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Productivity Matters for Trade Policy:

Theory and Evidence

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Abstract

There is a growing literature that investigates the effect of trade liberalization on productivity. Nearly all such studies assume that trade policy is determined independently of productivity, hence it is exogenous. I show, both theoretically and empirically, that this assumption is not valid in general and that researchers may be underestimating the positive effect of liberalization on productivity when they do not account for the endogeneity bias. On the theory side, I demonstrate that under a standard political economy model of trade protection, productivity directly influences tariffs. Moreover, this productivity-tariff relationship partly determines the extent of liberalization across sectors even in the presence of a large exogenous unilateral liberalization shock that affects all sectors. The link between productivity and tariffs is maintained after I include in my political economy model a learning-by-doing motive of protection, which also serves as the source of liberalization. On the empirical side, I examine total factor productivity (TFP) estimates obtained at the firm level for Colombia between 1983 and 1998, and find that more productive sectors receive more protection within this period. In estimating the effect of productivity on tariffs, I control for the endogeneity of the two main right-hand-side variables–the inverse import penetration to import demand elasticity ratio and productivity–by employing materials prices, the capital to output ratio, a measure of scale economies, and the TFP of the upstream industries as robust instruments. I also account for the large trade liberalization between 1990 and 1992, and find that the sectors with a higher productivity gain are liberalized less. Finally, I use a system of equations to illustrate that the positive impact of liberalization on productivity grows somewhat stronger when corrected for the endogeneity bias.

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1 Introduction

In general, how government policies affect economic outcomes is a crucial issue for both economists and policymakers. In particular, it is important to know how government trade policies affect productivity in the economy, hence eventually growth and development. This is a major issue in development and international trade economics and the interest in this topic is not new. The papers on this issue date back to the 1950s (e.g. Johnson 1955).[1] We recently see an increased interest in the topic through the ever-growing number of empirical studies testing the effect of trade liberalization on productivity (e.g. Tybout and Westbrook 1995, Pavcnik 2002, Schor 2004). Many developing countries (for example, Brazil, Colombia, Chile, India, Mexico, and Turkey) have aggressively pursued trade liberalization in the late 1980s and the early 1990s, in part, to boost productivity. So, does trade liberalization really increase productivity? Recent micro-level empirical findings indicate that the answer is "Yes." However nearly all these studies fail to recognize that trade policy might be endogenous with respect to productivity. And, even if they acknowledge the existence of this endogeneity, most do not control for it. In this paper, I show, both theoretically and empirically, that productivity directly affects trade policy. Thus, a concern for the endogeneity bias is well-founded. Moreover, when we account for the bi-directional causality between trade policy and productivity, the positive effect of trade reform on productivity may become stronger.

In Section 2, I provide a theoretical model of tariff policy determination for a small open economy. I show that under a standard political economy setup of protection, the sectoral tariffs depend positively on the industry production (size) and hence, on the sectoral productivity if these sectors are organized and lobby for protection.[2] The intuition for this result is that more productive sectors have got more to gain from lobbying and the potential to generate more protection. More specifically, the marginal benefit of a tariff, hence a higher domestic price is greater when it applies to more units and more productive processes.

In this paper, I focus on the effect of productivity on trade policy due to political economy motivations as I explain above. However, there are other plausible channels that could actually lead to more (not less) protection for less productive sectors as I discuss in Section 2. My purpose

[1] A detailed historical review of the papers that are concerned with the effects of trade on industrial performance appears in Pack (1988). He suggests that the early evidence is rather mixed.

[2] This is a modified result (as I explain later in the text) from the, now standard, political economy models such as Grossman and Helpman (1994). The results from Grossman and Helpman (1994) have been widely tested and confirmed. Also Ferreira and Facchini (2005), who find that more concentrated sectors receive more protection, share a similar view with my paper in the sense that the industry characteristics matter for trade policy.

of using this standard model as the starting point is to create a tractable setup for the effect of productivity on tariffs and then, having accounted for the economy-wide trade reform, to ultimately obtain structural equations for econometric analysis.

It is often argued that trade reform may be used as an exogenous change and this uniform shift in policy helps identify the effect of trade policy on productivity without worrying too much about its endogeneity. In order to account for this argument, I model a unilateral trade liberalization shock which is common across sectors. I find that under such a common exogenous shock, the reduction in tariffs is lower for the sectors that experience a higher productivity gain (or a lower productivity decline) as compared to the other sectors in the presence of political economy. Initially, I keep the additional channel simple making sure that it is clearly the political economy consideration that is driving the results. Next, I give more structure to the extra channel of protection and to the way the liberalization shock manifests itself by allowing for an infant industry argument.[3] This argument led to the widespread use of import substitution policies in most developing countries until the mid-1980s and its dismissal was the source of much unilateral trade liberalization since then.

In my two period model, the government initially believes that there exists a learning-by-doing (LBD) process and decides about the current tariffs by considering both the political economy effects and the effect of these tariffs on future welfare through LBD. In the second period, the government realizes that LBD does not actually exist and it is a false perception, and thus initiates a trade reform. Given that political economy forces still determine tariffs, the extent of the liberalization differs across sectors (due to political economy) despite this common shock across sectors. The implication from the models I present is that, assuming cross-sectional differences in trade policy to be independent of cross-sectional differences in productivity is incorrect.

I employ Colombian data for the empirical tests of my theory. Colombia has been used in various studies (for example, Roberts 1996; Fernandes 2003; Melendez, Seim and Medina 2003) given that it provides a great natural experiment environment. Colombia experienced a drastic trade reform in the early 1990s and had a stable economy in this period without major crises. Given the existence of other studies using the same country, I get the chance to test my predictions with a comparable dataset. In Section 3, I discuss the trade policy in Colombia during the sample period of 1983 through 1998, and describe how we can rule out a uniform change in tariffs across

[3] For example, the infant industry argument is mentioned as an important motive for protection in Grossman and Horn (1988).

sectors.

In Section 4, I briefly review the empirical literature to the extent that it relates to this paper and then, in Section 5 I make an empirical analysis based on the predictions from my theory using Colombian data for the 1983-1998 period. I analyze the effect of productivity on trade protection by following my theory closely. I confirm that the (4-digit ISIC[4] level) sectoral tariffs are inversely related to the import penetration ratio and import demand elasticity, whereas they are positively related to total factor productivity. The results also indicate that the sectors with more productivity gain (or less productivity decline), as compared to the other sectors, are liberalized less.

In the estimations, I account for the extra channels which I mention above and, more specifically, I account for their elimination which leads to a big decline in tariffs. For this purpose, I allow for a shift in the common terms across sectors over time. I tackle the potential endogeneity of the right-hand-side variables, namely the inverse import penetration to import demand elasticity ratio and productivity, by using instrumental variables. The instruments are the capital to output ratio, materials prices, a measure of scale economies (value added/number of firms), and the TFP of the upstream industries which I confirm to be valid based on a test of overidentifying restrictions and also explain intuitively in Section 5.

My productivity estimates come from Eslava, Haltiwanger, Kugler and Kugler (2004) and they are originally calculated at the firm-level which are then aggregated to the 4-digit ISIC level using production shares of each firm. The dataset has the great advantage of using plant level input and output prices. This enables obtaining good estimates with smaller bias as compared to the majority of the studies which need to employ non-parametric estimations and sector level price deflators due to lack of data.

By showing how trade policy depends on productivity both theoretically and empirically, I provide solid evidence for the endogeneity of trade policy with respect to productivity. Finally, in Section 6, I estimate a system of equations for illustrative purposes. In the system, I correct for the endogeneity of tariffs and show that the positive effect of trade liberalization on productivity can be underestimated when endogeneity bias is not accounted for.

[4]International Standard Industrial Classification, United Nations.

2 Theory

2.1 Basic Model

The output and factor markets are perfectly competitive. The numeraire good, $i = 0$, is produced with labor only, using a constant returns to scale process, whereas the non-numeraire goods, $i = 1, ...n$, are produced using labor and one sector-specific factor. The production function for the non-numeraire goods is $X_i(p_i) = A_i Q_i(p_i)$,[5] where A_i stands for the Hicks-neutral total factor productivity (TFP). The international prices for all goods $i = 0, ..., N$, denoted by p_i^w, are normalized to one. Furthermore, assuming a large enough aggregate supply of labor, the wage rate is also tied at one–the marginal revenue productivity of labor in the numeraire sector.

