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## Abstract

This paper develops a technique to decompose price distributions into contributions from markups and marginal cost. The estimators are then used as a laboratory to measure the relationship between increasing Chinese competition and the components of U.S. import prices. The estimates suggest that the intensification of Chinese exports in the 2000s corresponded to substantial changes in the distributions of both the markups and marginal cost of U.S. imports. The entry of a Chinese exporter in an industry corresponded to rest-of-world exporters shrinking their markup (lowering prices by up to 30 percent) and increasing their marginal cost (raising prices by up to 50 percent). The fact that marginal cost increased as competition stiffened strongly suggests that the composition of non-Chinese exports shifted toward higher-quality varieties. The estimates also imply a pattern in the acquisition of market share by Chinese exporters: They enter at relatively low cost/quality and then subsequently undertake quality improvements and markup reductions. These results provide some of the first measures of the dual nature of trade's procompetitive effects; exporters respond to tougher competition by simultaneously adjusting both markups and quality.

Key words: Procompetitive effects of trade, markup measurement

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One of the most remarkable changes in US international trade over the past two decades has been the increase in imports from China. China accounted for only 6 percent of total imports in the year 1995, increasing to 18 percent in 2011. This rise is equally impressive when looking at the intensive margin of trade, in which market share increased in the vast majority of products that China already exported at the beginning of the 2000s, or the extensive margin of trade, in which China increased the number of detailed product types it exported to the US by about 2,000 over the same period.

China's export growth has stimulated great interest in identifying and quantifying its effects on competing producers and the welfare of US consumers. One important implication of a burgeoning China in markets operating under imperfect competition is that the markups charged by other firms in the industry contract; this has been called a 'pro-competitive' effect of liberalization and the associated reduction of monopolistic rents is a potentially large source of gains from trade. A second pertinent implication of China's entry and expansion in US import markets is the changing quality composition of the US consumption basket. While China's growing market share indicates expenditure switching away from domestic sources and other exporters, we do not observe exactly to what extent Chinese merchandise is comparable to, and hence substitutable for, goods from those other sources. This is an important consideration because the degree of quality differentiation of import products and the relative quality level of Chinese exports will have a direct bearing on production and labor market outcomes due to import competition.

In this paper, I develop a technique to jointly estimate the distribution of markups and marginal cost across exporters, as well as the scope for quality differentiation in an industry. I then use this estimator as a laboratory to measure the relationship between increasing Chinese import competition and the average markups charged by countries exporting to the United States, as well as on the average cost and quality of imports. I find that in industries which China entered into exporting, the declining markups of other producers accounted for price reductions of up to 30 percent in some sectors during the early to mid-2000s. These decreases in markups, which were particularly large for manufactures such as machinery, electronics and transportation products, provide strong evidence of the pro-competitive effects of trade. It is a finding consistent with recent empirical work by Feenstra and Weinstein (2010), in which structural estimates of the effects of globalization are estimated to reduce US consumer prices over a similar period, with a substantial share of the price decrease due to increased competition and reduced markups. De Loecker, Goldberg, Khandelwal and Pavcnik (2012) estimate that declines in output tariffs in India reduced both the markups and prices of manufacturers. de Blas and Russ (2012) as well as Edmond, Midrigan and Xu (2012) demonstrate that changes in the distribution of markups due to decreasing trade costs can potentially lead to even larger welfare gains than earlier Ricardian models with variable markups. The present study builds on these results by quantifying the role of producers in the rest of the world (i.e., not only the domestic import-competing firms) in responding to increasing competition by lowering their markups. As described below, the methodology I propose has the additional benefits of not relying on a particular form of consumer demand nor even requiring firm-level data.

In addition to changing markups, I also find that coincident with China's entry into an industry, the marginal costs of non-Chinese exporters rose by up to 50 percent in some sectors during the early to mid-2000s. The fact that marginal costs increased as competition stiffened strongly suggests that the composition of non-Chinese exports shifted towards higher quality varieties. An upgrading response to Chinese competition is hinted at by Schott (2008) using changes in China's relative price within an industry. More generally, Amiti and Khandelwal (2011) estimate that lower tariffs were associated with faster quality upgrading for the set of countries participating in US import industries. All of these findings imply that there is a pro-competitive effect of trade on quality which is *in addition* to markups. Here, I provide some of the first joint measures of these dual pro-competitive effects; exporters respond to tougher competition by simultaneously adjusting both markups and quality.

Finally, the separation of prices into markups and marginal cost provides an estimate of the composition of China's prices. The results indicate that for non-commodity industries in which China entered, changes in the average price due to China were driven exclusively by China's relative cost and/or quality and not its relative markup. On the other hand, for industries in which China was an incumbent exporter to the US, Chinese markups tended to decline relative to other competitors and China's average cost and/or quality increased over time. These patterns suggest an intuitive dynamic in the acquisition of market share by Chinese firms: namely, that they enter at relatively low cost and/or quality and then maintain and grow their share by undertaking quality improvements and decreasing their relative markup.

The main methodological development below is the decomposition of average product-level prices into contributions from markups, quality, and productivity, and doing so without observing *anything* about specific imported varieties or exporting firms except the average price from each source country. The additional information used for identification of the components of price comes from the set of higher moments of the import price distribution for each product. Specifically, in addition to the average product price, country-specific unit values are used to measure the variance and skewness of prices within each product group. The mean, variance and skewness of prices, in turn, are reflections of the combination of underlying distributions of markups and marginal costs across export sources, and I solve for the parameters of those distributions in terms of the observed moments of prices.

Using higher moments is a departure from previous attempts to infer product quality and productivity from prices, which have tended to focus on the first moment (the mean) of prices combined with information on quantities, inputs or income. For example, Hallak and Schott (2010), Khandelwal (2010) and Gervais (2011) use the trade balance, market share, and output quantity, respectively, conditional on average price, as proxies for export quality. In Feenstra and Romalis (2012) non-homothetic preferences and specific transport costs give rise to an expression for quality that is proportional to the exporter's price divided by a productivity-adjusted wages. Johnson (2011) and Baldwin and Harrigan (2011) demonstrate that average export prices are increasing in the difficulty of entering or reaching a destination market, consistent with high quality firms being the most competitive ones. Kugler and Verhoogen (2011), Manova and Zhang (2011) and Verhoogen (2008) argue that export prices are related to input prices via the choice of product quality, which tends to be increasing in firm capability. Finally, Hummels and Klenow (2002) and Hallak (2010) illustrate the usefulness of quality heterogeneity in relating country size to export prices and the size of trade flows.

Importantly, the studies above largely abstract from the influence of variable markups across exporters on the pattern of prices.[1] In a similar manner, studies measuring the markups of exporting firms also tend to do so in isolation of the influence of quality on average prices. Recent examples of markup estimation in the international trade literature

[1] To be sure, in some instances the patterns generated by quality differentiation are different than one would expect due to variation in markups. In those cases it is possible to distinguish, at least qualitatively, between price effects due to quality and markups. However, since none of these studies attempts to measure markups, they are silent on the exact quantitative relationship between these factors and prices.

include De Loecker and Warzynski's (2010) plant-level estimates for Slovenian manufacturers, as well as Feenstra and Weinstein (2010), mentioned above. In either case, either the empirical identification or underlying model is not one which explicitly accounts for quality differentiation.[2]

The intuition for my joint estimation of an industry's markups, marginal cost and quality differentiation is that the observed distribution of international trade prices is the sum of the underlying distributions of markups and marginal costs, where the costs include those embodied in higher quality varieties in addition to other input costs. Estimating the distribution of markups and the distribution of marginal cost thus requires one to assume knowledge of the shape of the markup and productivity distributions in each industry. This assumption will ground the resulting estimates in a well-documented empirical fact: the size distribution of firms in an industry tends to follow a power law or similarly fat-tailed distribution. Buttressing this fact are studies of firm-level data which have found a significant and persistent degree of concentration of sales in the largest firms (Axtell, 2001), that this concentration is related to the decision to export (Bernard and Jensen (1999), onwards).[3] Taken together, these facts imply an exporter size distribution with a long right tail. Theoretical contributions have taken these cues and have specified the underlying distribution of firm productivity accordingly: Weibull in the case of Eaton and Kortum (2002), or Pareto in the case of Melitz (2003). Here, we will assume that the underlying productivity distribution of firms follows a Pareto distribution and then analyze the estimates of average markups and marginal costs under various assumptions about the distribution of markups across exporters.

The paper is organized as follows. The next section describes the impact of China's exports on the distribution of US import prices. Section 2 derives estimators that use the moments of the import price distribution to decompose prices into markup and quality components. Then, Section 4 uses the estimates to examine China's contribution to changes in markups and the product quality of US imports. Section 5 concludes.

[2] De Loecker, Goldberg, Khandelwal and Pavcnik (2012) is an exception in that input prices are modelled as a function of quality differences across outputs.

[3] di Giovanni, Levchenko and Rancière (2011) argue that the firm size distribution is itself a function of the intensity of international trade. Nontheless, in their setup the distribution of exporters and non-exporters are both characterized by a power-law.

# 1 China's effect on the distribution of US import prices

In this section, the effect of Chinese exports on the distribution of US import prices is documented. Import prices are defined at the level of detailed products and source countries using US customs data on import values and quantities.[4] The average unit value for a given product (indexed by $j$), exporting country (indexed by $i$), and frequency (indexed by $t$) is:

$$p_i^j = \frac{\sum_{t=2002}^{2006} M_{it}^j}{\sum_{t=2002}^{2006} Q_{it}^j}$$

where $M_{it}^j$ and $Q_{it}^j$ are the annual dollar value and quantity, respectively, of bilateral imports for a Harmonized System 10-digit product (HS10). It will be very important below to obtain an accurate measure of the cross-sectional distribution of import prices across source countries. Therefore, in order to mitigate some of the noisiness of the data at that fine a level of product aggregation (for example, due to infrequent trading), a relatively broad, five year time frame is adopted, from 2002 through 2006. Another reason to choose these dates is that 2002 and 2007 corresponded to broad changes in the HS10 classification scheme, which makes the intervening interval the most comparable over time. Consistent with other studies, we do a basic cleaning of the data by dropping any observations with $Q_{it}^j = 0$ or $M_{it}^j < \$10,000$.

We begin with the observation that China is nearly ubiquitous in US import product space over the period 2002-6. As detailed in Table 1, of the 15,980 HS10 products in the US customs data, China participated in 76 percent. That is, at least one year between 2002 and 2006 was characterized by Chinese imports greater than $10,000 in over three quarters of product categories. Weighting the count of products by import value, the rate of Chinese import participation rises to 87 percent. It is also noteworthy that the share of products with Chinese exports tends to vary a lot by sector, with agricultural and commodity products having relatively lower rates. Textiles, apparel and industrial products such as machinery and plastics had among the highest rates, followed by stones, metals and chemicals. In general, Chinese participation tended to be higher in more differentiated

[4] The data source is described in Feenstra, Romalis and Schott (2002).

manufactures relative to more homogeneous commodities.

In addition to broad participation in US imports categories, Chinese exports exert substantial influence on the distribution of prices within those categories. Table 2 displays the average mean and standard deviation of HS10 prices within each sector, computed both with and without China. The difference between the with and without statistics is a measure of the average contribution of China to the level and dispersion of prices. On average, the level of US import prices in a category was 2.2 percent lower and the standard deviation was 0.5 percent higher due to China. These effects tended to be most pronounced in the sectors with the highest China participation as well as those with the highest level of differentiation. One can think of the dispersion of prices within an HS10 as a proxy for its level of differentiation, since large prices among homogeneous varieties should largely be arbitraged away. Indeed, the largest price effects due to China are in the four sectors with average price dispersion of over 100 log points.

We also observe that the contribution of US imports from China to average product price is related systematically to their effect on price dispersion; products in which China's effect on average prices is high are those in which China's contribution to dispersion are also high. As illustrated in Figure 1, in the majority of HS10 products in which China participated – 10,312 out of 12,170 to be precise – China prices pulled down the average product price (i.e., the difference between average price with and without China is negative). Further, the more negative was China's relative price, the greater was its contribution to the variance of prices for that product. This was also the case in the minority of instances in which China had a relatively high price compared with other countries: higher relative prices corresponded to a higher contribution to price dispersion.

Finally, we document the contribution of Chinese export unit values to overall US import price changes over time, and find that it was much more pronounced in industries that China recently entered relative to incumbent industries. In other words, China contributed most to unit value changes in the products it began exporting to the US over the 2002 to 2006 period. To evaluate price changes over time, we compute similar statistics for the 1997-2001 period and then match those to industries in the 2002-6 period.[5] The top panel of Table

[5] Given the changes made to the HS classification in 2002, we attempt several different matching schemes of products in the early and later periods. The simplest, and the one which is presented, is to treat the products in the early and late periods as strictly comparable. An alternative classification scheme which

3 shows the contribution of China to price changes between the early and late periods, for products in which China participated in both periods. Both overall and across sectors, the difference between average price changes computed with and without China is modest, even in industries with rather large price changes in absolute terms. China's average contribution to import price changes for an HS product was -0.2 percent. This story is drastically different when we restrict our attention to the roughly 2,000 products that the US began importing from China in the more recent period. For those categories, China contributed an average of -5.2 percent to import price changes at the HS10 level.

It is also case that the mean and standard deviation of US import price changes due to China are systematically related, though this relationship depends on whether China recently entered the import market. The bottom panel of Figure 2 shows the same 'V' pattern for price changes of recently entered products as Figure 1 exhibited for price *levels*. That is, larger price changes due to China corresponded to larger increases in price dispersion due to China. However, for the set of products in which China participated during both periods, this relationship is no longer apparent, shown in the top panel of Figure 2. Even when China contributed substantially to price increases or declines, it did not do so in a way that systematically altered the dispersion prices in a product.

