups.) Alternatively, the number would drop out of the analysis if one assumed that the number of firms competing in any industry is a random variable with a Poisson distribution and integrating over its domain. In contrast, we preserve the number of rivals in the following analysis.

every other industry as given. The markup for industry j is then

$$M(j) = \min\left\{\frac{C_2(j)}{C_1(j)}, \bar{m}\right\}.$$

With this formula for the markup, we compute the expected output-weighted price for any good j in several steps. First, note that the price for good j, $P(j)$, is given by

$$P(j) = \begin{cases} C_2(j) & \text{for} \quad \frac{C_2(j)}{C_1(j)} \leq \bar{m} \\ \bar{m}C_1(j) & \text{for} \quad \frac{C_2(j)}{C_1(j)} \geq \bar{m} \end{cases}$$

Thus, the pricing rule is a transformation of the joint distribution of the first and second order statistics of the marginal cost. In Appendix A we use a straightforward Jacobian transformation on a result from Malik and Trudel (1982) to obtain the distribution of $\frac{C_2(j)}{C_1(j)}$, which is the distribution of the markup before imposing the unconstrained markup from the CES bundling of intermediate goods. Assuming that the frontier distribution of efficiency parameters is identical for every industry j, the probability density of the markup $M(j)$ is given by

$$h(m) = \begin{cases} \frac{r(r-1)\theta m^{-(\theta+1)}}{\left[(r-1)+m^{-\theta}\right]^2} & \text{for} \quad 1 \leq m < \bar{m} \\ \int_{\bar{m}}^{\infty} \frac{r(r-1)\theta m^{-(\theta+1)}}{\left[(r-1)+m^{-\theta}\right]^2} dm & \text{for} \quad m = \bar{m} \\ 0 & \text{for} \quad m > \bar{m} \end{cases}, \tag{3}$$

At the unconstrained markup, there is a mass point. For values less than that, the distribution of $H(m)$ takes on the value of the distribution of the ratio $\frac{C_2(j)}{C_1(j)}$.

Like the distribution of markups given in BEJK, this distribution is statistically independent of $C_1(j)$ and $C_2(j)$.[14] In fact, for very large r, we have

[14]In addition to the Weibull, this property of independence also emerges for the Pareto distribution, the Power Law, and the Exponential distributions (Malik and Trudel 1982). We are not aware of any other distributions for which the distribution of the ratio of two consecutive order statistics takes on an analytical form. The derivation of the special inde-

$\lim_{r\to\infty} h(m) = \theta m^{-\theta-1}$ for $1 \leq m \leq \bar{m}$, which is a Pareto density for markups identical to the one in BEJK. With the CES bundling technology, firms will never set a markup greater than $\bar{m}$, creating a mass point in the density at $\bar{m}$, since all cases where $\frac{C_2(j)}{C_1(j)}$ exceeds $\bar{m}$ are assigned a value of $\bar{m}$. The probability of charging the unconstrained markup is simply

$$\Pr\left[M(j) \geq \bar{m}\right] = \int_{\bar{m}}^{\infty} h(m)dm = \frac{r}{1 + (r-1)\bar{m}^{\theta}}. \tag{4}$$

Note that as $\bar{m}$ goes from its own upperbound of ∞ (for $\sigma = 1$) to its lowerbound of 1 (for $\sigma \to \infty$), this probability moves monotonically from 0 to 1, so it is a well behaved cumulative distribution function over the range of possible markups.

Proposition 1 *The distribution of markups with a lower number of rivals, r, stochastically dominates a distribution of markups with a higher number of rivals.*

Proof. For any given value $1 \leq m' \leq \bar{m}$, the probability that $M(j) \geq \frac{C_2(j)}{C_1(j)}$ is greater than or equal to m' is decreasing in r:

$$\frac{\partial \Pr\left[M(j) \geq m'\right]}{\partial r} = \frac{\partial \left(\int_{m'}^{\infty} \frac{r(r-1)\theta m^{-(\theta+1)}}{\left[(r-1)+m^{-\theta}\right]^2} dm \right)}{\partial r} = \frac{-[(m')^{\theta} - 1]}{[1 + (r-1)(m')^{\theta}]^2} < 0.$$

Equivalently, we can say that the distribution of markups when r is low first-order stochastically dominates the distribution of markups with a higher r. First-order stochastic dominance implies a higher expected value; therefore $E[M(j)]$ must be decreasing in r. ■

It follows from Proposition 1 that the number of rivals affects the size of the mass of firms charging the unconstrained markups, as stated in the following corollary.

pendence property for the Exponential and the Pareto is discussed more broadly by David and Nagaraja (2003, p.18).

Corollary 1 *In expectation, the fraction of firms charging the unconstrained markup is decreasing in the number of rivals r under autarky.*

Proof. The proof of Proposition 1, combined with equation (4) shows that the probability of $\frac{C_2(j)}{C_1(j)}$ being at least as large as $\bar{m}$ is decreasing in the number of rivals. Markups are set equal to $\bar{m}$ whenever $M(j)$ would be greater than $\bar{m}$ without the restriction of the CES upperbound. Thus, in expectation, the fraction of firms charging the unconstrained markup is decreasing in the number of rivals. ∎

As the number of rivals in an industry j increases, both the average markup and the probability that any firm charges the unconstrained markup falls—increased rivalry squeezes markups. Intuitively, the result emerges because, on average, increasing the number of rivals in our order-statistic framework diminishes the difference between the costs of the two best potential suppliers. This is not the case for a Pareto distribution of firm efficiency levels, as shown in Appendix A. When firms draw from a Pareto distribution of efficiency levels, markups are again Pareto distributed as in BEJK (and in our special case above with many competitors), with no impact from the number of rivals. In economic terms, the Fréchet distribution implies diminishing returns to technological growth through entry: as the number of rivals increases, there is a greater chance that additional rivals' efficiency draws will fall within the existing production possibilities frontier than that they will expand it outward.