The numeraire good is traded freely, hence its domestic price is equal to the world price of one. The owners of each specific factor organize into lobbies, and ask for government protection in their own sector only since they are assumed to constitute a negligible share of the total population. The consumers cannot overcome the free-rider problem and are not organized as discussed in Olson (1965). For simplification, export subsidies are not allowed and only tariffs are available for trade protection.[6] Maintaining the small country assumption and the world prices normalized to 1, the domestic price of the remaining goods are given by $p_i = 1 + \tau_i$, where τ_i denotes both the specific and the advalorem tariff rate.[7] The government, then, sets its trade policy by maximizing the following political support function

$$G \equiv L + \sum_{i=1}^{N} \left(\int_{1+\tau_i}^{\infty} D_i(\tau_i) d\tau_i + \omega \int_{0}^{1+\tau_i} A_i Q_i(\tau_i) d\tau_i + \tau_i M_i(\tau_i) \right) \tag{1}$$

where L is the aggregate labor supply and income; $D_i(\tau_i)$ is the aggregate demand, $X_i(\tau_i) = A_i Q_i(\tau_i)$ is the aggregate supply, and $M_i(\tau_i) = D_i(\tau_i) - A_i Q_i(\tau_i)$ is the aggregate import demand for good i. Thus, G is a weighted sum of the aggregate consumer and producer suplus, as well as labor income and tariff revenue.[8] The weight, $\omega \geq 1$, represents the relative importance given to the producer surplus with respect to the rest of the social welfare.[9]

[5] In the estimations I give $Q_i(p_i)$ more structure. Here, it just indicates part of the production function independent of productivity.

[6] The trade with the rest of the world is balanced through movements of the numeraire good.

[7] Note that the domestic price for a small economy is related to the world price and tariff rates with $p_i = (p_i^w + \textit{specific tariff}) = p_i^w(1 + \textit{advalorem tariff})$ but the assumption that $p_i^w = 1$ makes the specific and advalorem rates equal under this case.

[8] The tariff revenue, $\sum_{i=1}^{N} \tau_i M_i(.)$, is fully rebated back to the public in a lump-sum manner.

[9] This setup can be easily interpreted as a reduced form of a model where lobbying is given micro-foundations such as in Grossman and Helpman (1994). I prefer to take a shortcut here to keep the focus on the main subject

Given the additive separability of the government objective, we can obtain the optimal tariff rate for sector i by maximizing equation (1) with respect to $\boldsymbol{\tau}_i$. Consequently, the equilibrium specific and advalorem tariff rates for sector i are implicitly defined as[10]

$$\tau_i = (\omega - 1)\frac{A_i Q_i(\tau_i)/M_i(\tau_i)}{\varepsilon_i(\tau_i)} \tag{2}$$

where $\varepsilon_i(.)$ stands for the elasticity of import demand.[11] This expression is a standard one obtained in various political economy models (Helpman 1997). Accordingly, the tariff rate for sector i is an increasing function of the extra political economy weight provided to producers, whereas it is a decreasing function of the import demand elasticity, ε_i, and import penetration ratio, M_i/A_iQ_i. A tariff is a tax on imports, so just like a tax on a non-traded good, the deadweight loss created is lower the more inelastic the (import) demand is. Thus, a smaller value of ε_i allows for higher tariffs to be applied. In addition, a relatively larger market for imports creates a greater price distortion potential which should be avoided by the government. Finally, the marginal benefit of a tariff is higher when it applies to more units and more productive processes.

Partially and implicitly differentiating equation (2) with respect to A_i, we obtain the following relationships between tariff protection and productivity

$$\frac{\partial \tau_i}{\partial A_i} = -(\omega - 1)\frac{Q_i(\tau_i)}{M_i'(\tau_i)} > 0 \tag{3a}$$

$$\frac{d\tau_i}{dA_i} = -\frac{(\omega - 1)Q_i(\tau_i)}{M_i'(\tau_i) + (\omega - 1)A_i Q_i'(\tau_i)} > 0 \tag{3b}$$

I assume that $Q_i(\tau_i)$, $D_i(\tau_i)$ and hence, $M_i(\tau_i)$ are linear for ease of exposition (i.e. $Q_i''(\tau_i) = D_i''(\tau_i) = 0$).[12] Although initially $\omega \geq 1$ is the only restriction on the value of ω, I further assume it to be bounded above such that $\omega < 2 - \frac{D_i'(.)}{A_i Q_i'(.)}$ based on the observations from the empirical political economy literature. For example, Goldberg and Maggi (1999) estimate ω to be equal to 1.014 for the United States, whereas Karacaovali and Limão (2005b) estimate it to be between 1.0025 and 1.0039 for the European Union. Although these estimates might be a bit small, they

matter: the trade policy and productivity linkage in the presence of unilateral liberalization.

[10] Again note that the specific (first term) and advalorem (second term) tariff rates are equivalent since the international prices are normalized to one. See the appendix (Section A.1) for the derivation of equation (2).

[11] Here, the import demand elasticity is defined as $\varepsilon_i \equiv -M_i' p_i^w / M_i$, so it differs from the standard definition which is evaluated at the domestic price. I account for this in the empirical estimations as explained in the appendix (Section A.2).

[12] I have the same assumption throughout the text. This is not a necessary condition for the inequality in equation (3b) to hold or the other results to follow.

more than support my parameter restriction as a plausible one. If ω were so high to exceed $2 - \frac{D_i'(.)}{A_i Q_i'(.)}$[13], then more productivity would call for less protection. Under our political economy setup, this would be counter-intuitive given that a high ω together with a high A_i only indicate a stronger lobby and require more protection, not less.

The main result is that, based on a standard political economy model, we expect an organized sector with higher productivity to receive more protection because it has got more to gain for a marginal increase in the tariff rate, hence the domestic price level. Thus, this is a slight modification of the size effect identified by the influential work of Grossman and Helpman (1994) which has been tested and confirmed in various papers (like Gawande and Bandyopadhyay 2000, Goldberg and Maggi 1999, Mitra et al. 2002 and so on). More importantly, this basic observation naturally raises doubts about the assumption of exogeneity of trade policy with respect to productivity in the earlier empirical literature.

Before I extend this basic setup by introducing common shocks, I should note that we could potentially have a channel working in the opposite direction. That is, one can plausibly expect a less productive sector to obtain more protection. One way to model this is by allowing the political economy weight to differ across sectors based on certain sectoral characteristics as in Karacaovali and Limão (2005a). For example, a sector with a higher share of employment is likely to have a higher weight given that it generates more political votes (Caves 1976). Furthermore, sectors with lower wages may have a higher weight due to the government and society-wide sympathy with their situation or simply due to the lower opportunity cost of lobbying by the low wage workers (Magee et al. 1989). Typically, the low wage and labor intensive sectors are less productive so this could potentially reverse the results. I exclude such concerns from my model because I want to focus on the effect of productivity on tariffs in the presence of a big trade reform shock that affects all sectors and accounting for further sector characteristics would only complicate this analysis. On the other hand, I allow for such differences across sectors that could lead to different initial tariff rates by considering fixed effects in my estimations (Section 5).

2.2 Trade Reform

Nearly all the papers examining the trade reform-productivity linkage involve a period of unilateral liberalization which is usually considered to be an exogenous shock independent of productivity

[13] Note that $D_i'(.) < 0$.

and common across sectors. Then, the exogeneity of the liberalization shock is used to defend the argument that we should not be worried about the endogeneity of trade policy. Therefore, I provide room for a unilateral liberalization motive common across sectors in order to create a similar setup and analyze its effects. We would like to see whether such a common shock does indeed produce a proportional, non-selective decline in tariffs.