# 2 Estimating markups, productivity and quality

Having established that exports from China have had a meaningful effect on the distribution of US import prices, in this section method of moments estimators are derived for the marginal cost and markup components of import prices as a function of that distribution. Starting from the identity:

$$\ln p_i = \ln \rho_i + \ln MC_i \tag{1}$$

where

$$\ln MC_i = \beta \ln \varphi_i, \tag{2}$$

$\varphi_i$ is a measure of country-specific productivity and $\rho_i$ is that country's average markup, the objective is to decompose the observed moments of prices into a distribution for markups,

accounts for HS changes over time (suggested by Pierce and Schott, 2012) is also implemented, though the qualitative and quantitative exercises below are little changed as a result.

a distribution for productivity, and the covariance of markups and productivity. The parameter $\beta$ is the elasticity of marginal cost to productivity, and can be interpreted as the length of each product's quality ladder. In relatively homogeneous products, $\beta$ is negative and high productivity exporters set relatively low prices; vice versa applies for products with a high degree of quality differentiation.

Given this definition of price, the first three moments of prices within a given product group can be expressed generically as:[6]

$$\begin{aligned}
E[\ln p_i] &= E[\ln \rho_i] + \beta E[\ln \varphi_i] && (3)\\
Var[\ln p_i] &= Var[\ln \rho_i] + \beta^2 Var[\ln \varphi_i] + 2\beta cov[\ln \rho_i, \ln \varphi_i] && (4)\\
\frac{Skew[\ln p_i]}{Var[\ln p_i]^{-\frac{3}{2}}} &\approxeq \frac{Skew[\ln \rho_i]}{Var[\ln \rho_i]^{-\frac{3}{2}}} + \beta^3 \frac{Skew[\ln \varphi_i]}{Var[\ln \varphi_i]^{-\frac{3}{2}}} - 3\beta cov[\ln \rho_i, \ln \varphi_i] \\
&\quad + \frac{3}{2} Var[(\ln p_i)]^2 - \frac{3}{2} Var[\ln \rho_i]^2 - \frac{3}{2} Var[\beta \ln \varphi_i]^2 && (5)
\end{aligned}$$

The second expression is the familiar decomposition of a variance into the variance of its components and their covariance. Analogously, the third expression splits the skewness of log prices into contributions from the skewness of log markups, the skewness of log productivity and a number of cross terms approximated by the variances and covariance. Of course, the moments of the markup and productivity distributions, not to mention $\beta$, are unobserved in the international trade data. To achieve identification, enough restrictions need to be made so as to reduce the number of unknowns on the right-hand side to three.

We consider two types of restrictions: distributional and parametric. The distributional assumptions take a stand on the shape of the productivity and markup distributions; assumptions of this sort reduce the dimensionality of the right-hand side variables by expressing each moment of a distribution in terms of the smaller number of that distribution's parameters. These assumptions also leverage prior empirical studies documenting the shape of the firm size distribution. The second group of restrictions consists of additional assumptions about the parameters of the markup and productivity distribution. These assumptions are grounded in theory in the sense that different assumptions about the consumer's demand

[6] See the appendix for the derivation of (5).

curve or the firm's production function are consistent with different configurations of moment restrictions. In the following two sub-sections, we will work with the moment equations (3)-(5) under various assumptions about the markup and productivity distributions across exporters.

## 2.1 Case I: Constant markups and heterogeneous quality across exporters (i.e., CES plus quality differentiation)

In order to build intuition for how the estimator works, our first case applies the most restrictive distributional assumption about the range of markups across exporters. Let us assume that the utility function for a given product group is a constant elasticity aggregate of varieties in that product group. This assumption implies that markups are a constant across exporters ($E[\ln \rho_i] = \ln \rho, \nabla i$) and it follows immediately that $Var[\ln \rho_i] = 0$, $Skew[\ln \rho_i] = 0$, and $cov[\ln \rho_i, \ln \varphi_i] = 0$, which reduces the moment equations above to:

$$E[\ln p_i] = \ln \rho + \beta E[\ln \varphi_i] \quad (6)$$

$$Med[\ln p_i] = \ln \rho + \beta Med[\ln \varphi_i] \quad (7)$$

$$\frac{Skew[\ln p_i]}{Var[\ln p_i]^{-\frac{3}{2}}} = \beta^3 \frac{Skew[\ln \varphi_i]}{Var[\ln \varphi_i]^{-\frac{3}{2}}} \quad (8)$$

Since the markup distribution degenerates to a point, $\ln \rho$, the shape of the price distribution is driven exclusively by the shape of the productivity distribution. The last line uses the fact that $Var[\ln p_i] = Var[\beta \ln \varphi_i]$ to express the skewness of prices only in terms of the skewness of the productivity distribution and the cube of the quality scope parameter $\beta$. Also note that when the only source of variation across firms is productivity, the median can also be used as an *additional* equation in the system.

Our choice of distribution for productivity borrows from the stylized fact that firm sizes within an industry are distributed according to (or close to) a power-law. Therefore, we shall assume that the log of productivity is exponentially distributed with shape parameter $\lambda$: $\ln \varphi \sim \exp(\lambda)$, $\lambda > 0$. This assumption would be exactly correct if $\varphi$ followed a Pareto distribution with scale parameter 1 and shape parameter $\lambda$. Assuming that $\varphi \sim pareto(1, \lambda)$

implies that $\ln\varphi \sim \exp(\lambda)$ with inverse scale parameter $\lambda$ and probability density function:

$$f(\ln\varphi;\lambda) = \lambda e^{-\lambda \ln\varphi} \tag{9}$$

The equations above can then be re-expressed in terms of the parameter $\lambda$.

$$E[\ln p_i] = \ln\rho + \frac{\beta}{\lambda} \tag{10}$$

$$Med[\ln p_i] = \ln\rho + \ln 2\frac{\beta}{\lambda} \tag{11}$$

$$\frac{Skew[\ln p_i]}{Var[\ln p_i]^{-\frac{3}{2}}} = 2\left(\frac{\beta}{\lambda}\right)^3 \tag{12}$$

which is an overidentified system of 3 equations in 2 unknowns: $\ln\rho$ and $\frac{\beta}{\lambda}$. The interpretation of $\ln\rho$ is the average (log) markup for a particular HS10 product. The object $\frac{\beta}{\lambda}$ is a composite of the quality ladder length parameter, $\beta$, and the inverse scale parameter of the productivity distribution, $\frac{1}{\lambda}$; we can interpret this object as the dispersion of marginal costs in a product group either driven by the extent of quality differentiation or differences in firm ability. Yet another way of saying this is that $\frac{\beta}{\lambda}$ is a proxy for product differentiation, whether vertical ($\beta$) or horizontal ($\frac{1}{\lambda}$).

Note that although the sign of $\frac{\beta}{\lambda}$ is determined by $\beta$, the magnitudes of the numerator and denominator are not separately identifiable. That is to say, the scale parameter of the productivity distribution and the scope for quality differentiation in an industry affect the price distribution in similar ways. Solving the first two equations for $\ln\rho$ and $\frac{\beta}{\lambda}$ yields the following closed form solutions for the estimators:

$$\widehat{\frac{\beta}{\lambda}} = \frac{E[\ln p_i] - Med[\ln p_i]}{(1-\ln 2)}$$

$$\widehat{\ln\rho} = Med[\ln p_i] - \frac{(\ln 2)}{(1-\ln 2)}E[\ln p_i].$$

## 2.2 Case II: Variable markups and heterogeneous quality across exporters

Our second case is much more general, in that it allows for heterogeneous productivity, markups and quality across exporting firms. Again, identification of the underlying productivity distribution, markup distribution and the sign of the quality elasticity is achieved by assuming a shape for both the productivity and markup distributions. We maintain our assumption from above that $\ln\varphi \sim \exp(\lambda_\varphi)$.

One's prior for the shape of the distribution of markups across firms is somewhat less developed, though an important class of recent models with variable markups have suggested that is also looks much like a Pareto. In de Blas and Russ (2012) an extension of the Bernard, Eaton, Jensen and Kortum (2003) model featuring Pareto productivity under Bertrand competition gives rise to a Pareto distribution of markups. In Atkeson and Burstein (2008), Cournot competition gives rise to a density of markups which looks similar to a Pareto distribution. Thus, we shall assume that markups also follow a Pareto distribution which implies: $\ln\rho \sim \exp(\lambda_\rho)$, $\lambda_\rho > 0$.

The moment equations can now be re-expressed in terms of the parameters of these two exponential distributions:[7]

$$
\begin{aligned}
E[\ln p_i] &= \frac{1}{\lambda_\rho} + \frac{\beta}{\lambda_\varphi} \\
Var[\ln p_i] &= \left(\frac{1}{\lambda_\rho}\right)^2 + \left(\frac{\beta}{\lambda_\varphi}\right)^2 + 2\beta cov[\ln\rho_i, \ln\varphi_i] \\
\frac{Skew[\ln p_i]}{Var[\ln p_i]^{-\frac{3}{2}}} &\approxeq 2\left(\frac{1}{\lambda_\rho}\right)^3 + 2\left(\frac{\beta}{\lambda_\varphi}\right)^3 - 3\beta cov[\ln\rho_i, \ln\varphi_i] - \frac{3}{2}Var[\ln p_i] \\
&\quad + \frac{3}{2}\left(\frac{1}{\lambda_\rho}\right)^2 + \frac{3}{2}\left(\frac{\beta}{\lambda_\varphi}\right)^2
\end{aligned}
$$

Taken together, the mean, variance and skewness of prices are a system of three equations in three unknowns: $\lambda_\rho$, $\frac{\beta}{\lambda_\varphi}$and $\beta cov[\ln\rho_i, \ln\varphi_i]$. Substituting $\frac{\beta}{\lambda_\varphi} = E[\ln p_i] - \frac{1}{\lambda_\rho}$ and $\beta cov[\ln\rho_i, \ln\varphi_i] = \frac{1}{2}Var[\ln p_i] - \frac{1}{2}\left(\frac{1}{\lambda_\rho}\right)^2 - \frac{1}{2}\left(\frac{\beta}{\lambda_\varphi}\right)^2$ into the final expression gives a quadratic

[7] See Appendix for a more detailed derivation of the skewness decomposition.

equation in terms of only $\frac{1}{\lambda_\rho}$ and the observed moments of prices:

$$\begin{aligned} 0 &= 6\left[E[\ln p_i]+1\right]\left(\frac{1}{\lambda_\rho}\right)^2 - 6\left[E[\ln p_i]^2 + E[\ln p_i]\right]\frac{1}{\lambda_\rho} \\ &+3E[\ln p_i]^2 + 2E[\ln p_i]^3 - Skew[\ln p_i]Var[\ln p_i]^{\frac{3}{2}} - 3Var[\ln p_i] \end{aligned} \tag{13}$$

The solution algorithm to this system of equations yields the roots of the above equation subject to the constraints: $\lambda_\rho > 0 \in \mathbb{R}$ and $\lambda_\varphi > 0 \in \mathbb{R}$.

## 2.3 Case III: Allowing for measurement error in prices

As we will see below, there are a large number of HS10 import industries that do not have an exact, real solution for the Case II estimator (13). One reason that may occur is that the observed moments of import prices are imperfect measures of the true underlying import price distribution. I deal with the possibility of measurement error by simulating the markup and productivity distributions for a range of plausible parameter values. The preferred combination of parameters for each industry will be the one that minimizes the Euclidean distance between the implied price distribution and the observed one.

To be concrete, let us consider a very simple type of error where only the mean price ($E[\ln p_i]$) is mismeasured by a scalar $\varepsilon_1$. Each subsequent moment equation would be biased by an increasing power of $\varepsilon_1$; variance would be mismeasured by some function $f(\varepsilon_1^2)$, and skewness would be mismeasured by some function $f(\varepsilon_1^3)$. This follows directly from the fact that the variance of prices is a function of the square of $E[\ln p_i]$, and the skewness of prices is a function of the cube of $E[\ln p_i]$. I perform a search of the grid: $\frac{1}{\lambda_\rho} = [-0.2, 2.0]$, $\frac{\beta}{\lambda_\varphi} = [-2.0, 2.0]$, and $\beta cov[\ln \rho_i, \ln \varphi_i] = [-2.0, 2, 0]$, by increments of 0.1 within each parameter range. The optimal combination of parameters for each industry minimizes the sum of squared errors across the three moment equations, where the error of each subsequent moment is adjusted downwards exponentially so as not to overweight the errors of the higher moments:

$$\min_{\frac{1}{\lambda_\rho}, \frac{\beta}{\lambda_\varphi}, \beta cov[\ln \rho_i, \ln \varphi_i]} (\varepsilon_1)^{\frac{2}{1}} + f(\varepsilon_1^2)^{\frac{2}{2}} + f(\varepsilon_1^3)^{\frac{2}{3}} \tag{14}$$

The solution for the parameters of each industry satisfies (14), and I will consider only those solutions that lie on the interior of the grid space.

## 2.4 Evaluating the Case I-III estimators

Applying the estimators to the moments of the import price distribution, we can now evaluate the resulting markups and differentiation estimates against a selection of empirical and theoretical benchmarks. The first question one might ask is whether the estimated magnitude of markups is reasonable in comparison to previous studies. One suitable benchmark is a study by De Loecker and Warzynski (forthcoming), which provides several estimates of markups for Slovenian manufacturing plants based on a number of methodologies. Their estimates range from 1.03 to 1.12 using the methodologies of Hall (1986) and Klette (1999), respectively, to 1.2 using their own approach which extends Hall's to include a control for unobserved changes in plant productivity. They also find the variance across plants to be quite high and that exporters tend to have higher markups, on average, than non-exporters. Our estimates of average markups for US import industries will differ in their scope and composition; US imports include a much wider array of sectors, broader than only manufacturing, and we are additionally restricted to observing the subset of prices for exporting foreign firms.