We use θ=3.6 and σ=3.79, as estimated by BEJK.

3.2 The distribution of prices

As shown in de Blas and Russ (2013), the joint distribution for the first and second order statistic also contains the number of rivals r:

$$g_{1,2}(c_1, c_2) = r(r-1)\left[\theta T w^{-\theta}\right]^2 c_1^{\theta-1} c_2^{\theta-1} e^{-Tw^{-\theta}c_1^{\theta}} e^{-(r-1)Tw^{-\theta}c_2^{\theta}}. \tag{5}$$

To find the marginal distribution for $C_1(j)$ $(C_2(j))$, one can integrate the joint distribution over values of c_2 (c_1).[15] We find that increasing the number of rivals leads, on average, to lower costs in the industry. We compute the moment $1-\sigma$, which appears in the formula for the aggregate price level equation (1), for the first and second order statistics of marginal costs, so that we can use them below to construct the aggregate price level:

$$\begin{aligned} E[C_1(j)^{1-\sigma}] &= \left(rTw^{-\theta}\right)^{\frac{\sigma-1}{\theta}} \Gamma\left(\frac{1-\sigma}{\theta}+1\right), \\ E[C_2(j)^{1-\sigma}] &= \left(Tw^{-\theta}\right)^{\frac{\sigma-1}{\theta}} \Gamma\left(\frac{1-\sigma}{\theta}+1\right) \left[r(r-1)^{\frac{\sigma-1}{\theta}} - (r-1)r^{\frac{\sigma-1}{\theta}}\right]. \end{aligned}$$

Taking the derivative with respect to r, we see that these $1-\sigma^{th}$ moments are increasing in r as long as $\theta \geq \sigma - 1$ and undefined for any other range of parameter values. Since we assume that σ is greater than 1, the first moments, $E[C_1(j)]$ and $E[C_2(j)]$, by implication are falling in r.[16]

Proposition 2 *The aggregate price level P is decreasing in the number of rivals r.*

Proof. Intuitively, Proposition 2 is true because an increase in r shifts the distribution of markups to the left at the same time it reduces the expected marginal cost of the best supplier. More rigorously, since firms in all industries draw from the same underlying distribution, using the law of large numbers one can calculate the aggregate price level,

$$P^{1-\sigma} = E\left[\int_0^1 P(j)^{1-\sigma} dj\right] = \int_0^1 E[P(j)^{1-\sigma}]dj = E[P(j)^{1-\sigma}].$$

Recall that $P(j) = M(j)C_1(j)$. Using this pricing rule and noting that the distribution of the markup is independent of outcomes for the individual order

[15] Integrating the joint distribution over c_2 from c_1 to ∞, for instance, one obtains the marginal distribution $g_1(c_1)$ and sees immediately that it is equal to the first derivative of $G_1(c_1)$. To obtain the marginal for $C_2(j)$, one instead integrates over c_1 from zero to c_2.

[16] We also know from Proposition 1 that $E[C_2(j)]$ falls faster in r than $E[C_1(j)]$, since the expected ratio, $E\left[\frac{C_2(j)}{C_1(j)}\right]$ is falling in r.

statistics $C_1(j)$ and $C_2(j)$, we have

$$P^{1-\sigma} = E[M(j)^{1-\sigma}C_1(j)^{1-\sigma}] = E[M(j)^{1-\sigma}]E[C_1(j)^{1-\sigma}]$$

We show above that both $E[M(j)]$ and $E[C_1(j)]$ are decreasing in r as long as $\theta \geq \sigma - 1$, thus P is also falling in r. ■

3.3 The number of rivals

The variable in our model which BEJK normalize to suppress the effects of all other aspects of market structure on markups is the number of rivals r. We outline a very simple, one-shot entry game here to motivate the treatment of r as finite.[17] Following Melitz (2003), entrepreneurs must pay a fixed cost f in order to draw an efficiency parameter. This fixed cost is denominated in units of output. The finite number of entering rivals, an integer, must be such that the expected present discounted value of output for an active producer is no smaller than the sunk cost of entry,

$$\begin{aligned} E_t\left[P(j)Y(j) - C_1(j)Y(j)|r\right] &\geq f \\ E_t\left[P(j)Y(j) - C_1(j)Y(j)|r+1\right] &< f. \end{aligned} \tag{6}$$

We also use the labor market clearing condition to define market size Y.[18] It is given by

$$\omega L = \beta\lambda PY, \tag{7}$$

where L is the number of workers, β is labor's cost share in the input bundle used to produce intermediate goods and λ is the share of variable costs as a

[17] Since the circulation of this paper, new working papers by Holmes, Hsu, and Li (2011) and Zolas (2011) have also begun to consider entry in a similar context, with different applications relating to agglomeration and patenting.

[18] The labor market clearing condition stipulates that payments to labor equal labor's share in variable cost, $\omega L = \beta\lambda PY$, where λ is the share of variable costs in total revenues, defined below. See Appendix D for further detail within the open economy.

fraction of total expenditures.[19] Isolating Y in equation (7), normalizing the wage $w \equiv 1$, and then substituting for Y and λ in the free entry condition, equation (6), yields the simpler expressions

$$\begin{aligned} \frac{E[M^{1-\sigma}(j)|r]}{E[M^{-\sigma}(j)|r]} &\geq 1 + \frac{\beta f}{L}, \\ \frac{E[M^{1-\sigma}(j)|r+1]}{E[M^{-\sigma}(j)|r+1]} &< 1 + \frac{\beta f}{L}. \end{aligned} \tag{9}$$

Recall that the distribution of the markup is independent of the distribution of costs,[20] so in Appendix B using Jensen's inequality, we show that the free entry condition reduces to

$$E[\ln M(j)] \geq \ln\left(1 + \frac{\beta f}{L}\right). \tag{10}$$

In Appendix B.2, we prove that the left hand side is decreasing in r, resulting in a unique equilibrium solution for r.