In order to capture this common and exogenous shock argument, I simply augment the baseline government objective function, G, with an additional term, $\Sigma(\boldsymbol{\tau}) = \alpha \sum_{i=1}^{N} \sigma_i(\boldsymbol{\tau}_i)$. This extra term does not create a different economic structure, that is we still have consumers with quasilinear utility functions, a constant returns to scale production with no spillovers and so on. The government objective function can now be expressed as

$$\Gamma \equiv G + \alpha \sum_{i=1}^{N} \sigma_i(\boldsymbol{\tau}_i) \tag{4}$$

where G is the same as in equation (1), $\sigma_i(.)$ is increasing in $\boldsymbol{\tau}_i$ (and concave), and $\alpha > 0$ is a constant. $\Sigma(\boldsymbol{\tau})$ is meant to capture the government perceived benefit of using protective trade policy and would call for protection even in the absence of lobbying. One can think of the perceived benefit as a government view that favors import substitution or as an unquestioned historical legacy of trade protectionism. Initially, I use this approach to be able to clearly show that the tariff changes and levels depend on the productivity changes and levels even under the simplest setup of trade reform. However, in the next sub-section, I put more structure on the way liberalization manifests itself by modeling an infant industry argument, which is known to be a crucial protection motive for developing countries.

The equilibrium tariff rate obtained by maximizing equation (4) is given by[14]

$$\tau_i = (\omega - 1)\frac{A_i Q_i(\tau_i)/M_i(\tau_i)}{\varepsilon_i(\tau_i)} + \frac{\alpha \sigma_i'(\tau_i)}{M_i(\tau_i)\varepsilon_i(\tau_i)} \tag{5}$$

The first part of the expression in equation (5) is essentially the same as equation (2). The additional σ_i' term, on the other hand, captures the marginal perceived benefit of tariffs, again weighted by imports and import demand elasticity. I assume that the σ_i' terms are identical across sectors in order to get a uniform effect, that is $\sigma_i' = \sigma_j'$ for $i \neq j$. As I show in the appendix

[14]The derivation is similar to the one for equation (2), so it is omitted.

(Section A.1), tariffs increase in the coefficient of perceived benefit

$$\frac{d\tau_i}{d\alpha} > 0 \tag{6}$$

Many developing countries, including Colombia, have gone through significant unilateral trade liberalization in the late 1980s through the early 1990s. As I mention above, it is often argued that such liberalization episodes can be interpreted as an exogenous shock mostly uniform across sectors. Thus, empirical researchers regress productivity on tariffs by exploiting this variation over time maintaining an exogeneity assumption. Now, I model such a unilateral liberalization shock as a dramatic decline in the parameter α, say, all the way down to zero.[15] Note that, this shock is modeled to be common across sectors on purpose and it does not depend on any industry characteristics. Yet, as we will see below, the political economy motives still affect tariffs so that the reduction in tariffs for a sector depends on the change in its level of production or size and hence, its productivity.

$$\Delta\tau_{it+1} \equiv \tau_{it+1}|_{\alpha=0} - \tau_{it}|_{\alpha>0} = -\frac{(\omega-1)A_{it+1}Q_{it+1}(\tau_{it+1})}{M'_{it+1}(\tau_{it+1})} + \frac{(\omega-1)A_{it}Q_{it}(\tau_{it})}{M'_{it}(\tau_{it})} + \frac{\alpha\sigma'_i(\tau_{it})}{M'_{it}(\tau_{it})} \tag{7}$$

Then, using the linearity of M_i,[16] equation (7) can be re-expressed as

$$\Delta\tau_{it+1} = -(\omega-1)\frac{(\Delta A_{it+1})Q_{it}(\tau_{it}) + A_{it+1}(\Delta Q_{it+1})}{M'_i} + \frac{\alpha\sigma'_i(\tau_{it})}{M'_i} \tag{8}$$

The partial effect of A_{it} on τ_{it} is the same as given in equation (3a). Now, we also obtain the following relationships between tariffs and productivity in levels and changes

$$\frac{d\tau_{it}}{dA_{it}}|_{\alpha\geq 0} = -\frac{(\omega-1)Q_{it}(\tau_{it})}{M'_{it}(\tau_{it}) + (\omega-1)A_{it}Q'_{it}(\tau_{it}) + \alpha\sigma''_i(\tau_{it})} > 0 \tag{9a}$$

$$\frac{d\Delta\tau_{it+1}}{d\Delta A_{it+1}}|_{\tau_{it},A_{it}} = -\frac{(\omega-1)Q_{it+1}(\tau_{it+1})}{M'_i(.) + (\omega-1)A_{it+1}Q'_{it+1}(\tau_{it+1})} > 0 \tag{9b}$$

Equation (9a) is obtained by implicitly differentiating the first part of equation (5) (specific tar-

[15] This change could be due to a contingent loan from the IMF or a policy recommendation from the World Bank which require certain stabilization and liberalization policies from our "small" country. Or it could be due to a change in the paradigm having observed the success of other comparable liberalizing countries and a new international consensus degrading import substitution type of policies. For example, Edwards (1997) analyzes the role of the World Bank in its effect on trade liberalization reforms and acknowledges its contribution through research and policy dialogue.

[16] I assume that the paramaters do not change over time, and combining with the earlier linearity assumption we get $M'_{it+1}(.) = M'_{it}(.) = M'_i(.)$.

iff) with respect to A_{it} whereas, equation (9b) is obtained by implicitly differentiating $\Delta\tau_{it+1}$ as expressed in equation (8) with respect to ΔA_{it+1} for given initial levels of τ_{it} and A_{it}.[17]

We see that a sector with higher productivity is expected to receive more protection and a sector with a bigger increase (or a lower decline) in productivity is expected to have lower reduction in tariffs despite an exogenous shock common across sectors. Thus, we have reasons to worry about the endogeneity of tariffs with respect to total factor productivity. Accordingly, in the empirical studies where the sector level productivity is regressed on the sector level tariffs that are assumed to be exogenous, there will be a direct reverse causality problem. In the case of the firm level productivity being regressed on the sector level tariffs, this problem will be smaller. However, to the extent that the firm level productivities in a sector differ commonly from the firm level productivities in the other sectors or the more correlated the firm level productivities with the sector level productivities, the worse the endogeneity will be a problem. In the empirical section I use productivity estimates obtained at the firm level that are then aggregated to the sector level using production shares as weights to arrive at representative productivity values for each sector.

Finally, notice that the productivity-tariff linkage above is completely driven by the political economy channel. If political economy is not a concern for the determination of tariffs for a given sector, that is, if the extra political economy weight is null ($\omega - 1 = 0$), then productivity has no effect on the tariffs. On the other hand, again because of political economy, the reduction in tariffs varies across sectors based on the productivity differences regardless of the common shock.

2.3 Government Perceived Learning-by-Doing

In this sub-section, I provide more structure for the liberalization process and the government perceived benefit of protection by introducing an infant industry argument. In developing countries, learning-by-doing and infant industry arguments have been a major motivation for protection which should be accounted for. Grossman and Helpman (1995) provide a comprehensive survey of the literature on technology and trade and indicate that "some countries might wish to use trade or industrial policies to alter their patterns of specialization... The short-run income loss for such a country would be small, while the policy would generate a permanent boost to its productivity growth..." (p. 1297). However, it should be noted that import substitution policies and infant industry protection have been largely abandoned especially after the 1980s and some critics have

[17]Naturally, we also have $\partial\tau_{it}/\partial A_{it} > 0$ and $\partial\Delta\tau_{it+1}/\partial\Delta A_{it+1} > 0$.

indicated that the infants actually never seem to grow (see, e.g., Krueger and Tuncer 1982). In this spirit, the trade liberalization episodes in the developing countries can be seen as a result of the disillusion about the infant industry argument. That is, the governments go from strongly believing in the argument to understanding that it does not work. I would like to examine the effect of such a shift in the government beliefs on the structure of liberalization. Therefore, I model a learning-by-doing (LBD) process which is merely a perception by the government.[18] Although there is no LBD, the government believes that there is some and thus sets its tariffs accordingly until it realizes that this is a false perception and then embarks upon a trade reform.

More specifically, the government believes that more production today has a positive impact on tomorrow's productivity and hence takes this relationship into account while determining its current trade policy. On the other hand, the firms decide about their production by simply reacting to the prices determined by the government trade policy and their decisions do not depend on any LBD process. For simplicity, I assume that the government has a two-period policy setting horizon.[19] This assumption is not only computationally convenient but also helps us partially capture the real experience in Colombia[20] which I study in the empirical section to follow.