The second criterion by which to judge our estimators is the relationship between markups and the degree of product differentiation, which we would expect to be positive: more differentiation corresponds to greater market power for each individual exporter, which should translate into higher average markups. Recall that our estimate of product differentiation is the set of parameters $\frac{\beta}{\lambda_\varphi}$. The clearest case of the relationship between markups and differentiation is for industries with long quality ladders ($\beta > 0$): for that range of parameters, both higher $\beta$ and $\frac{1}{\lambda_\varphi}$ indicate a higher level of product differentiation. The relationship is ambiguous for less quality differentiated industries ($\beta < 0$), however, since over that range a larger magnitude of $\beta$ implies less quality differentiation and lower markups, whereas higher $\frac{1}{\lambda_\varphi}$ still implies more productivity dispersion and higher markups.

The third criterion for evaluating the estimators is the number of products with long quality ladders versus short quality ladders. This criterion is related to prior research showing that average export prices are increasing in exporter productivity and destination income. Since these statistics are indicative of quality differentiated industries – specifically, industries where the elasticity of marginal cost to productivity is positive – they imply that, on balance, there are more quality differentiated industries than less quality differentiated industries. That is, the number of industries with $\beta > 0$ is greater than the number with $\beta < 0$.[8]

Estimates from the Case I and Case II specifications are shown in Figure 3, where each histogram illustrates the density of markups ($exp(\frac{1}{\lambda_\rho})$) and product differentiation ($\frac{\beta}{\lambda_\varphi}$) across HS10 industries. The top panels, using the CES-based specification, illustrates several inconsistencies between the estimates and the criteria above for reasonable estimates. For one, there are a large number of observations with either markups of less than one, or else markups which are implausibly high. The median estimate across all 15,094 HS10 products in the 2002-2006 period is 7.60, over 5 times higher than one would expect based on the high end of the range of estimates in De Loecker and Warzynski. The second criterion is also not met by the CES-based estimator, since there is a negative estimated relationship between product differentiation and markups for the entire range of $\frac{\beta}{\lambda_\varphi}$. This statistic is summarized by the regression estimates in the top panel of Table 4. For each of the periods and for both positive and negative values of $\frac{\beta}{\lambda_\varphi}$, markups are lower for higher levels of product differentiation with an elasticity of around -1 for quality differentiated industries and around -2.3 for less quality differentiated industries. Moreover, the relationship is quite stable across time periods. Despite these shortcomings, the Case I estimator does do well in predicting that there are more quality differentiated industries than less-quality differentiated industries. In summary, while CES estimator has the advantage of extreme tractability (producing estimates for every industry) and allocates industries' quality differentiation in line with prior expectations, it misses along several other key dimensions.

The bottom panels show the results for the more flexible Case II estimator. In this case, there are only 3,937 products with real and positive solutions for both $\frac{1}{\lambda_\rho}$ and $\frac{\beta}{\lambda_\varphi}$. Despite the fact that only a minority of the roughly 15 thousand HS10 products have solutions, however, the estimates that were obtained fall much more closely in line with the criteria above. The median markup is 1.79, which is on the high end of the range in De Loecker and

[8] Consistent with this criterion, prior estimates of quality ladder length using trade data but different identification schemes, such as Khandelwal (2010) and Baldwin and Ito (2008), have found substantial numbers of products with long quality ladders.

Warzynski, but is quite plausible for the subset of exporters. The estimator also displays the expected positive relationship between markups and product differentiation for $\frac{\beta}{\lambda_\varphi} > 0$. Interestingly, the relationship between markups and differentiation reverses sign depending on the level of quality differentiation, as shown in the middle panel of Table 4. While the overall correlation between differentiation is negative and significant, there is a clear distinction between industries with high quality differentiation, where the relationship is positive and significant, and the more homogeneous industries. This result is consistent with the notion that a higher degree of dispersion in firm productivity translates into higher markups, even in industries that have little quality differentiation. On the third criterion, in contrast to Case I, the Case II estimator predicts that there are fewer industries with long quality ladders relative to those with short quality ladders, shown in the bottom-right panel of Figure 3. However, note the possibility that the small number of industries with solutions may be influencing this statistic. The Case III estimator will find solutions for many more industries under the same distributional assumptions.

We can use an additional criterion to evaluate the reasonableness of the Case I and II estimators, the covariance between markups and productivity. Recall that one of the outputs to the solution algorithm in the previous section was $\beta cov[\ln \rho_i, \ln \varphi_i]$. While there are very few empirical benchmarks for this relationship, most theories permitting variable markups across firms (such as Melitz and Ottaviano (2008) and Feenstra and Weinstein (2010)) imply that it is positive. That is because more productive firms obtain higher market share in an industry and hence command more market power and a higher markup. Although the CES-based estimator rules out this possibility by assumption of constant markups, the theoretical prediction is borne out, on average, in the Case II estimates. Figure 4 shows the density of estimates for $|\beta|\, cov[\ln \rho_i, \ln \varphi_i]$, which is simply $\beta cov[\ln \rho_i, \ln \varphi_i]$ divided by the sign of $\beta$. In spite of many estimates below zero, there is more density in the positive range than the negative. The median is a modest 0.05 and the average covariance, weighted by product size, is 0.57.

In summary, while the Case II estimator is more consistent with quantitative and qualitative benchmarks, its number of exact solutions is low. The idea of implementing the simulation technique described above (Case III) is to preserve the flexibility and desirable characteristics of the Case II estimator while expanding the number of products with solutions. Figure 5 illustrates that, in fact, controlling for possible measurement error in prices as described, the patterns of markups, product differentiation and the covariance of markups and productivity become even sharper. First, for the 12,244 HS10 products with interior solutions on the grid, the median markup is 2.0 with a much tighter concentration at lower values than Cases I or II; the interquartile range of markups is 1.35-3.32. It is also the case that there are a much larger number of industries with long quality ladders (9,920) than industries with short quality ladders (2,095), and that this makes the overall correlation between markups and differentiation positive. Finally, the Case III estimates provide compelling evidence of a positive covariance between markups and productivity, with over 75 percent of industries taking a value between zero and one.

# 3 The effect of China on markups and marginal cost

Given estimates of the decomposition of the average import price into a markup and a marginal cost term, we proceed to distinguish further between the contribution of Chinese exports from those of the rest of the world. The decomposition is straightforward: the moments of import prices are recomputed without China and fed back into the estimators. The difference between the implied average markup (or marginal cost) with and without China is then attributed to China. Using the Case II and III notation, China's markups and marginal cost can be rewritten:

$$\begin{aligned}\widehat{\left(\frac{1}{\lambda_\rho}\right)}_{i=China} &= \widehat{\left(\frac{1}{\lambda_\rho}\right)}_{i=all} - \widehat{\left(\frac{1}{\lambda_\rho}\right)}_{i\neq China} \\ \widehat{\left(\frac{\beta}{\lambda_\varphi}\right)}_{i=China} &= \widehat{\left(\frac{\beta}{\lambda_\varphi}\right)}_{i=all} - \widehat{\left(\frac{\beta}{\lambda_\varphi}\right)}_{i\neq China}\end{aligned}$$

China's contribution to product price changes can therefore be expressed as a function of changes in its components:

$$
\begin{aligned}
\triangle \ln p_{i=China} &= \triangle\left(\frac{1}{n}\sum_{i}^{n}\ln p_i\right) - \triangle\left(\frac{1}{n-1}\sum_{i\neq China}^{n-1}\ln p_i\right) \\
&= \triangle\widehat{\left(\frac{1}{\lambda_\rho}\right)}_{i=all} - \triangle\widehat{\left(\frac{1}{\lambda_\rho}\right)}_{i\neq China} \\
&\quad + \triangle\widehat{\left(\frac{\beta}{\lambda_\varphi}\right)}_{i=all} - \triangle\widehat{\left(\frac{\beta}{\lambda_\varphi}\right)}_{i\neq China}
\end{aligned}
$$

We are interested in measuring the relationship between the level of Chinese competition and the components of price change over time, with special attention paid to the prices of export competitors in the rest of the world (i.e., $i \neq China$). Similar to the analysis of China's contribution to price changes in Table 3, this expression matches HS10 products over time and then computes the change in their average unit value with and without China. Table 5 shows the estimates of these differences between the early period (1997-2001) and late period (2002-2006) under each of the three cases, weighting each underlying HS10 product by its average US import value over the two periods.

It is worth emphasizing that the decomposition of prices above does not identify an exogenous change in Chinese competition, so that a decline in the markups of non-Chinese exporters could be driven by any number of factors in addition to increasing Chinese exports. My approach will therefore be to explore different definitions of treatment for HS10 industries which one would expect to correspond to Chinese competition. It will be then be the relative change in markups and marginal cost of these treatment groups relative to the control industries which suggests the effect of Chinese competition. Of course, as the definition of treatment group will not be exogenous, this analogy to difference-in-differences analysis still does not control entirely for the endogenous sources of surging Chinese exports.

The first treatment group splits the sample into two types of industries: those in which China exported to the US in both periods (i.e., industries in which China was an incumbent exporter in the latter period) and those in which China began exporting to the US only in the latter period.[9] The top panel of Table 5 shows the average price, markup and marginal

[9] For the industries that China entered, there is obviously no estimate of either markup or marginal cost in the early period, and therefore the China changes represent the contribution of the *level* of China's markup or costs in the late period to US import prices.

cost changes for those products in which China was an incumbent exporter in the latter period. As documented in Table 3, the average price change due to China is quite moderate for continuing products, with the contribution hovering around zero across cases. However, this small price change masks heterogeneity among the components of price: across cases, the prices of Chinese exports tended to contribute to a slight decrease in average markups and a modest increase in marginal costs. The marginal costs of exports from the rest of the world were rising and, on balance, accounted for the bulk of price changes for those producers. Markup changes in the rest of the world did not have a consistent sign across cases, possibly reflecting the composition of industries for which solutions were obtained; I will show below that markup and marginal cost changes were very heterogeneous across US import sectors. For the set of entering Chinese varieties, shown in the bottom panel of Table 5, the low levels of Chinese export prices exerted substantial downward pressure on average prices. In contrast to incumbent industries, virtually all of the price declines due to China's entry are due to lower marginal costs, implying either relatively high productivity for the entering Chinese exporter or relatively low quality for the new Chinese varieties. China's relative markup upon entry was not substantially different from its competitors, as shown by the very slight contribution of China's markups to overall price changes. Prices for exports from the rest of the world were increasing in those industries, driven primarily by increasing marginal cost though, again, the sign of markup changes is ambiguous across cases.

Summarizing the aggregate dynamics of Chinese and rest-of-world prices, China's entry into an export product is typically at a relatively low cost level and similar markup level relative to competitors. Then, over time, the relative markup of Chinese exporters erodes and relative quality and cost begin to rise. Prices from exporters in the rest of the world were increasing over this period, largely driven by the marginal cost component of price and possibly due to the shifting composition of rest-of-world exports into higher quality varieties; consistent with this story, marginal cost increases for rest-of-world exporters were particularly large in the industries that China entered.

Underlying these aggregate trends are groups of industries with very heterogeneous price, markup and marginal cost behavior. For example, energy products and electronics manufactures have had very different price drivers over the past decade due to idiosyncratic supply and demand behavior as well as differences in market structure. Aggregating to the sector level, Figure 6 presents the weighted average changes in markups and marginal cost for the set of industries that China entered in 2002-6. Each bar averages the Case I and Case III estimates of those changes for a given sector. In the top panel, it is evident that some sectors, including electric machinery, footwear/headgear, transportation and mechanical/computers, had very large decreases in markups on the order of 10-30 percent (in units of import prices), while other sectors, including metals, stone/glass and mineral products, had very large increases in markups on the order of 20-40 percent (in units of import prices). There is also a difference in China's contribution to those changes among these groups of sectors, with China having larger, predominantly negative, contributions to markup changes in the first group and only slight contributions to markup changes in the second group. Also noteworthy is the coincidence of negative markup contributions by China and the rest of the world for the first group. Thus, for certain primary commodities, China's own commodity exports had little to do with the run up in the markup component of US import prices. Conversely, for the set of manufactured product sectors, China entered at a relatively low markup level at the same time as competing exporters made significant cuts to their markups.

The corresponding changes in marginal cost by sector are shown in the bottom panel of Figure 6. Though the majority of sectors experienced increases in their marginal cost component, the contribution of China's marginal cost to import prices was negative and highly concentrated in four sectors: transportation, mechanical/computers, plastics/rubber and textiles. In contrast to markups, where Chinese and rest-of-world markups both tended to decrease, the sectors where China's marginal costs pulled down prices corresponded to marginal cost *increases* in the rest of the world. In those industries, China entered into US imports at a relatively low marginal cost level, prompting an increase in the average quality and cost of their exports in addition to the decrease in their markups. Figure 7 reiterates that while the overall contours of markups and marginal costs look similar for industries with an incumbent Chinese competitor, China's contribution to changes in price is more limited in industries that it had already entered in some earlier period.