Considering the case where equation (10) binds, the number of rivals in each industry grows as the fixed cost f, as well as when market size L is bigger. Campbell and Hopenhayn (2005) show a negative relationship between markups and market size in U.S. cities consistent with the scale effect implied by our free entry condition. Note that entry is not proportional to changes in market size L, but can grow much faster than L, a departure from the Melitz (2003) model.

[19]We compute λ as in BEJK by substituting the ratio of average variable costs over average revenue, then substituting in the equations for demand and the pricing rule to get

$$\lambda = \frac{E[C_1(j)Y(j)]}{E[P(j)Y(j)]} = \frac{E[M^{-\sigma}(j)]}{E[M^{1-\sigma}(j)]}. \tag{8}$$

[20]To see this, recall that the cost parameters C_k do not enter into the expression for $h(m)$ for $k \in N$.

4 Trade in goods

Trade in our model not only shifts production toward lower-cost producers in the classic Ricardian sense, but also reduces markups in countries with low contestability, lowering the aggregate price level. The reason is simple: all else equal, openness increases the number of firms competing to serve the domestic market, therefore reducing market power among domestic producers. The effects of trade liberalization on exporters' markups is more subtle, depending on whether they face competition primarily from domestic rivals, in which case exporter markups could increase, or from rivals in third countries, in which case they may change very little. We analyze both cases below.

4.1 The distribution of costs

To fix ideas, we first show how the overall distribution of costs across suppliers to some country n and the probability of any good coming from a particular trading partner is similar to the original BEJK framework. To this end, we add the subscript n to the terms $C_k(j)$, $g_k(c_k)$, and $G_k(c_k)$ from the autarkic case to refer to the costs and distribution of costs for goods supplied to country n in the open economy. When the potential supplier is from country i we add the subscript i, so that the unit cost of the k^{th} most efficient firm from country i when supplying any good (j) to country n becomes $C_{kni}(j)$, drawn from the underlying cumulative distribution function $G_{kni}(c_k)$, with the corresponding probability density $g_{kni}(c_k)$. We assume that Eaton and Kortum's (2002) no arbitrage condition for trade costs holds: $d_{ni} < d_{ui}d_{nu}$, where $d_{ni} \geq 1$ is an iceberg trade cost involved in shipping goods from country i to country n for $i \neq n$. This means that it is always cheaper to send a good directly to its destination market, never to re-route it through a third country.

Let $G_{1n}(c_1)$ be the probability that the low-cost supplier of a good j to the home country n has a marginal cost less than or equal to some level c_1 under trade. The probability is equal to one minus the probability that any other potential supplier—domestic or foreign—has a marginal cost greater than c_1.

The cumulative distribution for low-cost suppliers under trade is thus

$$\begin{aligned} G_{1n}(c_1) = \Pr[C_{1n}(j) \leq c_1] &= 1 - \prod_{i=1}^{N}[1 - G_{1ni}(c_1)] \\ &= 1 - e^{-\Phi_n c_1^\theta}, \end{aligned} \tag{11}$$

where $G_{1ni}(c_1)$ is the distribution of low-cost suppliers to n from country i; $\Phi_n = \sum_{i=1}^{N} T_i(w_i d_{ni})^{-\theta} r_i$; and $d_{ni} \geq 1$ is an iceberg trade cost involved in shipping goods from country i to country n for $i \neq n$ which may include tariffs, transport, or other costs. It is straightforward to show that the probability that a country exports to n is the same as in Eaton and Kortum (2002) and BEJK, but allowing for the number of rivals. This probability, assigned the label π_{ni}, will be used below and is given by

$$\pi_{ni} = \Pr[EXPORT_{ni}] = \frac{r_i T_i(w_i d_{ni})^{-\theta}}{\Phi_n}. \tag{12}$$

4.2 Geography and markups

To understand the effect of trade on markups and prices, we compute the full distribution of markups under costly trade with asymmetric countries. Intuitively, this distribution can be decomposed into two cases. The first occurs when the best two rivals for a destination market n originate in the same country i. In this case, the probability distribution for markups less than $\bar{m}$ is simply the autarkic distribution in the source country,

$$h_i(m) = \frac{\theta r_i m^{\theta-1}}{[1 + r_i(m^\theta - 1)]^2}. \tag{13}$$

Let the probability that this case applies be ψ_{ni}. Then ψ_{ni} is equal to

$$\psi_{ni} = \pi_{ni}\psi'_{ni}, \tag{14}$$

which is the probability that a firm in i is the low-cost supplier of any good to country n (π_{ni}), times the conditional probability ψ'_{ni} that the second best supplier of the good to market n is also in country i, with $\psi'_{ni} = \frac{(r_i-1)T_i(w_i d_{ni})^{-\theta}}{\Phi_n - T_i(w_i d_{ni})^{-\theta}}$.[21]

The second case occurs when there is cross-border competition: the best two rival suppliers to destination market n are not from the same country. Suppose that the best supplier is again from country i, but the second best supplier is now in some other country $\hat{\imath} \neq i$. Let $h_{ni\hat{\imath}}(m)$ represent this density. Appendix C contains the full derivation of $h_{ni\hat{\imath}}(m)$, which is given by

$$h_{ni\hat{\imath}}(m) = \frac{\theta T_i(w_i d_{ni})^{-\theta} r_{\hat{\imath}} T_{\hat{\imath}}(w_{\hat{\imath}} d_{n\hat{\imath}})^{-\theta} m^{\theta-1}}{\left[T_i(w_i d_{ni})^{-\theta} + r_{\hat{\imath}} T_{\hat{\imath}}(w_{\hat{\imath}} d_{n\hat{\imath}})^{-\theta}(m^{\theta}-1)\right]^2}. \tag{15}$$

This density is quite different from BEJK in that it can be destination-specific. Exporters, on average, will charge a different markup depending on the underlying level of contestability r, input prices w, distance d, and technology T applying to their competitors in each market.