In this setup, I aim to provide a plausible explanation for the way unilateral liberalization is introduced. The liberalization shock is common across sectors as in the basic model but the government's perceived benefit of protection now has a specific reasoning based on a LBD process.

I model the government objective in equation (1), but now the government has the following belief about the form of the supply function

$$X_{it}(\tau_{it}) = A_{it}(\phi_{it}, \lambda_{it})Q_{it}(\tau_{it}) \tag{10}$$

$A_{it}(.)$, like before, denotes the total factor productivity, $\lambda_{it} = \lambda(X_{it-1}, X_{it-2}, ...)$ represents the learning-by-doing process, and ϕ_{it} stands for the determinants of TFP that are independent of LBD. The government believes that $\lambda(.)$ is an increasing function of the past production within the same sector, that is $\lambda'(.) > 0$. Note that the true supply function is actually $X_{it}(\tau_{it}) = A_{it}(\phi_{it})Q_{it}(\tau_{it})$. Each period, the government sets tariffs considering their current effects on the weighted social

[18] I gratefully acknowledge Nuno Limão for his suggestions here.

[19] One can think that the government sets trade policy quite infrequently such that tariffs are first determined when the government believes that there exists a strong learning-by-doing process at play and later when this perception is discarded because productivity gain is not observed or the process reaches its terminal point. Alternatively, this might be a short lived government that expects to be in power for two periods only.

[20] This is a feature shared by many other developing countries such as Turkey, Brazil, and India that experienced significant amounts of liberalization around the 1983-1985, 1991-1996, and 1990-1993 periods, respectively.

welfare as discussed in the previous section but now it additionally considers the perceived future effects of current tariffs via learning-by-doing.

The equilibrium tariffs for period t can be obtained as

$$\hat{\boldsymbol{\tau}}_t \equiv \arg\max_{\boldsymbol{\tau}_t}[G_t + \delta E_t(G_{t+1}|\iota_t)] \tag{11}$$

where the G_j terms are defined as in equation (1) but with time subscripts and $X_{it}(.)$ takes the form in equation (10). ι_t denotes the information set of the government in period t, and $\delta < 1$ is the time discount factor. At period t the government knows that TFP has some baseline value $A_{it}(.) = \phi_{it}$ and believes that the future expected TFP is given by $E_t(A_{it+1}(.)) = E_t(\phi_{it+1}\lambda_{it+1}) = \overline{\phi}_{it+1}\lambda(\phi_{it}Q_{it})$.[21]

Solving backwards, we obtain the tariffs for period $t+1$. The realized values of these tariffs are set after the government observes A_{it+1} and finds out that there is actually no LBD. Therefore, the actual period $t+1$ tariff rate is equal in its form and value to the one in equation (2). On the other hand, in order to determine the tariffs set in period t, the government needs to compute the future expected welfare which depends on the expected period $t+1$ tariffs. Given that there are two periods, the expected tariffs for period $t+1$ have the standard form similar to equation (2); however, due to the LBD process, each of its components, hence itself is expected to depend on period t tariffs

$$E_t(\tau_{it+1}) = \tau^e_{it+1}(\tau_{it}) = (\omega-1)\frac{\overline{\phi}_{it+1}\lambda(X_{it}(\tau_{it}))Q_{it+1}(X_{it}(\tau_{it}))/M_{it+1}(X_{it}(\tau_{it}))}{\varepsilon_{it+1}(X_{it}(\tau_{it}))} \tag{12}$$

As I show in Section A.1 in the appendix, the equilibrium tariff rate for period t is obtained from equation (11) such that the tariffs now include the perceived learning-by-doing motive in addition to the political economy channel.

$$\tau_{it} = (\omega-1)\frac{\phi_{it}Q_{it}(\tau_{it})/M_{it}(\tau_{it})}{\varepsilon_{it}(\tau_{it})} + \delta\omega\frac{\Lambda_i/M_{it}(\tau_{it})}{\varepsilon_{it}(\tau_{it})} \tag{13}$$

The variable Λ_i stands for the LBD effect and it is defined as

$$\Lambda_i \equiv \left(\frac{\lambda'(\phi_{it}Q_i(\tau_{it}))}{\lambda(\phi_{it}Q_i(\tau_{it}))}\phi_{it}Q'_{it}\right)\int_0^{1+\tau^e_{it+1}}\overline{\phi}_{it+1}\lambda(\phi_{it}Q_{it})Q_{it+1}d\tau_{it+1} > 0 \tag{14}$$

[21]Note that the government is not taking expected values over alternative values of ϕ_{it+1}. Instead it expects ϕ_{it+1} to be equal to $\overline{\phi}_{it+1}$ with probability 1.

Thus, Λ_i measures the government perceived growth in productivity due to the LBD process multiplied by the responsiveness of the current supply to tariffs and weighted by the future producer surplus. The tariff rate is increasing in the additional LBD term since the government considers the positive effect of increased production through today's protection on tomorrow's welfare.

Let's consider the following functional form for the LBD process[22]

$$\lambda_{it+1} = \lambda(X_i(\tau_{it})) = [\phi_{it} Q_i(\tau_{it})]^n,\ n < 1 \tag{15}$$

Next, in order to see the effect of productivity on tariffs, we plug equation (15) in equation (13) and, as I show in the appendix (Section A.1), obtain

$$\frac{d\tau_{it}}{d\overline{\phi}_{it+1}} > 0 \tag{16a}$$

$$\frac{\partial\tau_{it}}{d\phi_{it}} > 0 \tag{16b}$$

$$\frac{d\tau_{it}}{d\phi_{it}} > 0 \tag{16c}$$

Thus, assuming that ϕ_{it}, the part of the government perceived productivity that is independent of the LBD process, and $\overline{\phi}_{it+1}$, its future expected value, are positively correlated with the actual underlying determinants of TFP, the tariff rate increases in the current and expected future productivity. This might be one of the reasons why we need to worry about using lagged tariff rates as a way to get around the endogeneity problem while regressing productivity on tariffs. More importantly, the positive effect of productivity on tariffs confirms the main result in my basic model in this richer setup.

Next, I also confirm that the change in tariffs is positively related to the change in productivity as in the previous section[23]

$$\frac{d\Delta\tau_{it+1}}{d\Delta\phi_{it+1}}|_{\tau_{it},\phi_{it}} > 0 \tag{17}$$

We see that, introducing a government perceived LBD process adds a new channel of protection and a structure for the onset of the unilateral trade liberalization. However, the productivity to tariff linkages, as established in the basic political economy model, prevail.

[22] I assume $\lambda(.)$ is concave. Otherwise, in the multi-period case, tariffs could be raised unboundedly which is quite unrealistic.

[23] Apart from the supposedly temporary nature of protection due to the infant industry argument, I assume that in period $t+1$ the government actually realizes that the LBD process is not working. See the appendix (Section A.1) for the derivation.

As a final note, I acknowledge that in several empirical studies, declining industries such as textiles, clothing, footwear, and steel receive more protection in industrialized nations. Therefore, these studies naturally look at developed countries and especially the United States for evidence (see for example Baldwin 1985, and Marvel and Ray 1983). On the theory side, two recent papers that build up on Grossman and Helpman (1994) are worth noting: Baldwin (2002) uses a monopolistic competition model with sunk entry costs and random Markov process demand shocks; whereas, Tovar (2004) introduces loss aversion in preferences. One implication from these papers is that less productive sectors could receive more protection. However, none of the models on declining industries specifically account for unilateral liberalization or focus on establishing a link from productivity to trade policy. The models I presented in this and previous sections intend to show this link in the presence of unilateral liberalization which is taken to be an exogenous shock and hence used as the working assumption to identify the effects of tariffs on productivity in the earlier literature. Yet, the common denominator of my models and implications from these is that productivity matters for trade policy. Thus, how productivity specifically affects tariffs needs to be tested and documented empirically as I do in Section 5.