The relative changes in price components for industries in which China entered versus those with a Chinese incumbent are summarized in Figure 8.[10] Pro-competitive effects of China's entry are suggested by the relative change in markups and marginal cost of the

[10] Figure 8 contains a subset of the data reported in Table 5. First, the Case I and Case III estimates are aggregated over common HS10 industries, weighted by average industry size. Then, an unweighted average of the two cases is shown by each bar in Figure 8.

rest-of-world exporters. Markups in the rest of the world were growing for all industries containing a Chinese exporter, on the order of 2 percent, but at a 1 percentage point *slower* pace in industries with a Chinese entrant. Analogously, marginal costs in the rest of the world were increasing for all industries, but at a 4 percentage point *faster* pace in industries with a Chinese entrant, roughly double the growth rate in China's incumbent industries. And, again, the relatively low price of Chinese entrants is shown by the negative markup and marginal cost contributions to price changes for entering Chinese exporters, which contrasts with the modestly positive contributions in China's incumbent industries.

The claim that increasing Chinese competition is related to changes in the markups and quality of other exporters has thus far identified increasing competition as Chinese entry into an industry. Another way of characterizing the rising Chinese presence is to look at the evolution of China's market share in US imports of an industry. Given China's small presence in US commodity imports, it will be helpful to abstract from the set of primary commodity products and to focus on the seven manufacturing sectors with the most pronounced decreases in markups, namely: electric machinery, footwear/headgear, transportation, mechanical/computers, wood products, textiles, and plastics/rubber. Figure 9 shows the average estimates of markups and marginal costs for these sectors sorted by the size of China's market share change in each industry; the left-most bar is the weighted average of industries in the bottom decile of China share changes while the right-most bar is the weighted average of industries in the top decile of China share changes. The overall change in markups for these sectors was a decrease of about 4 percentage points, though the markups in industries with the greatest increase in China market share declined by almost 17 percentage points. In contrast, the industries with the smallest China share increases experienced *increases* in their average markup of almost 7 percentage points. Similar to Figure 6, most of the markup declines were for non-Chinese exporters, especially for industries in which China increased its share by a lot, while China itself contributed only modestly to the overall decline. With regard to marginal costs, overall increases were driven primarily by non-Chinese exporters in industries with large increases in Chinese export share. These results are consistent with the idea that increasing Chinese competition contributed to other exporters decreasing their markups and shifting the composition of their exports to higher quality.

Finally, another gauge of changing competition is the rate of entry of new suppliers. In the international trade data, we observe the rate at which new supplier countries enter into a given industry; the average rate of entry for non-Chinese suppliers in the set of industries in Figure 9 is shown by the right-most set of bars. Interestingly, in the industries with the largest increases in China's market share, the rate of entry of new suppliers was considerably higher than the overall average. This is consistent with our earlier interpretation of intensifying competition leading to falling average markups and a shift into higher quality exports. However, ascribing all of the pro-competitive effects as being caused by China may overstate China's role. Rather, China's expansion was likely but one part of a broader trend of entry and tougher competition in those industries.

# 4 Concluding remarks

This paper suggests an easily implementable decomposition of unit values into markup and marginal cost components. As demonstrated above, the resulting estimates of these components are quite reasonable even when applied to industry-level trade data. The estimators suggest that the intensification of exports from China in the early to mid-2000s significantly influenced the levels of markups and marginal costs of exporters to the US, with the rest of the world shrinking markups and increasing their marginal costs. The fact that more intense competition corresponded with increasing marginal costs strongly suggests that the composition of non-Chinese exports shifted towards higher quality varieties. These results provide some of the first evidence of the dual nature of international trade's pro-competitive effects; exporters respond to tougher competition along the two related margins of price and quality.

While the analysis above is based on relatively aggregate data, in principle the same estimators could be used to decompose micro-level prices into markups and costs to provide even richer characterizations of pricing behavior for producers within the same exporting country. The only crucial inputs are dependable measures of the moments of prices and a stance on the shape of the two underlying markup and cost distributions. In this exercise, the fact that the power law distribution of markups was more in line with the price data than that implied by a constant elasticity of substitution demonstrates the potential of the estimator as a tool to discern among models.

Finally, the finding of dual pro-competitive effects may have implications for the degree of gains to international trade. In Edmond, Midrigan and Xu (2012), the pro-competitive effects of trade on markups are shown to be potentially quite large and positive, in contrast to other models such as Arkolakis, Costinot and Rodriguez-Clare (2012) and Arkolakis, Costinot, Donaldson and Rodriguez-Clare (2012). The key distinction between these models is that, in the former, the markup distribution is a function of trade policy. This implies that the pro-competitive contraction of markups is an *additional* source of gains from trade. My conjecture is that there exists a similar result for the distribution of import quality. The welfare implications of a the distribution of quality are not pinned down in a model with CES preferences; CES consumers are ambivalent between a large quantity of low quality varieties and a low quantity of high quality varieties. However, in a setting with non-homothetic preferences, demand for quality is a function of income and certain low quality varieties would not be consumed at all in rich countries. The composition of quality in such a setting may be both a function of trade policy and a contributor to consumer welfare.

# References

[1] Amiti, Mary and Amit Khandelwal (2011), "Import Competition and Quality Upgrading," forthcoming in *The Review of Economics and Statistics.*

[2] Arkolakis, Costas, Arnaud Costinot, and Andres Rodriguez-Clare (2012): "New Trade Models, Same Old Gains?," *American Economic Review*, 102(1), 94-130.

[3] Arkolakis, Costas, Arnaud Costinot, Dave Donaldson, and Andres Rodriguez-Clare (2012): "The Elusive Pro-Competitive Effects of Trade." mimeo.

[4] Atkeson, Andrew and Ariel Burstein (2008): "Pricing to Market, Trade Costs, and International Relative Prices." *American Economic Review,* 98(5): 1998-2031.

[5] Autor, David H., David Dorn, and Gordon H. Hanson (2012), "The China Syndrome: Local Labor Market Effects of Import Competition in the United States." NBER Working Paper No. 18054.

[6] Axtell, Robert L. (2001), "Zipf Distribution of U.S. Firm Sizes," *Science,* 293(5536), pp. 1818-1820.

[7] Baldwin, Richard, and James Harrigan. 2011. "Zeros, Quality, and Space: Trade Theory and Trade Evidence." *American Economic Journal: Microeconomics*, 3(2): 60–88.

[8] Baldwin, Richard Tadashi Ito (2008): "Quality Competition Versus Price Competition Goods: An Empirical Classification." NBER Working Paper No. 14305.

[9] Bernard, Andrew B. and J. Bradford Jensen (1999) "Exceptional Exporter Performance: Cause, Effect, or Both?", *Journal of International Economics*, 47(1), 1-25.

[10] Bernard, Andrew B., Jensen, J. Bradford and Schott, Peter K. (2006), "Survival of the best fit: Exposure to low-wage countries and the (uneven) growth of U.S. manufacturing plants," *Journal of International Economics*, 68(1), pages 219-237.

[11] Bernard, Andrew, Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum (2003): "Plants and Productivity in International Trade." *American Economic Review,* 93(4): 1268-1290.

[12] de Blas, Beatriz and Katheryn N. Russ (2012): "Understanding Markups in the Open Economy." NBER Working Paper No. 16587.

[13] De Loecker, Jan and Frederic Warzynski (2011), "Markups and Firm-Level Export Status," forthcoming in *American Economic Review*.

[14] De Loecker, Jan, P. Goldberg, A. Khandelwal and N. Pavcnik (2012), "Prices, Markups and Trade Reform," mimeo.

[15] di Giovanni, Julian, Andrei A. Levchenko and Romain Rancière, (2011): "Power laws in firm size and openness to trade: Measurement and implications." *Journal of International Economics*, 85(1), pp. 42-52.

[16] Eaton, Jonathan and Kortum, Samuel (2002) "Technology, Geography, and Trade," *Econometrica*, 70(5), 1741-1779.

[17] Edmond, Chris, Virgiliu Midrigan and Daniel Yi Xu (2012): "Competition, Markups, and the Gains from International Trade," NBER Working Papers 18041.

[18] Feenstra, Robert C. and John Romalis (2012): "International Prices and Endogenous Quality," NBER Working Papers 18314.

[19] Feenstra, Robert C., John Romalis, and Peter K. Schott (2002): "U.S. Imports, Exports, and Tariff Data, 1989-2001." NBER Working Paper #9387, December.

[20] Feenstra, Robert C. and Shang-Jin Wei (forthcoming): *China's Growing Role in World Trade.* Robert Feenstra and Shang-Jin Wei, Editors. National Bureau of Economic Research.

[21] Feenstra, Robert C. and David E. Weinstein (2010), "Globalization, Markups and the U.S. Price Level." NBER Working Paper 15749.

[22] Gervais, Antoine (2011), "Product Quality, Firm Heterogeneity and International Trade," mimeo.

[23] Hall, R.E. (1986). "Market Structure and Macroeconomic Fluctuations." Brookings Papers on Economic Activity 2, 285-322.

[24] Juan Carlos Hallak & Peter K. Schott, 2011. "Estimating Cross-Country Differences in Product Quality," *The Quarterly Journal of Economics*, Oxford University Press, vol. 126(1), pages 417-474.

[25] Houseman, Susan, Christopher Kurz, Paul Lengermann and Benjamin Mandel (2011), "Offshoring Bias in U.S. Manufacturing." *Journal of Economic Perspectives*, 25(2): 111-32.

[26] Johnson, Robert C. (2012): "Trade and Prices with Heterogeneous Firms," *Journal of International Economics*, 86(1).

[27] Khandelwal, Amit (2010), "The Long and Short (of) Quality Ladders," *Review of Economic Studies*, 77(4), 1450-1476.

[28] Klette, T. J. (1999). "Market Power, Scale Economies and Productivity: Estimates from a Panel of Establishment Data." *Journal of Industrial Economics,* 47(4), 451-476.

[29] Kugler, Maurice and Eric Verhoogen (2012), "Prices, Plant Size, and Product Quality," *Review of Economic Studies*, 79(1), pp. 307-339

[30] Melitz, Marc J. (2003) "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", *Econometrica*, 71, 1695-1725.

[31] Melitz, Marc J. & Giancarlo I. P. Ottaviano (2008): "Market Size, Trade, and Productivity," *Review of Economic Studies*, 75(1), pages 295-316, 01.

[32] Pierce, Justin R. and Peter K. Schott (2012): "Concording U.S. Harmonized System Categories Over Time." *Journal of Official Statistics*, 28:1, pp. 53-68.

[33] Schott, Peter K. (2008): "The relative sophistication of Chinese exports," *Economic Policy*, 23(53), pp. 5-49.

[34] Verhoogen, Eric (2008), "Trade, Quality Upgrading and Wage Inequality in the Mexican Manufacturing Sector." *Quarterly Journal of Economics*, 123(2), pp. 489-530.

## Appendix: Decomposition of price skewness into markups and productivity

$$
\begin{aligned}
Skew[\ln p_i] &= \frac{\sum_{i=1}^{k} \frac{1}{k} \left(\ln p_i - E[\ln p_i]\right)^3}{\left[\sum_{i=1}^{k} \frac{1}{k} \left(\ln p_i - E[\ln p_i]\right)^2\right]^{\frac{3}{2}}} \\
\frac{Skew[\ln p_i]}{Var[\ln p_i]^{-\frac{3}{2}}} &= \sum_{i=1}^{k} \frac{1}{k} \left(\ln p_i - E[\ln p_i]\right)^3 \\
&= \sum_{i=1}^{k} \frac{1}{k} \left(\ln \rho_i - E[\ln \rho] + \beta \ln \varphi_i - \beta E[\ln \varphi]\right)^3 \\
&= \frac{Skew[\ln \rho_i]}{Var[\ln \rho_i]^{-\frac{3}{2}}} + \beta^3 \frac{Skew[\ln \varphi_i]}{Var[\ln \varphi_i]^{-\frac{3}{2}}} - 6cov[\ln \rho_i, \beta \ln \varphi_i] \\
&\quad +3cov[(\ln \rho_i)^2, \beta \ln \varphi_i] + 3cov[\ln \rho_i, (\beta \ln \varphi_i)^2] \\
&= \frac{Skew[\ln \rho_i]}{Var[\ln \rho_i]^{-\frac{3}{2}}} + \beta^3 \frac{Skew[\ln \varphi_i]}{Var[\ln \varphi_i]^{-\frac{3}{2}}} - 6cov[\ln \rho_i, \beta \ln \varphi_i] \\
&\quad +\frac{3}{2} \left\{Var[(\ln \rho_i)^2 + \beta \ln \varphi_i] - Var[(\ln \rho_i)^2] - Var[\beta \ln \varphi_i]\right\} \\
&\quad +\frac{3}{2} \left\{Var[\ln \rho_i + (\beta \ln \varphi_i)^2] - Var[\ln \rho_i] - Var[(\beta \ln \varphi_i)^2]\right\} \\
&= \frac{Skew[\ln \rho_i]}{Var[\ln \rho_i]^{-\frac{3}{2}}} + \beta^3 \frac{Skew[\ln \varphi_i]}{Var[\ln \varphi_i]^{-\frac{3}{2}}} - 3cov[\ln \rho_i, \beta \ln \varphi_i] - \frac{3}{2} Var[\ln p_i] \\
&\quad +\frac{3}{2} Var[(\ln \rho_i)^2 + \beta \ln \varphi_i] - \frac{3}{2} Var[(\ln \rho_i)^2] \\
&\quad +\frac{3}{2} Var[\ln \rho_i + (\beta \ln \varphi_i)^2] - \frac{3}{2} Var[(\beta \ln \varphi_i)^2]
\end{aligned}
$$