The probability that this cross-border competition occurs between i and any particular country $\hat{\imath}$ is derived in Appendix C and given by

$$\psi_{ni\hat{\imath}} = \psi'_{ni\hat{\imath}} \pi_{ni}(1 - \psi'_{ni}). \tag{16}$$

Intuitively, we see that the probability $\psi_{ni\hat{\imath}}$ of cross-border competition arising is the product of three probabilities: (1) that a firm in i supplies some good to country n, π_{ni}; (2) the conditional probability that the firm's next best rival is not from the same country, $1 - \psi_{ni}$; and (3) the conditional probability that the next best rival is from $\hat{\imath}$, which is given by $\psi'_{ni\hat{\imath}} = \frac{r_{\hat{\imath}} T_{\hat{\imath}}(w_{\hat{\imath}} d_{n\hat{\imath}})^{-\theta}}{\Phi_n - r_i T_i(w_i d_{ni})^{-\theta}}$. It is easily verified that $\sum_{\hat{\imath}\neq i} \psi'_{ni\hat{\imath}} = 1$.

Using Equations (13), (14), (15), and (16), we arrive at the full or 'macroe-

[21]See Appendix C for the full derivation. Under symmetry, the probability ψ_{ni} collapses to the very intuitive expression $\psi = \frac{1}{N} * \frac{r-1}{Nr-1}$.

conomic' distribution of markups[22],

$$\tilde{h}_n(m) = \sum_{i=1}^{N} \psi_{ni} h_i(m) + \sum_{i=1}^{N} \sum_{\hat{i} \neq i}^{N} \psi_{ni\hat{i}} h_{ni\hat{i}}(m). \tag{17}$$

This is in contrast to BEJK where the distribution of markups under trade is the same as under autarky, $\tilde{h}_n(m) = h_n(m)$.

To illustrate the difference between the BEJK result and ours, we show numerically in Figure 1 that for two identical countries, the cumulative macroeconomic distribution of markups is different under trade from the one that prevails under autarky. To make the point as stark as possible, in our example here we start with a low level of r ($r = 2$) and there is no exit after opening to trade.[23] The difference between the distributions grows smaller when countries have higher levels of contestability r under autarky or if there is enough exit to reduce the number of competitors worldwide to the same number under autarky. In the BEJK framework, the distribution would never under any circumstance depart from the cumulative distribution under autarky.

We claimed above that under costly trade, the price charged by exporters will be bounded by the geographically closer rival. Using the probability density when there is cross-border competition, $h_{ni\hat{i}}(m)$, this claim can be formalized in the following Proposition.

Proposition 3 *All else equal, if a producer from country i exports to country n with the next-best rival to supply the same good to country n from a different country $\hat{i} \neq i$, then the exporter's market power on average is increasing in country i's technology relative to country $\hat{i}$ ($\frac{T_i}{T_{\hat{i}}}$), but decreasing in country i's relative wage ($\frac{w_i}{w_{\hat{i}}}$), relative distance to the destination market, ($\frac{d_{ni}}{d_{n\hat{i}}}$), and the level of contestability in the rival's home country ($r_{\hat{i}}$).*

Proof. Integrating the probability density given in equation (15), for any markup m', $1 \leq m' \leq \bar{m}$, the probability that the exporter's markup is greater

[22] Again, the relevant weights sum to 1: $\sum_{i=1}^{N} \psi_{ni} + \sum_{i=1}^{N} \sum_{\hat{i} \neq i}^{N} \psi_{ni\hat{i}} = 1$.

[23] Since previous studies using similar frameworks keep the number of rivals in each country constant, we do so here, as well. We set θ=3.6 and σ=3.79, as estimated by BEJK.

than or equal to m', given that its rival resides in a different country, is

$$\Pr[M_{ni\hat{\imath}} \geq m'] = \frac{T_i(w_i d_{ni})^{-\theta}}{T_i(w_i d_{ni})^{-\theta} + r_{\hat{\imath}} T_{\hat{\imath}}(w_{\hat{\imath}} d_{n\hat{\imath}})^{-\theta}(m'^{\theta} - 1)}. \tag{18}$$

All else equal, the derivative of this probability is increasing in $\frac{T_i}{T_{\hat{\imath}}}$. By the property of stochastic dominance, the average markup is also increasing in $\frac{T_i}{T_{\hat{\imath}}}$. Similarly, the probability is decreasing in $\frac{w_i}{w_{\hat{\imath}}}$, $\frac{d_{ni}}{d_{n\hat{\imath}}}$, and $r_{\hat{\imath}}$. Thus, the average markup in this case is also decreasing in these three factors.[24] ∎

Proposition 3 also implies that under costly trade, the markups that firms charge are different when they sell domestically compared to when they export providing some more evidence of pricing-to-market. Equation (18) reveals that firms internalize a portion of the trade cost, unless they are so technologically superior or have such a huge unit input cost advantage that they can pass the entire trade cost on to the foreign consumer. We can see in Figure 2 an illustration of this principle. In a two-country world, the markups charged by domestic producers and exporters selling in a common market n actually move in opposite directions when trade costs fall from $d_{ni} = 1.5 > d_{nn} = 1$ to the case of free trade where $d_{ni} = d_{nn} = 1$. Domestic producers exhibit pro-competitive effects (the average markup falls), which exporters exhibit anti-competitive effects (the average markup increases) when $\frac{d_{ni}}{d_{nn}}$ falls.[25] Yet we know from Figure 1 that quantitatively the two effects do not cancel out, making the average markup lower than under autarky.