3 Trade Policy in Colombia

Colombia is a perfect example of a developing country that went through phases of heavy trade protection prior to the mid-1980s and finally a dramatic unilateral trade liberalization in the early 1990s, as can be seen in Figure 1. Therefore, it is no surprise that Colombia has been used as the case study of several papers to examine the impact of trade reform on productivity (for example, Roberts 1996; Fernandes 2003; Melendez, Seim and Medina 2003).

The barriers were first lowered during the 1977-1981 period in response to an increase in the coffee prices, increased foreign borrowing, and drug trafficking (Fernandes 2003). On the other hand, the Latin American debt crisis and the worsening terms of trade led to an increase in protection in the first half of the 1980s (Edwards 2001). President Virgilio Barco Vargas started the initial movement towards a real trade reform after he took office in 1986. He was succeeded by President Cesar Gaviria who completed the trade reform swiftly in two years (1991 and 1992).

As I mentioned above, nearly all studies in the trade reform and productivity literature neglect the endogeneity of trade policy. Although some authors (e.g., Pavcnik 2002 for Chile; Ferreira and Rossi 2003 for Brazil) acknowledge the potential for endogeneity, they argue that it may not

be such an issue in their studies given that the tariffs were reduced uniformly or proportionally across sectors. This is not true at least for Colombia; the liberalization was not uniform. Edwards (2001) notes that the trade liberalization reform of Colombia ("*La Apertura*") was "announced during the presidential campaign [of Cesar Gaviria] as a 'gradual' and 'selective' process." As can be observed from Figures 2 through 4, there is quite some variation in the tariff reductions across sectors.[24] Moreover, the Spearman's rank correlations of tariffs in Table 1 indicate that the correlations reduced over time, implying a selective process as opposed to a uniform one in liberalization. Otherwise, the ranking of sectors in terms of their protection rate would not change.

The average advalorem tariff rates in my sample of 4-digit ISIC industries declined from 43% in 1983 to about 14% in 1992 and stayed around that rate in the following years (Table 2). The dispersion of tariffs across sectors also declined (Table 2). If we just look at the standard deviations, the decline appears to be markedly higher. However, we need to take into account the differences in the magnitude of tariffs across periods and the coefficient of variation[25] is a better measure for that matter. The decline in the dispersion is notably lower when we use the coefficient of variation. However, this outcome does not indicate that political economy is no more a factor in tariffs after reform. The decrease in the dispersion is predicted by my models given the fact that the liberalization occurs through the elimination of some extra channels other than the political economy channel.

In my theoretical models and the main estimations, I use tariff rates as a measure of protection for import-competing sectors. I also have access to effective rate of protection (ERP) data which I use to augment my results with tariffs. The effective rates take into account the tariffs on inputs, and they are based on the value added. They are considerably higher than the nominal rates but show a similar pattern with the tariffs as can be observed from Figure 1.

Before I discuss my empirical methodology and the results, in the next section I briefly review the existing empirical literature to the extent that it relates to this paper.

4 Empirical Literature Overview

Tybout (1991) briefly reviews the literature that contains implications for the linkages between trade and productivity, and he indicates that the net effect of a liberalization episode is ambiguous.

[24]Note that the reductions are computed as percentages to account for the variation in the initial tariffs.
[25]Coefficient of variation is the mean divided by the standard deviation of a given group.

Therefore, a majority of the studies that appear in the last decade remain empirical and do not test any particular theory.[26,27]

Nearly all researchers take a two-step approach, where they first estimate productivity usually at the firm level (and some at the sector level), and then regress this productivity estimate on trade policy measures such as import penetration or tariffs for a single country (e.g., Fernandes 2003, Schor 2004, and Tybout and Westbrook 1995). Another strand of the literature focuses on the effect of imperfect competition in estimation and seeks to analyze the change in the price-cost margins after liberalization (Harrison 1994, Krishna and Mitra 1998 and so on).[28]

Although nearly all the studies neglect the endogeneity issue, Fernandes (2003) is an exception. She controls for endogeneity by using lagged tariff rates instead of current ones. She also considers the variables from Trefler's (1993) non-tariff barrier (NTB) equation as instruments for tariff rates in a robustness check. However, using lagged tariff rates might not get around the endogeneity problem, because trade policy might differ across sectors due to persistent factors related to productivity. For instance, productivity might be autocorrelated, or tariffs may be influenced by anticipated changes in productivity as predicted by one of my theoretical results. What is more, the validity of the instruments initially used by Trefler (1993) for a different study is debatable since some of the instruments (like import penetration or regional concentration) could very well be influenced by productivity, and hence be endogenous themselves.[29] Muendler (2004) is another exception in trying to control for the endogeneity of trade policy. He regresses the growth rate of productivity on both tariffs and import penetration at the same time. He considers certain components of the real exchange rate as instruments for the trade policy measures.[30] However,

[26]The motivation for the micro-level liberalization impact studies is based on two basic conjectures. First, trade liberalization may produce a productivity growth for the firm and the industry through economies of scale, improved access to foreign technology, and the elimination of X-inefficiencies. Second, liberalization may reallocate resources from the less efficient to the more efficient firms after the less efficient ones exit, hence provide a rise in the average productivity.

[27]There are also ex-post theoretical studies that provide an explanation for some of the results found in the recent empirical research. For example, in an influential paper, Melitz (2003) shows how industry productivity may grow due to reallocation between firms after an exogenous trade reform shock.

[28]In this paper, I focus on the single-country micro studies and relate my results directly to these. However, there is also a related group of empirical papers where authors analyze cross-country growth regressions (as summarized in Harrison 1996) linking openness to output growth. Such studies miss the micro variation, which is crucial in distinguishing among various channels of productivity changes, in the data. A recent criticism of these studies appears in Rodriguez and Rodrik (2001) who are in turn criticized by Srinivasan and Bhagwati (2001).

[29]Fernandes (2003) acknowledges that these robustness results are not reliable, as some of her instruments are clearly correlated with productivity.

[30]The measures are the nominal US dollar exchange rate, the average sector-specific European and US-Canadian producer price indices, and the Brazilian consumer price index. Muendler (2004) recognizes that the domestic prices can be correlated with the productivity of the firms so does not consider this as one of his baseline instruments but rather keeps it as a component of the real exchange rate.

both the nominal and real exchange rates lack sectoral variation and cannot explain why tariff rates differ across sectors.[31]

Harrison (1994) uses time dummies for capturing trade liberalization but these do not account for the firm/industry level variation in policy. She also considers tariff changes and import penetration in her estimations by interacting the trade policy measures with the relevant mark-up variable. These estimations invariably suffer from the same endogeneity problems I discussed above.

Pavcnik (2002) takes yet another approach and compares the productivity changes in the tradable versus non-tradable sectors around a trade liberalization period, finding that the import sectors experienced a larger increase in productivity relative to the non-tradable sectors but the results are inconclusive for export-oriented sectors.[32] This methodology does not account for the sectoral variations in trade policy as well. Furthermore, Tybout (1996) notes that firms usually self-select their trade-orientation and if more productive firms are more likely to become an exporter, then one must use caution in asserting a casual relationship from policy to performance. Pavcnik (2002) also regresses productivity on tariffs and import penetration as a robustness check, and she does not control for the endogeneity of trade policy.

Next, I would like to test my theory which predicts that tariffs depend on productivity, and liberalization differs across sectors based on productivity changes despite a common exogenous shock.

5 Estimation

5.1 Econometric Model

In the theory section I present two similar models of tariff policy where political economy is the common determinant. Moreover, the government has some positive perception about using tariffs which serves as the extra channel for protection. Both models imply protection even in the absence of political economy. A large negative shock, which is common across sectors, appears through these channels and serves as the source of trade liberalization.

In the estimations, I intend to capture the common features of protection and liberalization

[31]Note that, I show in my theoretical model and the corresponding estimations that tariffs directly depend on import penetration as well as import penetration depends on tariffs in a systematic way so this might further create multicollinearity problems in Muendler's (2004) estimations.