**Case II skewness decomposition**

$$
\begin{aligned}
\frac{Skew[\ln p_i]}{Var[\ln p_i]^{-\frac{3}{2}}} &= \frac{Skew[\ln \rho_i]}{Var[\ln \rho_i]^{-\frac{3}{2}}} + \beta^3 \frac{Skew[\ln \varphi_i]}{Var[\ln \varphi_i]^{-\frac{3}{2}}} - 3cov[\ln \rho_i, \beta \ln \varphi_i] - \frac{3}{2} Var[\ln p_i] \\
&\quad - \frac{3}{2} Var[(\ln \rho_i)^2] - \frac{3}{2} Var[(\beta \ln \varphi_i)^2] \\
&\quad + \frac{3}{2} Var[(\ln \rho_i)^2 + \beta \ln \varphi_i] + \frac{3}{2} Var[\ln \rho_i + (\beta \ln \varphi_i)^2] \\
&= 2\left(\frac{1}{\lambda_\rho}\right)^3 + 2\left(\frac{\beta}{\lambda_\varphi}\right)^3 - 3\beta cov[\ln \rho_i, \ln \varphi_i] - \frac{3}{2} Var[\ln p_i] \\
&\quad - 30\left(\frac{1}{\lambda_\rho}\right)^4 - 30\left(\frac{\beta}{\lambda_\varphi}\right)^4 \\
&\quad + \frac{3}{2} Var[(\ln \rho_i)^2 + \beta \ln \varphi_i] + \frac{3}{2} Var[\ln \rho_i + (\beta \ln \varphi_i)^2] \\
&\approxeq 2\left(\frac{1}{\lambda_\rho}\right)^3 + 2\left(\frac{\beta}{\lambda_\varphi}\right)^3 - 3\beta cov[\ln \rho_i, \ln \varphi_i] - \frac{3}{2} Var[\ln p_i] \\
&\quad + \frac{3}{2}\left(\frac{1}{\lambda_\rho}\right)^2 + \frac{3}{2}\left(\frac{\beta}{\lambda_\varphi}\right)^2
\end{aligned}
$$

The second line exploits the fact that the square of an exponentially distributed variable with inverse scale parameter $\lambda$ is a Weibull distribution with the same scale parameter and a shape parameter of $\frac{1}{2}$. The final equality approximates $(\ln \rho_i)^2 + \beta \ln \varphi_i$ with the sum of two independent chi-squared random variables with variances matching those of the Weibull variable $(\ln \rho_i)^2$ and exponential variable $\beta \ln \varphi_i$. The expression for $\ln \rho_i + (\beta \ln \varphi_i)^2$ is approximated analogously. These approximations simplify the final expression considerably by cancelling out the quartic Weibull variances.

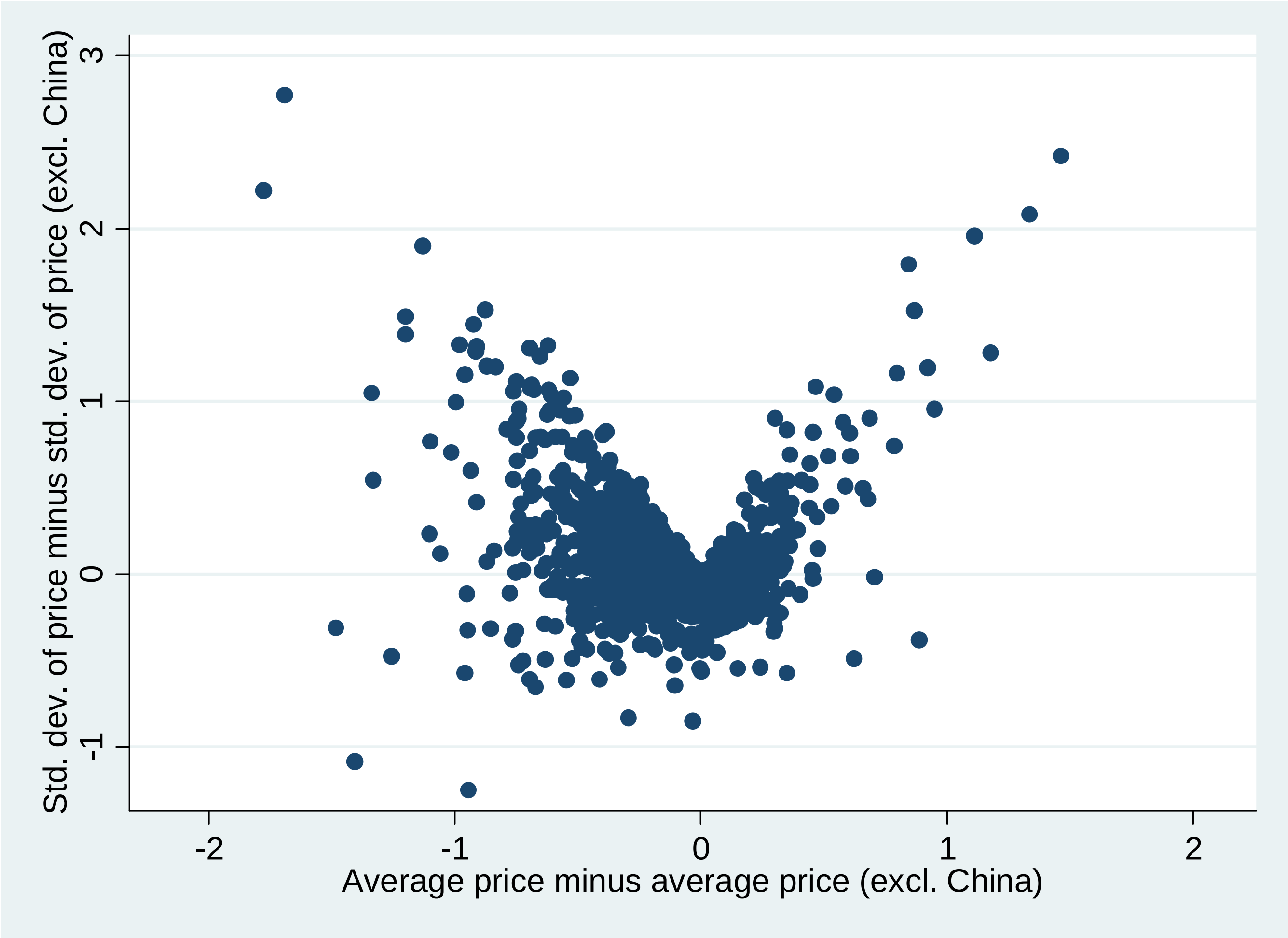
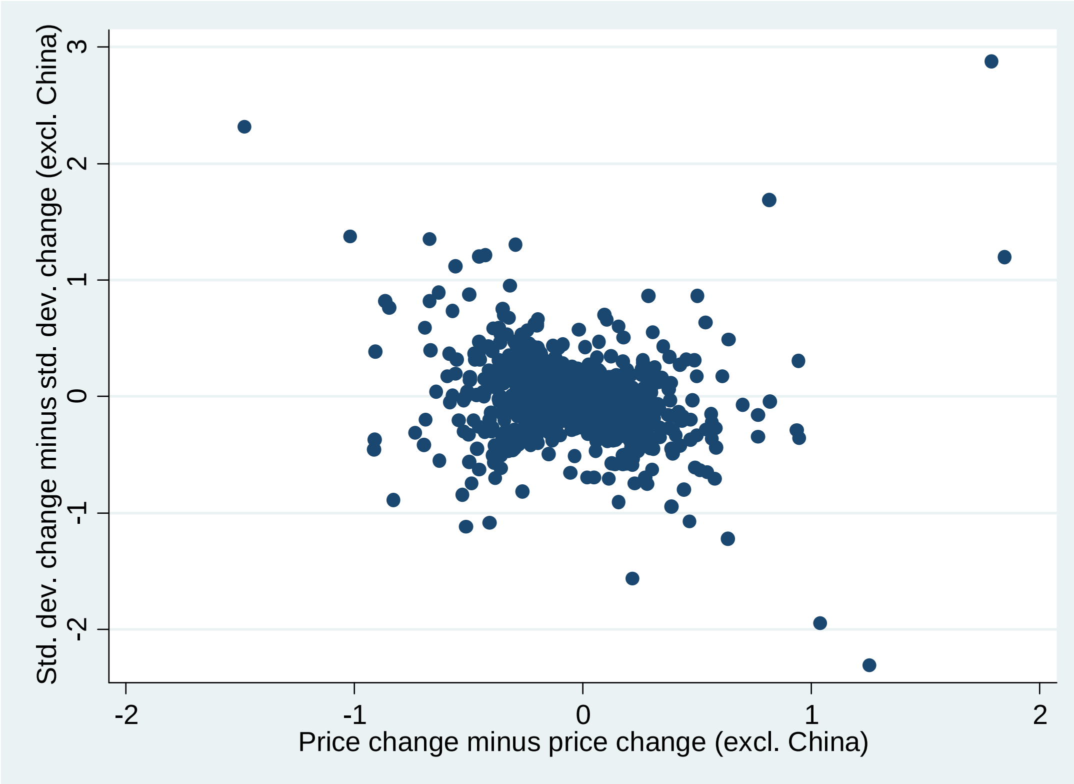
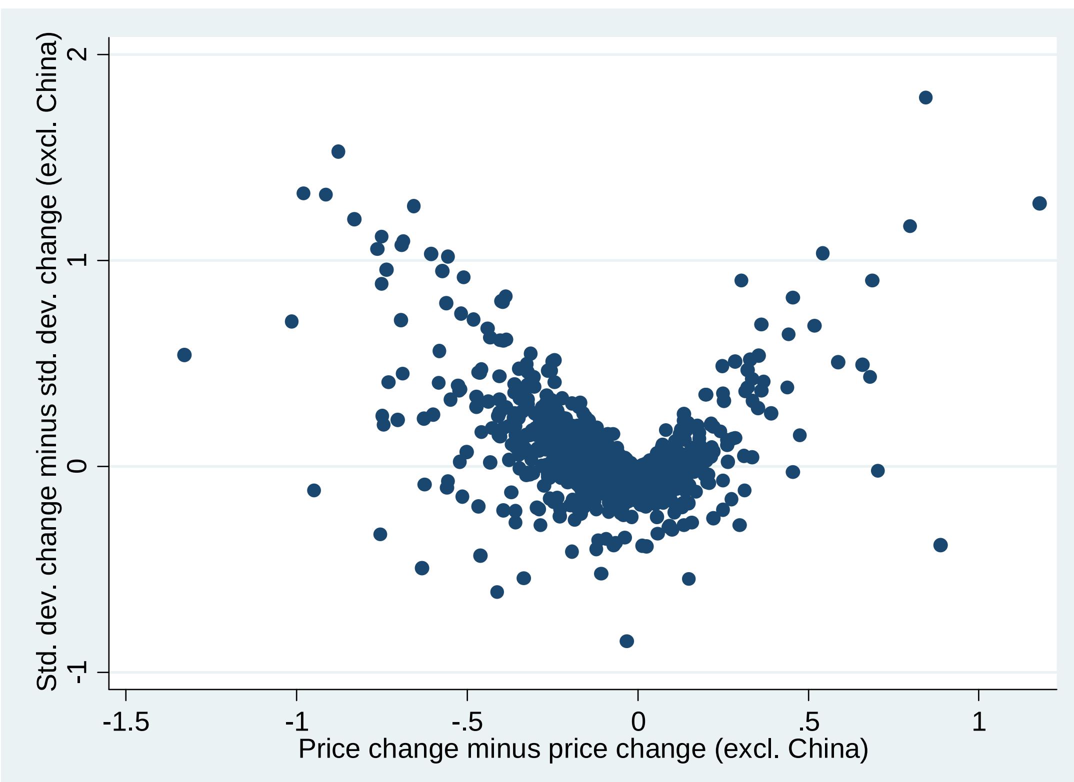