4.3 Bilateral vs multilateral trade

As seen above in Figure 2, our model nests the anti-competitive mechanism underlying results in EMX and Arkolakis, Costinot, Donaldson, and Rodríguez-Clare (2012), but it also shows that this anti-competitive effect can be miti-

[24]We note here that the cumulative probability $Pr[M(j) \leq m'] = 1 - \Pr[M_{ni\hat{\imath}} \geq m']$ ranges from 0 to 1 as m' increases from 1 to ∞, so it is a well behaved cumulative distribution function for markups.

[25]The principle of stochastic dominance implies that the average is higher for a cumulative distribution further to the right.

gated by multilateral, as opposed to bilateral, trade liberalization.

Corollary 2 *All else equal, if an exporter to country n is located in a country $i \neq n$ with its next best rival to supply n in a third country $\hat{\imath} \neq i, n$, and trade barriers are higher toward country $\hat{\imath}$ than country i, then changing from bilateral ($d_{ni} < d_{n\hat{\imath}}$) to multilateral ($d_{ni} = d_{n\hat{\imath}}$) trade liberalization reduces the average markup among exporters from i.*

Proof. Lowering trade costs only between i and n (d_{ni}) reduces i's geographic friction with respect to n relative to its competitor in country $\hat{\imath}$, $\frac{d_{ni}}{d_{n\hat{\imath}}}$. It follows from Proposition 3 that exporters from i to n can proceed to charge a higher markup on average than before the bilateral liberalization given that the next best rival is in country $\hat{\imath}$. If afterward, country n lowers trade costs with respect to $\hat{\imath}$, changing from bilateral to multilateral liberalization, then $\frac{d_{ni}}{d_{n\hat{\imath}}}$ increases and by the same Proposition 3, the probability $\Pr[M_{ni\hat{\imath}} \geq m']$ falls. ■

Thus, bilateral liberalization can create an anti-competitive effect, increasing market power for exporters on average, while switching from bilateral to multilateral agreements can generate a pro-competitive effect.

4.4 Trade, prices, and welfare

The microeconomic effects of trade analyzed in previous sections lead to an important result at the aggregate level. As in any Ricardian model, regardless of whether it is bilateral or multilateral, trade openness reduces prices, as seen in the following Proposition.

Lemma 1 *Trade lowers the aggregate price level.*

Proof. See Appendix D.2. ■

The gains from trade liberalization cannot be inferred from the value of aggregate flows alone because liberalization reduces markups, distorting the relationship between the trade cost and observed expenditures. Thus, trade liberalization has the potential to create welfare gains not only through productivity-based comparative advantage, but also by reducing firms' market power. We close the model and show output growth under free trade versus autarky under symmetry and free trade in Appendix D. The result is a quantification of gains from trade given incremental increases in the number of rivals for any particular market. Figure 3 shows how much aggregate output increases given the number of rivals that exist in any industry under autarky and the number that exist after opening to free trade, given two identical countries.[26]

In Figure 3, we show an estimate of the gains for a country opening to free trade with an arbitrary number of partners identical to itself. In this stylized case, the number of rivals competing to supply the domestic market under trade relative to autarky determines the increase in aggregate output. Each line in the graph represents an increase in the number of rival suppliers compared to autarky by 1, 5, or 10. The ratio $\frac{Y^t}{Y^a}$ on the vertical axis is computed as in Appendix D. The number of total competitors for a market under trade, R, lies on the horizontal axis. Where R equals 20 under trade, for instance, we see the gains from trade if there were 10, 15, or 19 domestic rivals under autarky. A country which under free trade has 20 potential suppliers of a product experiences an increase in aggregate output of less than 3 percent if it already had 19 competitors under autarky, but greater than 40 percent, if it had only 10 competitors under autarky.[27]

5 Empirical Implications

The results of the previous section immediately yield four empirical predictions. First, markups of domestic producers on average should decrease under trade liberalization. Second, markups of incumbent exporters on average should increase under trade liberalization. Third, exporters from developing

[26]We use this general way of considering the number of rivals before and after liberalization since fixed costs could be chosen to achieve many different combinations.

[27]Equation (9) suggests that small countries, ones with smaller market size L, will have fewer rivals in each industry under autarky. Thus, gains from trade are greatest for small countries opening to trade, even if a pair of small countries establishes a free trade agreement, echoing a result in representative firm models such as Devereux and Lee (2001) under Cournot competition or Novy (2010) with translog preferences.

countries will have less market power when exporting to a country with a higher level of available technologies, or where the other foreign competitors are from countries with higher levels of technology. Finally, markups of exporters from a favored country will increase with bilateral trade liberalization, but be kept in check if trade liberalization is multilateral and the primary competitors for the destination market are also foreign.

The empirical literature clearly supports the first prediction (Levinsohn (1993), Harrison (1994), Roberts and Supina (1996), Bottasso and Sembenelli (2001), Novy (2010), and Feenstra and Weinstein (2010)). The second prediction is consistent with a wide class of trade models, but so far has seen no clear test in existing empirical literature.[28] Feenstra and Weinstein (2010) find evidence in support of the third prediction, finding that developing countries exporting to the U.S. charge lower markups on average. We are not aware of any study that tests the fourth prediction, examining the behavior of exporters following a liberalization that widens the set of favored trading partners. Yet all of these implications from the model are important to understanding the aggregate welfare effects of trade policy. Since it is difficult to obtain information on markups for a wide array of countries, differentiated by good and by domestic versus import status, we propose that these predictions also can be tested by examining the volatility of aggregate measures of traded goods prices.