[32]Ozler and Yilmaz (2003) use the same approach to analyze the effect of trade liberalization on productivity in Turkey.

implied by my models. According to the political economy channel, tariffs are inversely related to import penetration (that is Imports/Domestic Production) and import demand elasticity. Recall that the production function is denoted as $X_{it} = A_{it}Q_{it}$ where A_{it} stands for total factor productivity (TFP) and we have the following definition: *Inverse Import Penetration/Import Demand Elasticity*= $\frac{A_{it}Q_{it}/M_{it}}{\varepsilon_{it}}$. The additional source of tariff protection causes a major unilateral liberalization when it vanishes. This occurs after the paradigm changes as discussed in Section 2.2, or after learning-by-doing is realized to be a false perception as in Section 2.3. I model the additional channels of protection under both models with a combination of overall and sector specific constants. Then, the trade reform that occurs due to the disappearance of such motives is a shift in the intercept terms (constants) of the tariff determination rule. Given the parsimonious nature of the models, the sector-specific effects also help to control for the other determinants of tariffs that may not be considered already.

As illustrated in Figure 1, tariffs in Colombia declined drastically starting in 1990 and the liberalization continued until 1992. Based on the theory, I first start out by assuming that liberalization is a major, once and for all shift in tariffs and relax this assumption afterwards. I capture the shift with a dummy variable, $UNILIB_t$, that takes the value one for 1990 and onwards, and zero otherwise. The econometric model can then be expressed as

$$\log \tau_{it} = \alpha + \beta_1 \log(Q_{it}/M_{it}\varepsilon_{it}) + \beta_2 \log A_{it} + \beta_3 UNILIB_t + \mu_i \beta_4 + u_{it} \tag{18}$$

where τ_{it} is the advalorem tariff rate for sector $i = 1, ..., N$ at period $t = 1, ..., T$. Note that the effect of A_{it} (TFP) on tariffs is taken in isolation with the use of logarithms. $Q_{it}/M_{it}\varepsilon_{it}$, together with A_{it}, are measures of the main political economy channel.[33] μ_i is a $1 \times (N-1)$ vector of industry dummy variables and depicts sector-specific effects. $UNILIB_t$ serves as an intercept-shifter with the interpretation I described above. According to the theory, we expect positive estimates of β_1 and β_2. On the other hand, the estimate of β_3 should be naturally negative by definition (it is a unilateral liberalization).[34]

In the theory section, the liberalization shock results in a one time permanent decline in tariffs although it is not necessarily how a real reform progresses. By looking at Figure 1, we can distinguish three periods with plausibly three different intercept terms: 1983-1989 (pre-reform), 1990-1992

[33] Q_{it} is not directly observable but it is estimated by dividing X_{it} by the estimate of A_{it}.

[34] α, β_1, β_2, and β_3 are scalars, whereas β_4 is an $(N-1) \times 1$ vector of coefficients.

(reform), and 1993-1998 (post-reform). What is more, there exists considerable variation within the pre-reform and reform periods.[35] Therefore, I estimate two different versions of equation (18). In the first version, I replace $\beta_3 UNILIB_t$ with $\rho_1 REF_t + \rho_2 POSTREF_t$, where REF_t is a dummy variable which equals one for 1990-1992 and zero otherwise. Similarly, $POSTREF_t$ is equal to one for 1993-1998 and zero otherwise.[36] Both control for the shift in tariffs in their respective periods relative to the constant term, α. In the second version, I replace $\beta_3 UNILIB_t$ with $\theta_t \gamma$ where θ_t is a $1 \times (T-1)$ vector of year dummies that capture the yearly common variation in tariffs and further relaxes the assumption of a one time overall tariff reduction.[37]

Next, to eliminate the fixed effects, I use a first-differenced model based on equation (18)

$$\Delta \log \tau_{it} = \beta_1 \Delta \log(Q_{it}/M_{it}\varepsilon_{it}) + \beta_2 \Delta \log A_{it} + \beta_3 \Delta UNILIB_t + v_{it} \tag{19}$$

where the error term is $v_{it} = \Delta u_{it}$ and it is essentially autocorrelated so I correct for this autocorrelation in my estimations. Given the definition of $UNILIB_t$, $\Delta UNILIB_t$ becomes just a year dummy for 1990. This may not be adequate to capture the action in the actual data. When we take first differences, the differenced data for 1983, 1985, and 1988 automatically get dropped given the gaps in the sample. Moreover, the trade liberalization took place gradually between 1990 and 1992. I consider this downward trend in the reform years by employing a different version of equation (19), where I replace $\beta_3 \Delta UNILIB_t$ with φREF_t. REF_t is a dummy variable for 1990-1992 as above, and φ is a scalar. I also estimate this modified version of equation (19) with a constant term to account for the small tariff changes before and after the reform period where the interpretation of REF_t becomes the deviation from the constant term.

There are potentially endogeneity problems in the estimation. First, $Q_{it}/M_{it}\varepsilon_{it}$ is endogenous with respect to tariffs since it depends on domestic prices, hence on tariffs. Second, the previous empirical work documented that trade policy affects productivity which requires accounting for a potential reverse causation. I use the following list of instruments to deal with the endogeneity issues: the capital to output ratio, materials prices, a measure of scale economies (value added/number of firms), and the TFP of the upstream industries.[38] Instruments should be cor-

[35] Tariffs actually increase between 1982 and 1984 and then start to decline in 1985. The sample, on the other hand, only includes 1983, 1985, and 1988-1990 for the pre-reform era. Between 1983 and 1988 the trend for tariffs is a gradual decline within the sample.

[36] ρ_1 and ρ_2 are scalars.

[37] γ is a $(T-1) \times 1$ vector of coefficients.

[38] The detailed variable definitions and sources are in the appendix (Section A.3).

related with the endogenous regressors and yet be orthogonal to the error term. I present the formal tests of instrument validity in Section 5.4 but I would like to provide some intuition here. Capital share is expected to be negatively related to the output/imports ratio (Q_{it}/M_{it}) given that Colombia is more likely to produce products with smaller capital content and import those rich in capital based on a comparative advantage argument. The materials prices affect the domestic output prices, hence $Q_{it}/M_{it}\varepsilon_{it}$ but not the tariffs of a given sector i, conditional on Q_{it}, M_{it}, and ε_{it}. Scale is positively correlated with productivity and it is an inherent characteristic of a sector. The productivity of a sector is also expected to be affected from the embodied upstream productivity which is likely to be independent of the sector's own tariffs.

Since the model is quite parsimonious, it is also prone to an omitted variable bias. The use of the fixed industry effects in equation (18) and its different versions, and the first differencing in equation (19) and its different versions should alleviate this potential problem along with the Instrumental Variables (IV) estimation.

In the rest of this section I present and discuss the data, results, and robustness of my estimations. In Section 6, I test how accounting for the endogeneity of tariffs with respect to productivity affects the regressions that analyze the impact of trade reform on productivity.

5.2 Data

The base data for the estimations span 1982 through 1998 but given the lack of tariff and production information for certain years the sample reduces to 1983, 1985, and 1988-1998. The tariff and effective rate of protection (ERP) figures are obtained from DNP (National Planning Department) of Colombia at the 8-digit product level,[39] which are then aggregated to the 4-digit ISIC sectors by using simple averages.[40] The 4-digit ISIC level import data come from the COMTRADE dataset, United Nations Statistics Division and the industry production data at the same level are available through UNIDO's Industrial Statistics Database.

The productivity estimates, value added, input, and materials prices data are obtained from Eslava, Haltiwanger, Kugler and Kugler (2004), where each variable (except the value added[41]) is aggregated from the firm level to the 4-digit ISIC industry level with production shares used as

[39]The product classification code, called "Nabandina", is due to the Andean Community of Nations. I thank Marcela Eslava at Universidad de Los Andes/CEDE, Colombia for generously sharing the data.

[40]I use simple averages to be consistent with the earlier literature. An alternative way would be to use the import or production shares of each product as weights but these data do not exist for all sample years at this level of disaggregation.

[41]The value added is used to compute a measure of scale economies where it is an unweighted total in each sector.

the weights. The main data source for Eslava et al. (2004) is the Colombian Annual Manufacturers Survey (AMS) by DANE (National Statistical Institute). I discuss further details about the productivity estimates below in Section 5.2.1.