**Figure 1: China's effect on the mean and variance of HS10 import prices**

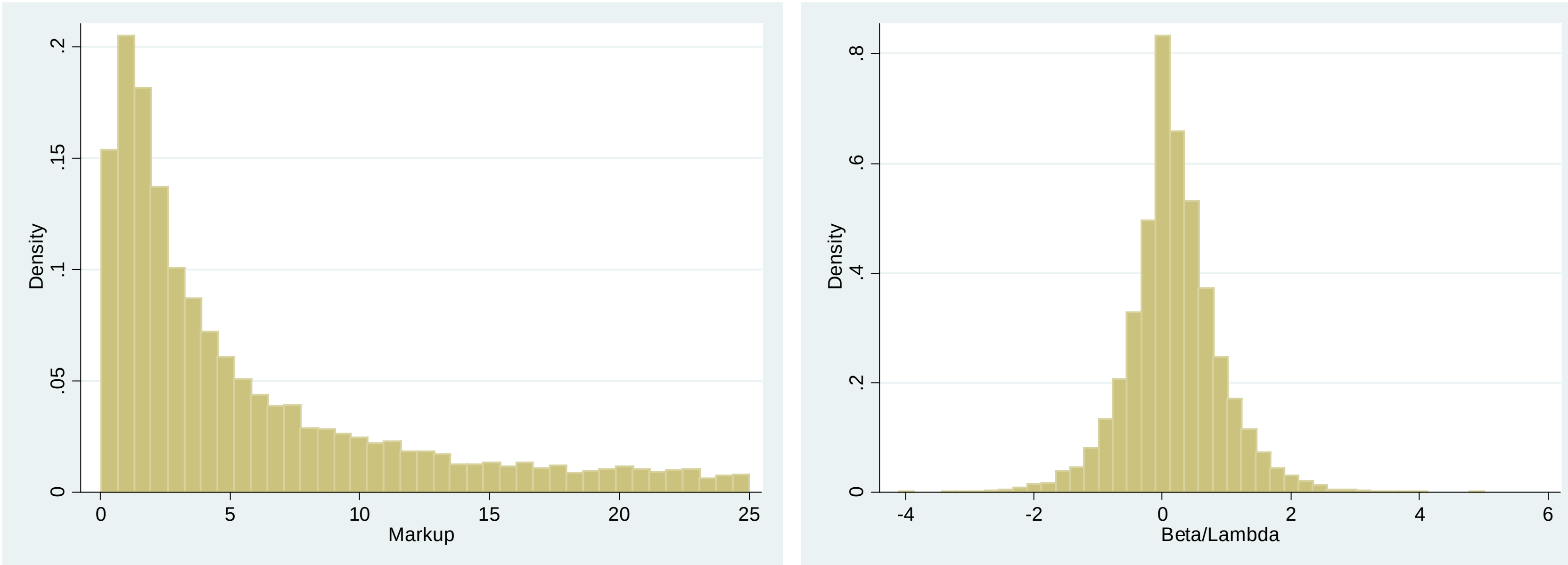



(a) China exports to US in both periods

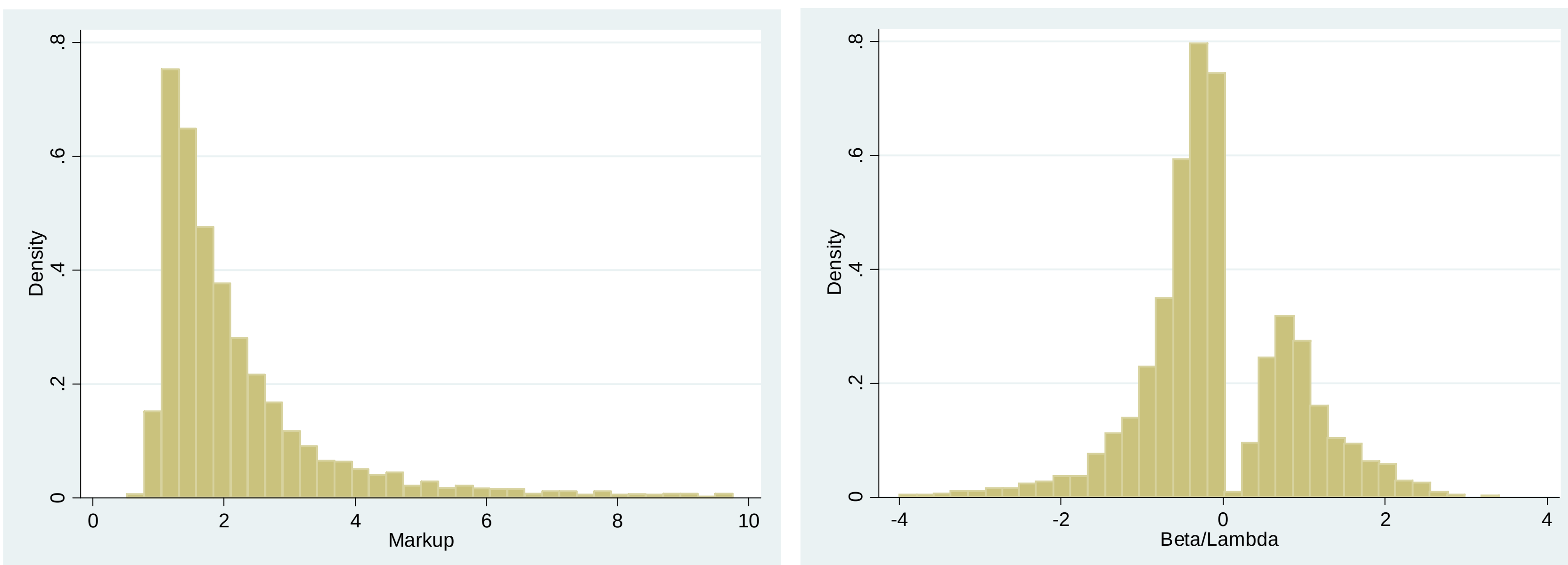



(b) China begins exporting to US in the later period

**Figure 2: China's effect on changes in the mean and variance of HS10 import prices over time**

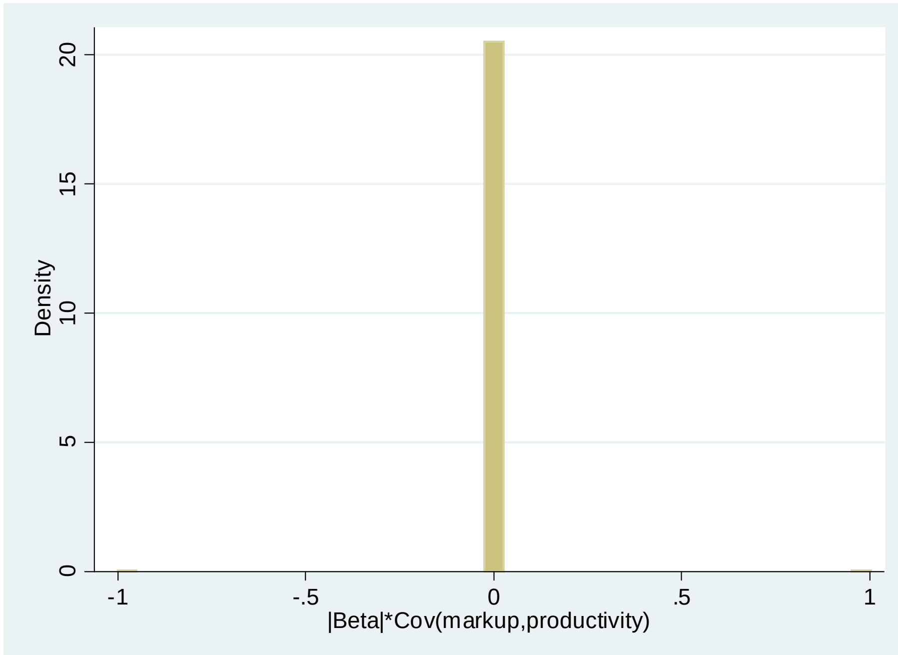



(a) Case I: CES preferences

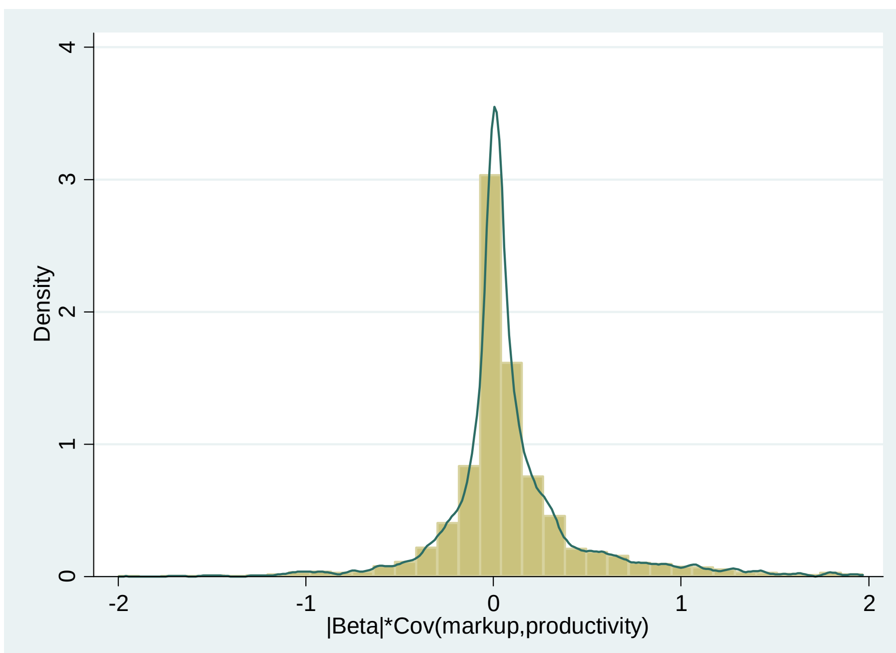



(b) Case II: Variable markups across exporters

**Figure 3: Estimated markups and product differentiation for HS10 products (Average for 2002-6)**




(a) Case I: CES preferences




(b) Case II: Variable markups across exporters

**Figure 4: Estimated covariance between exporter markup and productivity (distribution of estimates across HS10 products)**

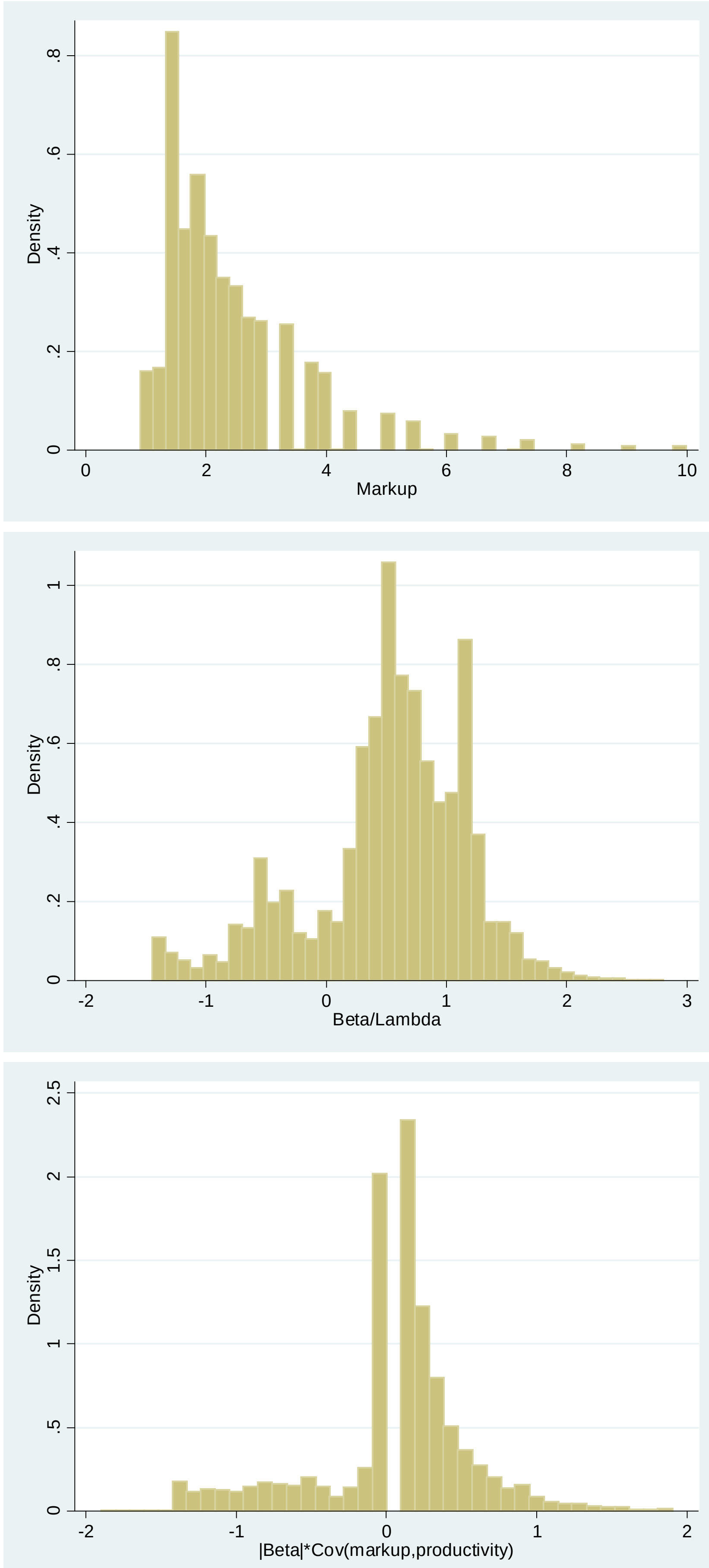
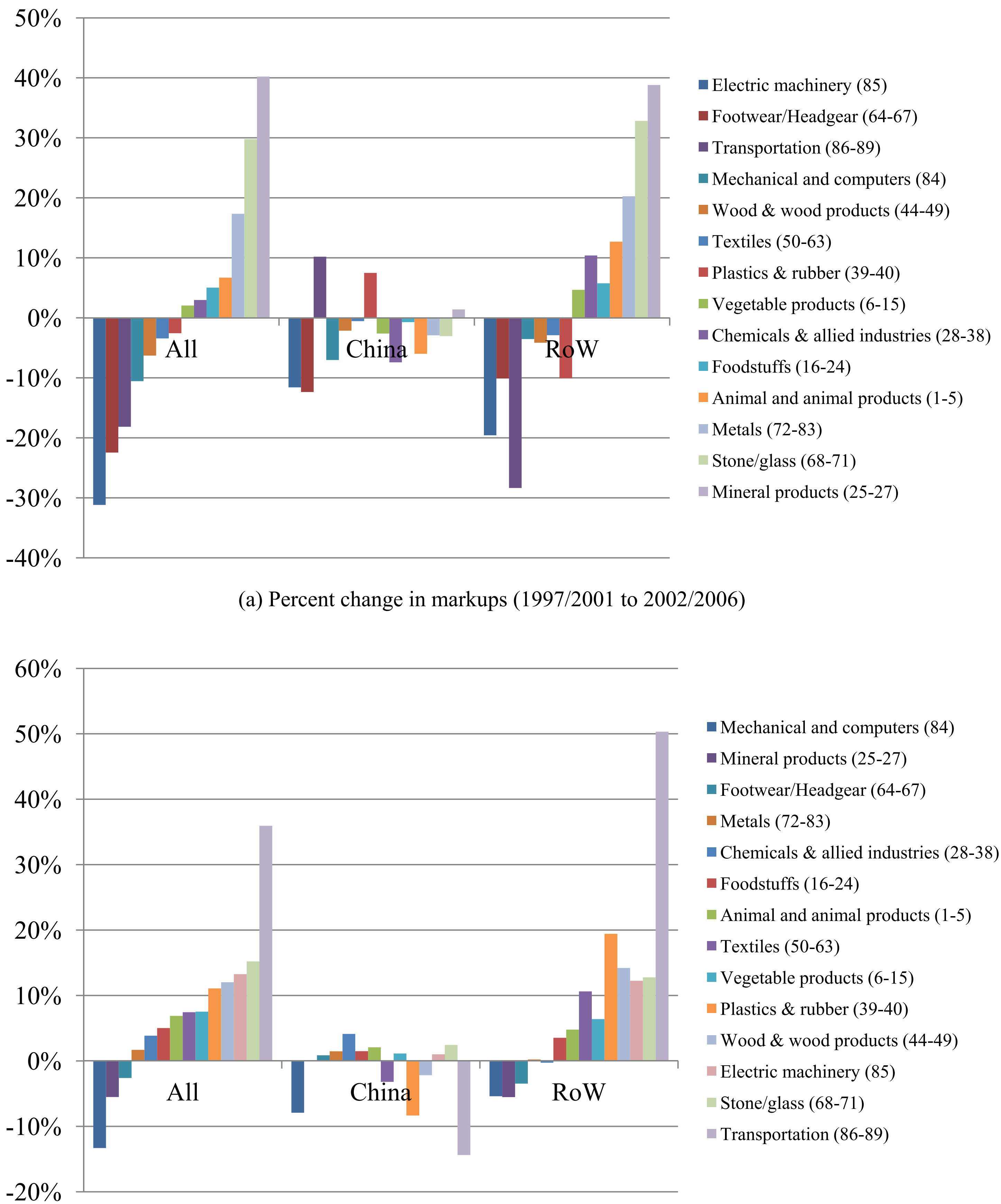