We suggest that aggregate measures of volatility in traded goods prices can act as a sufficient statistic to indicate how the elements driving market structure discussed above affect markups. The logic is simple. Firms with a greater cost advantage can charge higher markups. If they charge higher markups on average, there are more firms charging the unconstrained markup, allowing them to increase prices to some degree in response to a positive shock to their relative cost before having to worry about being undersold by rivals. Likewise, for a negative cost shock, firms with a greater cost advantage are more likely

[28] Choi (2013) finds that retail firms increase markups on imported goods after trade liberalization, so it is plausible that a drop in trade costs might be split between higher markups for exporters and importing retail firms or intermediaries.

to exceed the unconstrained markup if they do not adjust prices downward to some degree. Therefore, on average, a population of firms with a cost advantage over another population of firms—whether driven by more favorable trade costs or a technological edge—should exhibit more pass-through of a relative cost shock like an exchange rate movement. In Appendix E, we formalize this argument using Proposition 3.[29]

We also show simulated results for the volatility of aggregate traded goods prices in Tables 1 and 2. The key measure is the volatility of the terms of trade (the ratio of the home export price index to the home import price index) relative to the real exchange rate (the foreign price level converted to home currency divided by the home price level). To illustrate the relationship between the micro and macro effects of relative cost shocks across countries, such as a small movement in the nominal exchange rate[30], Table 1 lists the volatility of the terms of trade relative to the real exchange rate in U.S. data alongside results from simulated data for small cost shocks in our model.[31] In Table 1, we see that given two identical countries, the volatility is falling with the level of trade costs, which corresponds with a the drop in markups for exporters discussed in Proposition 3 and shown numerically in Figure 2. This is our second empirical prediction but now expressed in terms of volatility,

[29]In Appendix F, we show in a closed economy framework that there is no discontinuity in firms' pricing behavior as producer's products become perfect substitutes, building entirely from the insights of an analytical proof by Kucheryavyy (2012). Thus, we differ with the suggestion in Atkeson and Burstein (2008, p.2013) that the discontinuity in the number of firms, which jumps from $r > 0$ to 1 when the elasticity reaches infinity, causes a discontinuity in pricing behavior which would make Bertrand competition less useful than Cournot or that assuming perfect substitutability is not a useful approximation to examine limited price flexibility.

[30]See Burstein, Eichenbaum, and Rebelo (2005) for a discussion contrasting the impact of large versus small shocks on the real exchange rate

[31]That is, to focus on the main mechanism of the Bertrand pricing behavior, these are small departures from a symmetric steady state without second-order effects on wages or entry. We use the same calibration as in Figure 1, with lognormal shocks that enter like ε above, but applied to all firms within a country. The shock is lognormally distributed with log of these shock distributed as normal with mean zero and variance 0.015, so that the standard deviation is equal to the standard deviation of aggregate technology shocks in the U.S. estimated by Basu, Fernald, and Kimball (2006), applied to each of two symmetric countries. We hold r constant in each case.

as Figure 2 and Table 1 demonstrate that volatility and markups related to exporters' prices are positively correlated as trade costs fall.

In Table 2, we illustrate our third and fourth empirical predictions through the lens of volatility instead of markups. We see that a country n with a technological disadvantage ($T_n < T_i$) exhibits higher volatility in traded goods prices than in the symmetric case, regardless of the level of trade barriers, consistent with the lower markups for low-tech exporters in our third empirical prediction. In fact, in studies by Calvo and Reinhart (2001), Ca'Zorzi, Hahn, and Sanchez (2007), Frankel, Parsley, and Wei (2012), and Bussiere, Chiaie, and Peltonen (2013) using industry- or country-level data, there is less exchange rate pass-through in the prices of goods exported by developing countries, and more pass-through in prices of goods imported by developing countries than among advanced economies. Our model suggests that this phenomenon may be due to competitive pressures. In the last two columns, we see that volatility in traded goods prices falls when a low-tech country expands its trade liberalization from one to two high-tech trading partners. This is consistent with our fourth prediction, that markups of existing exporters from the favored nation would fall under an expansion of a bilateral treaty to additional countries. This predicted reduction in volatility for developing countries has some support in findings by Flach and Cao (2011) that entry into multilateral trade agreements like the GATT/WTO or FTAs reduces import and export price volatility in developing countries.

6 Conclusions

In summary, we have shown that the overall distribution of markups in a model of Bertrand competition with heterogeneous firms can be sensitive to changes in market structure. In an open economy, this means that the distribution of markups can vary by destination market, or by source country. The key to achieving this result is to assume there is a finite number of firms competing in each industry. Assuming that the number of rivals in an industry is infinitely large, or that it is Poisson-distributed across industries, drowns out the effect of other factors— like the degree of trade openness or the local level of technology— on the macroeconomic distribution of markups.

The model yields four empirical predictions. One, that foreign competitors squeeze the markups that domestic firms can charge on domestic sales, is well established in the empirical literature. Others, relating to the behavior of markups set by exporters in response to market conditions that vary across destinations, are more difficult to test due to the relative scarcity of firm-level datasets with both costs and prices by product and destination. We propose that average volatility of traded goods prices aggregated by industry, by source country, or by destination market, may be positively correlated with the behavior of markups averaged across affected firms. Studies of volatility and exchange rate pass-through in traded goods prices are consistent with the predictions of the model in this sense, but are still quite sparse, suggesting interesting realms for future research.