The import demand elasticity measure is based on the structural estimates in Kee, Nicita and Olarreaga (2004), which I combine with the GDP data from the World Development Indicators (WDI), and import data from COMTRADE. The import demand elasticities are available only at the 3-digit ISIC level.[42]

In order to obtain the TFP measure of the upstream industries, I employ the input-output tables provided at the 3-digit ISIC level by Nicita and Olarreaga (2001), which were compiled from version 4 of the Global Trade Analysis Project (GTAP) database. Excluding the inputs being used from the own sector, the upstream measure is based on a combination of TFPs of the remaining input sectors as weighted by their share of usage.

The variable definitions and sources are presented more in detail in the appendix (Section A.3). In Table 4, I provide the summary statistics for all the variables I use in the estimations.

5.2.1 Productivity Estimates

The productivity estimates come from Eslava, Haltiwanger, Kugler and Kugler (2004). They estimate total factor productivity (TFP) as the residual from the following production function for each firm $i = 1, ..., N$ and period $t = 1982, ..., 1998$

$$\log X_{it} = b_1 \log K_{it} + b_2 \log L_{it} + b_3 \log E_{it} + b_4 \log I_{it} + \log A_{it} \tag{20}$$

where K_{it}, L_{it}, E_{it}, and I_{it} denote capital, labor (total employment hours), energy consumption, and materials, respectively. An important concern in such an estimation is the simultaneity bias; that is, productivity shocks may be correlated with the inputs. They correct for this bias by considering a measure of downstream demand as an instrument for inputs along with regional government expenditures and input prices. A great advantage of this dataset is that it involves plant level input prices which have not been available to the other researchers in the field requiring them to use non-parametric estimation techniques.[43] Furthermore, the output measures commonly

[42]See the appendix for a discussion on how the import demand elasticity is computed (Section A.2).

[43]The methodology in these studies was developed by Olley and Pakes (1996), and advanced by Levinsohn and Petrin (2003). They employ investment or intermediate inputs to control for the correlation between the input levels and the unobserved firm-level productivity shocks.

used in the literature have usually been the firm revenue deflated by the the industry-level prices. Thus, within-industry price differences (e.g. due to different markups) have been part of the output and productivity estimates of such studies, potentially biasing their results.

5.3 Estimation Results

Before moving on to the results, let us first observe the simple correlations of total factor productivity and tariffs. The overall correlation coefficient for $\log A_{it}$ and $\log \tau_{it}$ in the whole sample of 920 observations is -0.222. This is significant at the 1% level and can be observed graphically in Figure 5 as well. In Table 3, I present the correlation matrix for all the combinations of $\log A_{it}$ and $\log \tau_{it}$ across years. The two variables again have a relatively small negative correlation for the most part which is insignificant for certain years such as 1992 through 1994. These relationships also appear in Figure 6 which includes plots of TFP versus tariffs by year. In Table 3, it is interesting to note that the two variables can be concurrently and also intertemporally correlated. This is one reason why using lagged tariff rates may not get around the endogeneity problem of tariffs with respect to productivity. Topalova (2004) notes a similar pattern in the Indian data for the 1997-2001 period and excludes this period from her analysis due to her concern about endogeneity.

However, we cannot establish a causal relationship between tariff protection and productivity with these crude observations alone. We need to control for the other important variables as required by the theory and tackle the endogeneity issues. In this section, I show how productivity influences tariffs after I control for the endogeneity of productivity. Later in Section 6, I estimate a system of equations related to this setup and show that accounting for the effect of productivity on tariffs may strengthen the positive impact of trade reform on productivity.

As noted in Section 5.1, the two right-hand-side variables–the inverse import penetration to import demand elasticity ratio, and total factor produtivity–in the tariff regressions are portentially endogenous. I use instrumental variables to address this problem. More specifically, I employ the two-step efficient generalized method of moments (henceforth IV-GMM) estimator with either fixed effects or first differences for my unbalanced panel. This methodology is more efficient than regular instrumental variables in the presence of heteroskedasdicity of unknown form due to its use of an optimal weighting matrix (Cragg 1983). A Pagan-Hall (1983) test confirms the presence of heteroskedasticity in the data and further justifies the use of the IV-GMM methodology.

In Table 5, I present the main estimation results. In column 1, we have the estimates for equa-

tion (18). As predicted by theory, tariff rates depend positively on the inverse import penetration to import demand elasticity ratio ($Q_{it}/M_{it}\varepsilon_{it}$) and positively on total factor productivity (A_{it}). The coefficients for the two main variables, β_1 and β_2, are positive and statistically significant at the 1% level. The unilateral liberalization variable, $UNILIB_t$, takes out the common reduction in the tariffs after 1990, and it is significant and negative as expected. In column 2, I provide the estimates for the fist variant of equation (18). Here, we take into account the variation in the data by dividing it into three periods as opposed to imposing a one time major decline in the tariffs. The two intercept-shifters, REF_t (period dummy for 1990-1992) and $POSTREF_t$ (period dummy for 1993-1998), control for the common decline in tariffs across sectors relative to the 1983-1989 period and come out negative and significant. Thus, the results are in line with the ones in column 1. In column 3, we have the estimates for the second variant of equation (18) that allows for further variation across time with the year effects and captures the gradual decline in tariffs. Both β_1 and β_2 are still positive and statistically significant at the 1% level in columns 2 and 3. The year dummies in column 3 are jointly significant just like the industry fixed effects are in all three equations.

A positive coefficient on $Q_{it}/M_{it}\varepsilon_{it}$, such that tariffs are inversely related to import penetration and import demand elasticity is a result consistent with the previous findings in the empirical political economy literature (such as Gawande and Bandyopadhyay 2000 for the U.S., Mitra et al. 2002 for Turkey, and Karacaovali and Limão 2005a for the EU). A positive coefficient for A_{it}, that is more productive sectors receive higher tariff protection, complements this result and confirms my major theoretical prediction. This result is also important because none of the earlier researchers separate the size effect into A_{it} and Q_{it}. Moreover, I account for the exogenous unilateral liberalization shock common across sectors in all specifications so there is no doubt that political economy does matter for the sectoral variation in tariffs. Therefore, endogeneity of tariffs with respect to productivity is a prevailing problem when researchers plainly regress tariffs on productivity.

In Table 6, I provide the estimates of equation (18) and its variants that measure the effect of yearly productivity changes on tariff changes with the first differenced data. The methodology is still IV-GMM and I employ the first differences of each instrument from Table 5. The sample now reduces to 1988-1998 given the gaps in the data. In column 1, β_1 and β_2 have the expected signs but are not significant. This result is not surprising given that $\Delta UNILIB_t$ fails to recognize the gradual decline in tariffs and acts as a single year effect for 1990. I correct for this by estimating

equation (18) and replacing $\Delta UNILIB_t$ with a common term for the 1990-1992 period (REF_t) during which the liberalization took place step by step (column 2). In this version, β_1 becomes significant at the 10% level and β_2 at the 5%. REF_t has a negative and significant (at the 1% level) coefficient capturing the common downward trend. In column 3, I further allow for a common constant term on top of REF_t recognizing the small changes in the other years, and both β_1 and β_2 become significant at the 5% level. These results indicate that due to political economy, the extent of liberalization is smaller for the sectors with a smaller reduction or a higher increase in their productivity as compared to similar sectors. Note that in all differenced results, β_1 and β_2 are statistically identical, which is predicted by the model. In levels, this may not occur because of fixed effects.

Although the theoretical section involves protection through tariffs, I repeat the specifications in Table 5 and Table 6 with the effective rates of protection (ERP) in order to see whether the results hold with a different measure of protection. Effective rates are based on value added and essentially take into account the effect of tariffs on the inputs as well. ERP data are provided by the National Planning Department of Colombia (DNP) and I am limited by their computations since I do not have the detailed data to calculate them myself. As can be observed from Figure 1 and Table 4, the effective rates are higher than the regular tariff rates but otherwise display a similar trend. I exclude the three sectors[44] that exhibit negative ERP (in levels not logs), because it is hard to argue that these sectors are indeed protected. In Table 7, I repeat the specifications from Table 5 and the results appear to be totally consistent. The only difference is that the significance levels for the main variables are lower, and the constant term becomes insignificant in columns 2 and 3. The same arguments apply to the figures in Table 8 which are the replicas of the estimates from Table 6 with ERP. The results are again qualitatively similar but less significant.