**Figure 5: Estimated parameters for HS10 products; Case III simulation results (Average for 2002-6)**

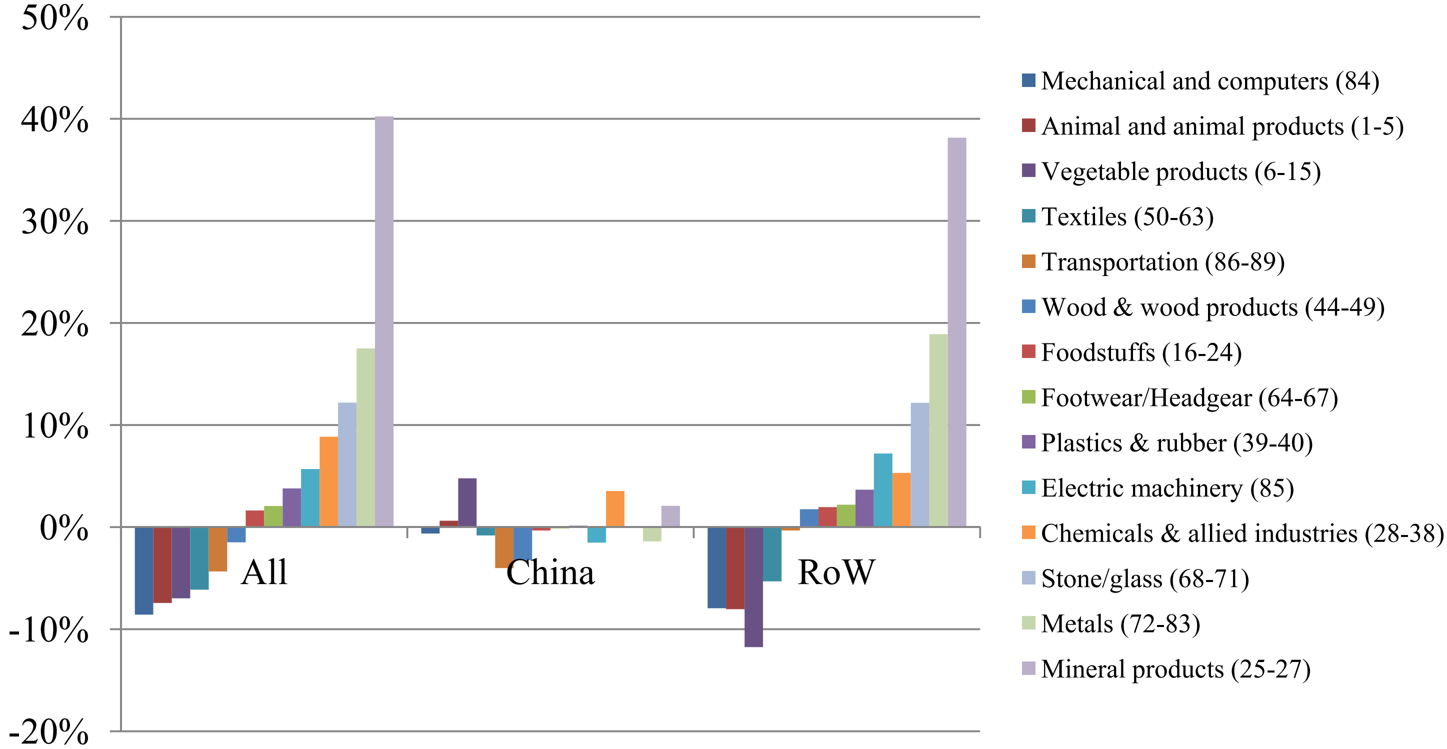



(a) Percent change in markups (1997/2001 to 2002/2006)

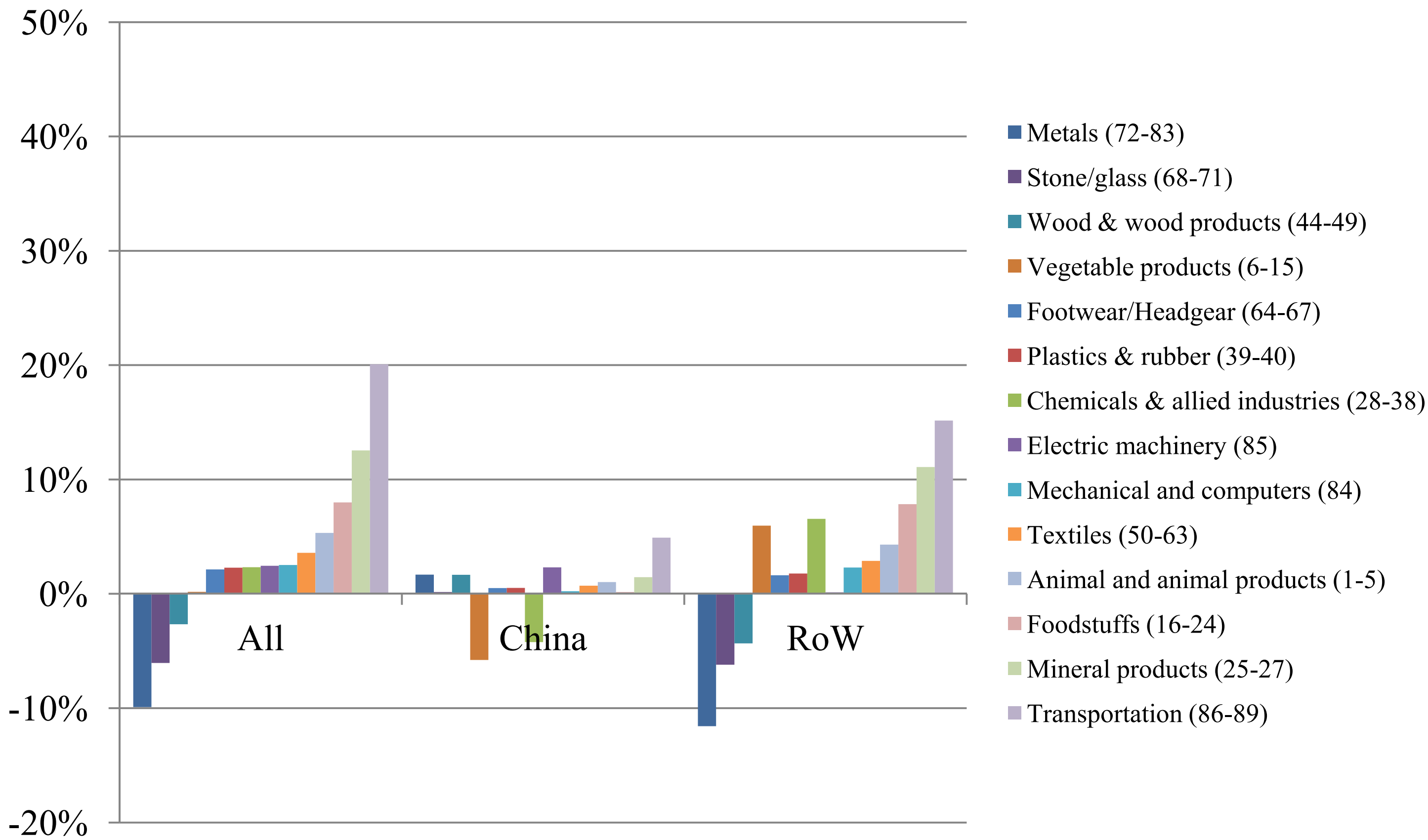


(b) Percent change in marginal cost (1997/2001 to 2002/2006)

**Figure 6: Changes in markups and marginal cost by sector (China entry)**




(a) Percent change in markups (1997/2001 to 2002/2006)




(b) Percent change in marginal cost (1997/2001 to 2002/2006)