In addition, there is some scope for investigating the role of endogenous markups in the long-run adjustment to gradual changes in relative marginal costs across countries. Obstfeld (2009), for instance, proposes that the gradual appreciation of the yen between 1985 and 1995 squeezed Japanese exporters' markups and had significant effects on the structure of the Japanese economy. Structural studies of large exchange rate movements would require a more careful modelling of entry and exit than is in this paper, but potentially could benefit from explicitly considering the role of endogenous markups and profit margins.

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Tables

Table 1: Volatility and passthough, two identical countries

	U.S. data*	$d = 1.75$		$d = 1.5$		$d = 1.25$	
		r=2	r=20	r=2	r=20	r=2	r=20
$\frac{\sigma_{TOT}}{\sigma_{RER}}$	0.56	0.36	0.38	0.56	0.59	1.16	1.21
Avg. pass-through, exports	0.25	0.06	0.06	0.06	0.06	0.06	0.07
$\frac{\sigma_{P_{EX}}}{\sigma_{RER}}$		0.70	0.68	0.87	0.84	1.47	1.40
$\frac{\sigma_{P_{IM}}}{\sigma_{RER}}$		0.71	0.68	0.90	0.85	1.55	1.39

*U.S. figures for $\frac{\sigma_{TOT}}{\sigma_{RER}}$ are from Corsetti, Dedola, and Leduc (2008), frequencies from Schoenle (2010), and pass-through from Gopinath, Itshoki, and Rogobon (2010).

Table 2: Volatility and passthrough, developing country

	2 countries, $T_n < T_i$				3 countries, $T_n < T_i = T_j$			
	$d = 1.75$		$d = 1.25$		$d_{ni} = 1.25 < d_{nj}$		$d_{ni} = d_{nj} = 1.25$	
	r=2	r=20	r=2	r=20	r=2	r=20	r=2	r=20
$\frac{\sigma_{TOT}}{\sigma_{RER}}$	1.04	1.03	3.68	4.27	2.92	3.15	2.56	2.70
Avg. pass-through, imports	0.03	0.05	0.06	0.08	0.17	0.22	0.14	0.12
$\frac{\sigma_{P_{EX}}}{\sigma_{RER}}$	1.55	1.58	4.12	4.25	3.20	3.23	2.71	2.71
$\frac{\sigma_{P_{IM}}}{\sigma_{RER}}$	1.58	1.55	4.92	4.25	3.50	3.23	2.88	2.71

*$T_n = 0.5$ and $T_i = 1$ in the 2-country case. $T_j = 1$ also in the 3-country case, with $d_{nj} = 1.75$ in the 3-country case with asymmetric trade costs.

Figures

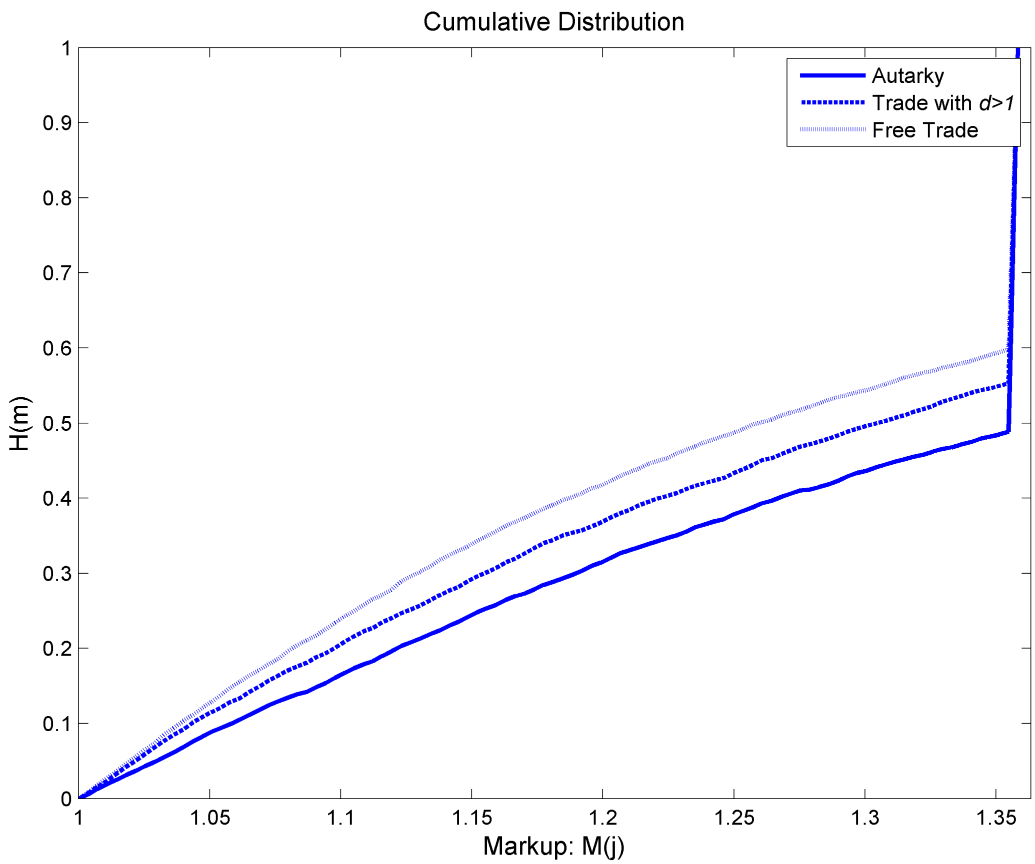

Figure 1: The cumulative distribution of markups under autarky, costly trade, and free trade

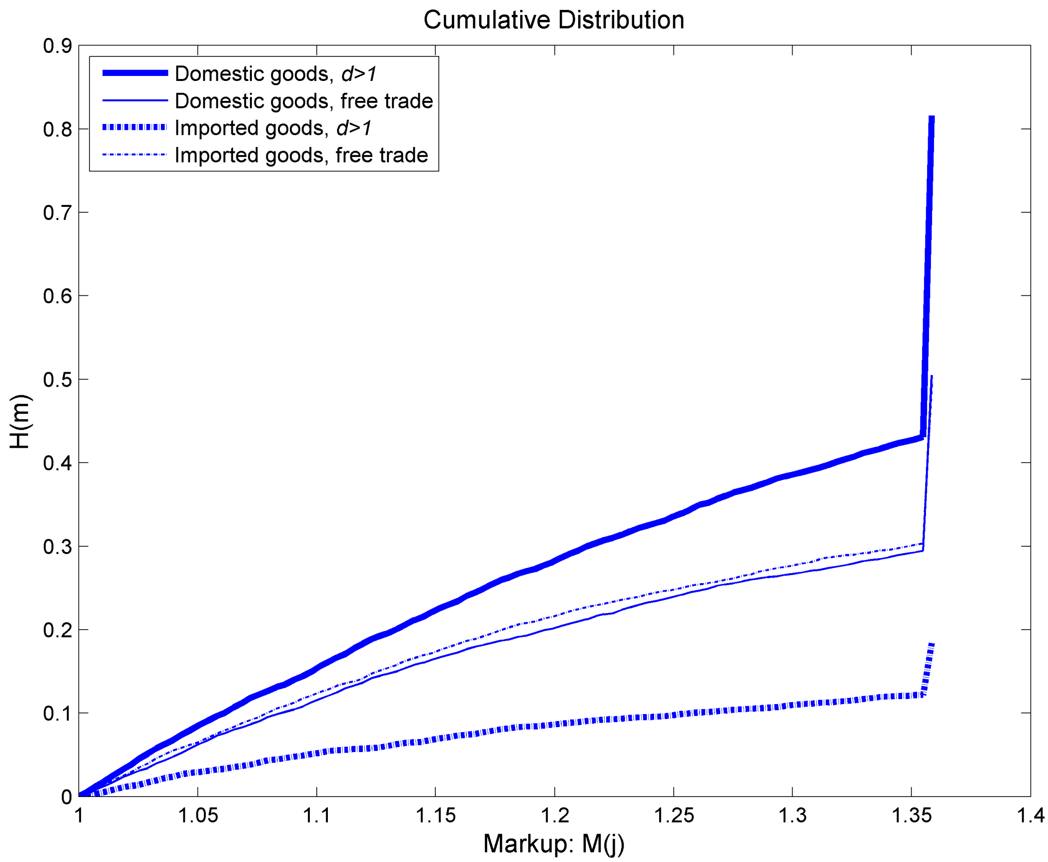

Figure 2: The cumulative distribution of markups in domestic vs. import prices before and after trade costs fall

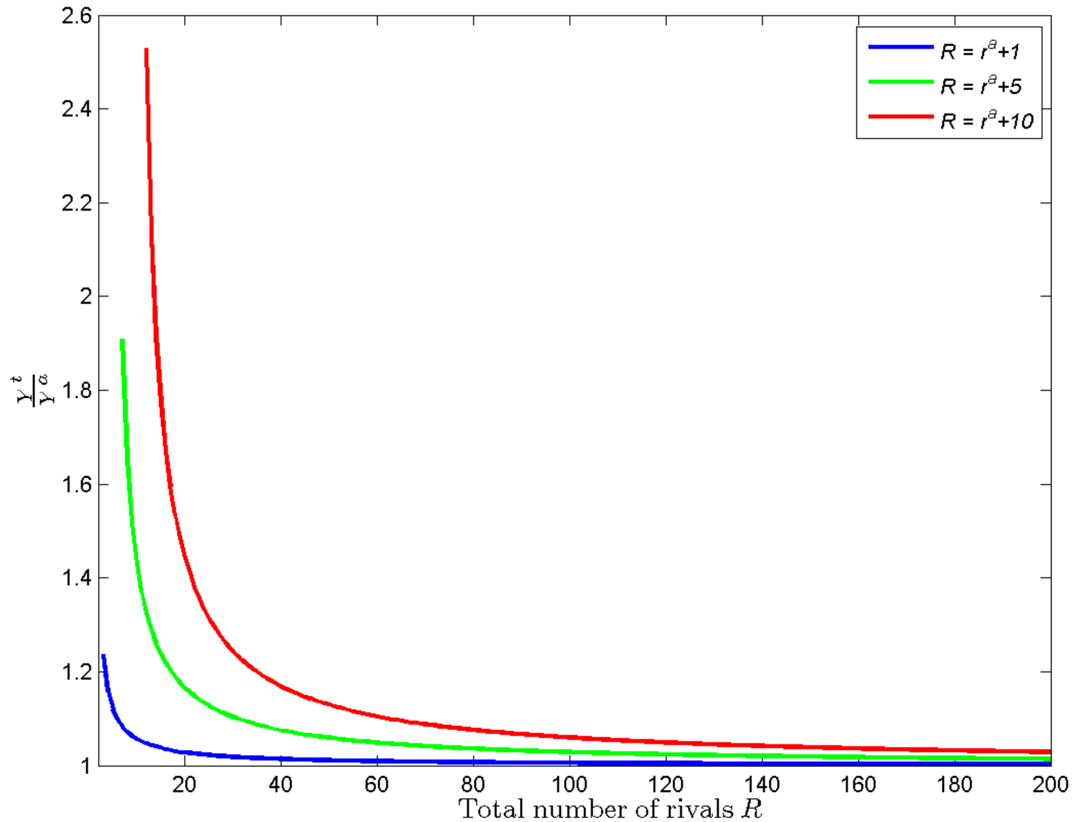

Figure 3: Gains from trade depend on the number of additional rivals