**Figure 7: Changes in markups and marginal cost by sector (China incumbent)**

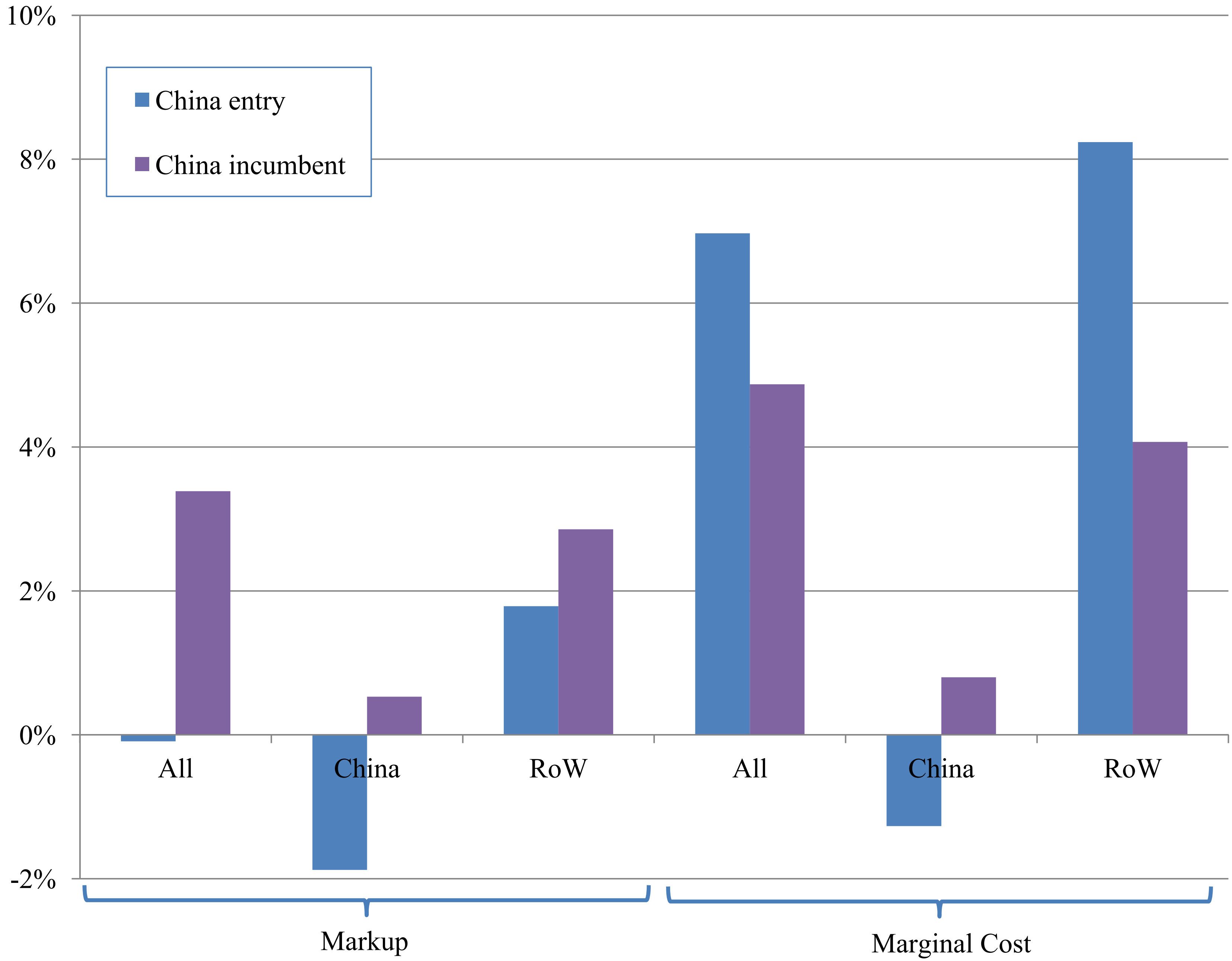



**Figure 8: Growth in the markup and marginal cost components of import prices in industries that China entered**

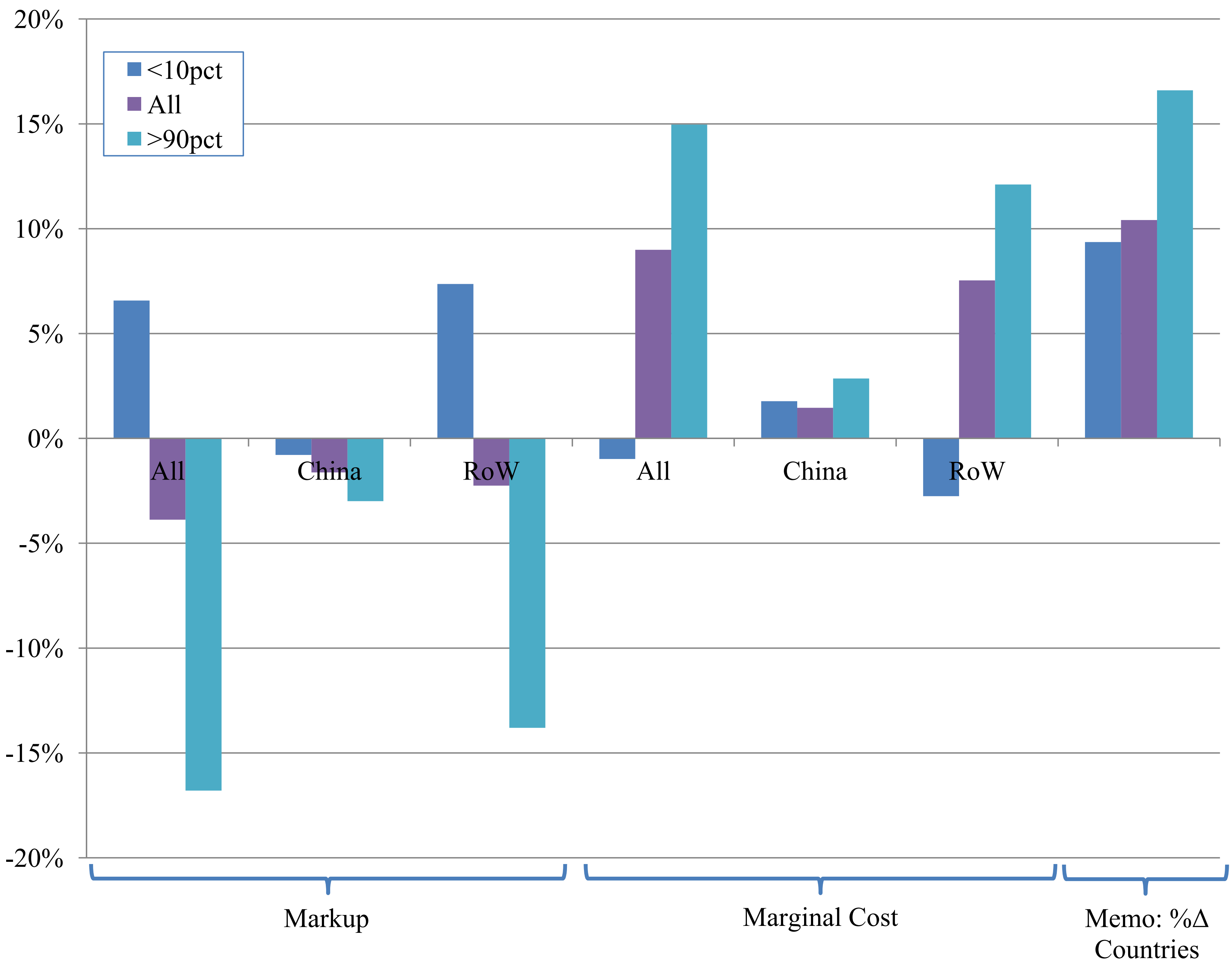



**Figure 9: Growth in markups, marginal cost and the number of source countries sorted by changes in an industry's China share**

| | # Industries | | | By Industry Import Value | | |
|---|---|---|---|---|---|---|
| Industry | China | Overall | Share | China ($bn) | Overall ($bn) | Share |
| Animal and animal products (1-5) | 261 | 767 | 34% | 40 | 80 | 50% |
| Foodstuffs (16-24) | 447 | 976 | 46% | 112 | 145 | 77% |
| Vegetable products (6-15) | 449 | 864 | 52% | 48 | 88 | 54% |
| Mineral products (25-27) | 164 | 299 | 55% | 836 | 1,060 | 79% |
| Raw hides, skins & leather (41-43) | 209 | 324 | 65% | 15 | 16 | 97% |
| Transportation (86-89) | 285 | 425 | 67% | 872 | 1,030 | 85% |
| Wood & wood products (44-49) | 609 | 795 | 77% | 162 | 190 | 85% |
| Chemicals & allied industries (28-38) | 1,623 | 2,025 | 80% | 419 | 505 | 83% |
| Textiles (50-63) | 2,940 | 3,567 | 82% | 344 | 345 | 100% |
| Metals (72-83) | 1,393 | 1,682 | 83% | 294 | 320 | 92% |
| Miscellaneous (90-96) | 746 | 889 | 84% | 121 | 130 | 93% |
| Mechanical and computers (84) | 1,188 | 1,387 | 86% | 560 | 573 | 98% |
| Stone/glass (68-71) | 363 | 400 | 91% | 157 | 167 | 94% |
| Plastics & rubber (39-40) | 400 | 440 | 91% | 135 | 137 | 99% |
| Footwear/Headgear (64-67) | 338 | 354 | 95% | 29 | 29 | 100% |
| Electric machinery (85) | 755 | 786 | 96% | 509 | 511 | 100% |
| Total | 12,170 | 15,980 | 76% | $4,650 | $5,330 | 87% |

**Table 1: China's participation rate in US import industries**

| | Mean | Excl. China | Mean - Excl. China | Standard Deviation | Excl. China | Std. Dev. - Excl. China |
|---|---|---|---|---|---|---|
| Transportation (86-89) | 8.41 | 8.45 | -3.9% | 108% | 106% | 2.1% |
| Mechanical and computers (84) | 6.61 | 6.65 | -3.7% | 151% | 150% | 0.9% |
| Chemicals & allied industries (28-38) | 4.05 | 4.09 | -3.4% | 147% | 145% | 1.2% |
| Electric machinery (85) | 3.89 | 3.93 | -3.4% | 148% | 148% | 0.0% |
| Footwear/Headgear (64-67) | 3.04 | 3.06 | -1.6% | 70% | 70% | -0.1% |
| Metals (72-83) | 1.38 | 1.39 | -1.5% | 78% | 78% | -0.4% |
| Plastics & rubber (39-40) | 1.75 | 1.77 | -1.4% | 84% | 84% | -0.2% |
| Animal and animal products (1-5) | 1.86 | 1.87 | -1.2% | 44% | 44% | 0.2% |
| Vegetable products (6-15) | 0.76 | 0.77 | -1.0% | 69% | 69% | -0.1% |
| Stone/glass (68-71) | 4.91 | 4.92 | -1.0% | 88% | 89% | -0.4% |
| Textiles (50-63) | 3.69 | 3.69 | -0.9% | 85% | 85% | -0.5% |
| Foodstuffs (16-24) | 1.03 | 1.04 | -0.5% | 59% | 59% | -0.3% |
| Wood & wood products (44-49) | 3.13 | 3.13 | -0.2% | 74% | 75% | -0.8% |
| Mineral products (25-27) | 3.68 | 3.68 | 0.1% | 33% | 33% | -0.2% |
| Total | 4.71 | 4.73 | -2.2% | 100% | 100% | 0.5% |

**Table 2: China's effect on the mean and variance of sectoral import prices (2002-2006)**

| | %Δ Mean Price | Excl. China | Δ | n |
|---|---|---|---|---|
| Transportation (86-89) | 20.7% | 22.0% | -1.2% | 222 |
| Chemicals & allied industries (28-38) | 15.9% | 16.9% | -1.1% | 1,082 |
| Vegetable products (6-15) | -8.3% | -7.7% | -0.7% | 272 |
| Textiles (50-63) | -3.5% | -3.1% | -0.5% | 2,116 |
| Foodstuffs (16-24) | 8.4% | 8.8% | -0.4% | 276 |
| Wood & wood products (44-49) | -3.6% | -3.3% | -0.4% | 271 |
| Mineral products (25-27) | 62.5% | 62.7% | -0.2% | 106 |
| Plastics & rubber (39-40) | 5.8% | 6.0% | -0.2% | 267 |
| Footwear/Headgear (64-67) | 8.5% | 8.5% | 0.0% | 313 |
| Stone/glass (68-71) | 9.5% | 9.3% | 0.2% | 274 |
| Metals (72-83) | 16.6% | 16.3% | 0.3% | 992 |
| Electric machinery (85) | 9.4% | 9.0% | 0.4% | 647 |
| Mechanical and computers (84) | -0.1% | -0.6% | 0.5% | 883 |
| Animal and animal products (1-5) | -5.7% | -6.2% | 0.5% | 190 |
| Total | 15.9% | 16.1% | -0.2% | 8,676 |

(a) China exports to US in both periods

| | %Δ Mean Price | Excl. China | Δ | n |
|---|---|---|---|---|
| Footwear/Headgear (64-67) | -35.3% | -21.7% | -13.6% | 12 |
| Transportation (86-89) | 44.2% | 53.6% | -9.4% | 57 |
| Mechanical and computers (84) | -8.5% | 0.3% | -8.7% | 196 |
| Electric machinery (85) | 14.2% | 21.4% | -7.2% | 51 |
| Chemicals & allied industries (28-38) | 22.5% | 25.0% | -2.5% | 315 |
| Textiles (50-63) | 2.0% | 4.3% | -2.3% | 546 |
| Animal and animal products (1-5) | 21.3% | 23.0% | -1.7% | 46 |
| Stone/glass (68-71) | 43.7% | 44.4% | -0.7% | 40 |
| Vegetable products (6-15) | 9.8% | 10.5% | -0.6% | 115 |
| Metals (72-83) | 24.9% | 25.0% | -0.1% | 259 |
| Foodstuffs (16-24) | 13.8% | 13.3% | 0.5% | 105 |
| Wood & wood products (44-49) | 14.3% | 13.8% | 0.5% | 79 |
| Plastics & rubber (39-40) | 7.6% | 6.2% | 1.5% | 47 |
| Mineral products (25-27) | 45.1% | 43.5% | 1.6% | 24 |
| Total | 28.0% | 33.2% | -5.2% | 1,957 |

(b) China begins exporting to US in the later period

**Table 3: The effect of China on sectoral prices over time.**

Notes: Percent change in price is a tornqvist average of changes in HS10 unit values between the periods 1997-2001 and 2002-2006. Included in the overall statistics but not shown are Miscellaneous (90-96) and Wood products (44-49).

| | Dependent variable: Log of markup | | | | | |
|---|---|---|---|---|---|---|
| | 1997-2001 | | | 2002-2006 | | |
| | (i) | (ii) | (iii) | (iv) | (v) | (vi) |
| CASE 1 | | | | | | |
| β/λ | -1.52 | | | -1.45 | | |
| | (0.02) | | | (0.02) | | |
| β/λ<0 | | -2.37 | | | -2.29 | |
| | | (0.07) | | | (0.07) | |
| β/λ>0 | | | -0.95 | | | -0.96 |
| | | | (0.04) | | | (0.03) |
| n | 14,780 | 5,373 | 8,887 | 15,094 | 5,216 | 9,407 |
| CASE 2 | | | | | | |
| β/λ | -0.50 | | | -0.45 | | |
| | (0.01) | | | (0.01) | | |
| β/λ<0 | | -0.72 | | | -0.67 | |
| | | (0.01) | | | (0.01) | |
| β/λ>0 | | | 0.25 | | | 0.28 |
| | | | (0.01) | | | (0.01) |
| n | 3,781 | 2,630 | 1,151 | 3,937 | 2,701 | 1,236 |
| CASE 3 | | | | | | |
| β/λ | 0.20 | | | 0.20 | | |
| | (0.01) | | | (0.01) | | |
| β/λ<0 | | -0.25 | | | -0.37 | |
| | | (0.03) | | | (0.03) | |
| β/λ>0 | | | 0.74 | | | 0.71 |
| | | | (0.01) | | | (0.01) |
| n | 11,834 | 2,110 | 9,521 | 12,244 | 2,095 | 9,920 |

**Table 4: The correlation between the level of differentiation (β/λ) and markups across HS10**

| | | %Δ Price | | | %Δ Markup | | | %Δ Marginal Cost | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample | Estimator | All | China | Rest of World | All | China | Rest of World | All | China | Rest of World | # HS10 |
| China exports a given HS10 to US in both periods | Case I | 14.3% | -0.2% | 14.4% | 7.1% | -2.2% | 9.3% | 7.2% | 2.1% | 5.2% | 8,696 |
| | Case II | 13.7% | 0.0% | 13.8% | -2.4% | -1.0% | -1.4% | 16.1% | 1.0% | 15.1% | 1,652 |
| | Case III | 8.3% | 1.3% | 6.9% | 3.4% | 0.5% | 2.9% | 4.9% | 0.8% | 4.1% | 6,841 |
| China begins exporting an HS10 to US in the later period | Case I | 27.8% | -5.2% | 33.0% | -13.5% | 1.0% | -14.5% | 41.3% | -6.3% | 47.5% | 1,963 |
| | Case II | 16.1% | -1.6% | 17.7% | 6.5% | 0.0% | 6.5% | 9.6% | -1.6% | 11.1% | 437 |
| | Case III | 6.9% | -3.1% | 10.0% | -0.1% | -1.9% | 1.8% | 7.0% | -1.3% | 8.2% | 1,392 |

**Table 5: China's effect on markups and marginal cost over time**