In the next section, I provide specification tests and some sensitiviy analysis for the main estimations I covered. Then, in Section 6, I discuss how accounting for the endogeneity of tariff policy, as implied by my theoretical and empirical results, may improve the estimates of the effect of trade reform on productivity.

[44] The excluded sectors are: a) ISIC 3122, manufacture of prepared animal feeds; b) ISIC 3512, manufacture of fertilizers and pesticides; c) ISIC 3822, manufacture of agricultural machinery and equipment.

5.4 Robustness and Specification Tests

In Table 9, I examine the effect of past productivity on current tariffs to check whether policy implementation occurs with a one period lag although it is not part of the model. I employ one period lags of scale and upstream TFP as instruments for the lag of productivity, and hence repeat the specifications in Table 5 with $\log A_{it-1}$ instead of $\log A_{it}$. I find that more productivity yesterday calls for more protection today in all three specifications. However, precaution is required while interpreting this result since it might be picking up the persistence in tariffs as well.

In tables 10 and 11, I present the biased ordinary least squares (OLS) results for comparison. In Table 10, I provide the estimates of equation (18), and in Table 11 the estimates of equation (19) with OLS using both tariffs and effective rates of protection. The OLS coefficients have the same signs as the IV-GMM estimates but they are smaller. In addition to that, $\log(Q_{it}/M_{it}\varepsilon_{it})$ and $\Delta\log(Q_{it}/M_{it}\varepsilon_{it})$ have significant coefficients in all specifications while the coefficients for $\log A_{it}$ and $\Delta\log A_{it}$ are insignificant in all except the one for $\Delta\log A_{it}$ in Table 11, column 2.

I confirm the endogeneity of $\log(Q_{it}/M_{it}\varepsilon_{it})$ and $\log A_{it}$ econometrically through a Durbin-Wu-Hausman endogeneity test, which further justifies the use of instrumental variables instead of OLS. Furthermore, the Hansen-Sargan test of overidentifying restrictions indicate that our instruments are valid, that is they are uncorrelated with the error term and correctly excluded from the estimated equations. The probability value for the null hypothesis that the instruments are valid, range from 0.144 to 0.933 for the main specifications presented in Table 5. The Hansen-Sargan test probability values are presented in the last row of each relevant table and they have high values, as desired, for the estimations in first differences (Table 6) as well. The tests are not strong for the ERP specifications, but given the endogeneity and good performance with tariffs, it is prudent to keep these instruments and ensure comparability with the tariff results.

In Table 12, I report the first stage regressions for the main tariff specification in Table 5, column 1, where we see that all the instruments are jointly significant and the regressions have a high explanatory power. I also find that the results are not driven by any specific instrument which I check by excluding each one at a time.[45] In Table 13, we have the first stage regressions for the main first-differenced specification (Table 6, column 1) which are not as strong as the ones in Table 12 in terms of the explanatory power but all the instruments are still jointly significant. The partial R-squared values based on Shea (1997) indicate that the instruments for $\log A_{it}$ explain a

[45] Including labor share as an additional instrument also does not change the results qualitatively but lowers the probability value of the Hansen-Sargan test.

substantial fraction of its variation. The same is not true for $\log(Q_{it}/M_{it}\varepsilon_{it})$ and the first-differenced equations.

Figure 1 indicates that in Colombia the major trade liberalization era started in 1990 and continued until 1992 where new persistently lower levels of tariffs were reached. Given the restrictiveness of $UNILIB_t$ by construction, I allowed it to take 1991 instead of 1990 as the cutoff point as well and the results remain robust to this different cutoff value. Furthermore, when $UNILIB_t$ is excluded, the coefficient magnitudes rise but the results carry through.

6 Endogeneity Bias and the Effect of Tariffs on Productivity

The theoretical and empirical results I presented in the earlier sections indicate that we should be worried about the endogeneity of trade policy with respect to productivity. If the researchers do not account for the endogeneity, their estimates of the trade policy effects on productivity will be biased. However, it is hard to tell the direction and magnitude of the endogeneity bias unless the system is very simple.[46] Once we have other regressors in the system, the correlations among them do not permit us to make any predictions about the bias. Therefore, I illustrate how the bias might be working with a system of equations below.

In constructing this system, I partly rely on the setup of my estimations in the previous section. On the other hand, I do not have a structural equation showing how productivity depends on tariffs so I just try to keep it similar to the estimations in the earlier empirical literature. I model the tariff and inverse import penetration equations as before and add a third equation for productivity as follows

$$\log A_{it} = \alpha_1 + \alpha_2 \log \tau_{it} + (\log Z_{1it})\alpha_3 + \mu_{1i}\alpha_4 + Z_{2t}\alpha_5 + \upsilon_{1it} \tag{21a}$$

$$\log \tau_{it} = \beta_1 + \beta_2 \log A_{it} + \beta_3 \log(Q_{it}/M_{it}\varepsilon_{it}) + \mu_{2i}\beta_4 + \theta_t\beta_5 + \upsilon_{2it} \tag{21b}$$

$$\log(Q_{it}/M_{it}\varepsilon_{it}) = \gamma_1 + \gamma_2 \log \tau_{it} + (\log Z_{3it})\gamma_3 + \upsilon_{3it} \tag{21c}$$

where υ_{1it}, υ_{2it}, and υ_{3it} are the error terms for sector $i = 1, ..., N$ at period $t = 1, ..., T$. μ_{1i} and

[46] Suppose that we have the following two equations that relate tariffs and productivity: (1) $\log A_{it} = a_1 + a_2 \log \tau_{it} + w_{1it}$ and (2) $\log \tau_{it} = b_1 + b_2 \log A_{it} + w_{2it}$ where w_{1it} and w_{2it} are mean zero error terms with constant variances $\sigma^2_{w_1}$ and $\sigma^2_{w_2}$. Then assuming that the covariance between the two error terms is zero, i.e. $cov(w_{1it}, w_{2it}) = 0$, we obtain $cov(w_{1it}, \log \tau_{it}) = \frac{b_2}{1-b_2 a_2}\sigma^2_{w_1}$. If the true values of a_2 and b_2 are such that $a_2 < 0$ and $b_2 > 0$, then we have $cov(w_{1it}, \log \tau_{it}) > 0$. If we estimate a_2 with OLS, ignoring equation (2), and get $\widehat{a}_2 < 0$ which is positively correlated with a_2, we would have an upward bias, hence underestimate a_2.

μ_{2i} are $1 \times (N-1)$ vectors of industry dummies, and θ_t is a $1 \times (T-1)$ vector of year dummies. Z_{1it} and Z_{3it} are 1×2 vectors of control variables at the 4-digit ISIC sector level, whereas Z_{2t} is a 1×2 vector of economy-wide controls.[47] Z_{1it} includes the scale measure and upstream TFP, whereas Z_{3it} includes the capital to output ratio and materials prices. Note that these industry level control variables are precisely the instruments I used in the instrumental variables estimations in Section 5 so they are expected to be exogenous. The other advantage of these controls is that I get a consistent framework with the rest of my estimations. Z_{2t} includes GDP growth and inflation to control for the macro changes in the economy that might affect the productivity in all the sectors.

My estimates of equation (21a) are at the 4-digit industry level. This limitation precludes any direct comparison between my estimates and the ones in the recent firm-level studies. However, after I estimate the system with three-stage least squares (3SLS), I compare these results with the simple OLS estimates of equation (21a) that ignore the endogeneity and get the chance to test whether accounting for endogeneity improves the results within my dataset.

In Table 14, I provide the comparative results of estimating the whole system with 3SLS and estimating equation (21a) with OLS only. As in line with the earlier literature, a negative OLS estimate of the coefficient for tariffs in equation (21a), i.e. $\widehat{\alpha}_2 < 0$, indicates that productivity is inversely related to tariffs. The 3SLS regression results not only confirm this finding but also show that the positive effect of lower tariffs on productivity grows slightly stronger (by 1.5%) when I account for the endogeneity of tariffs. The 3SLS results from equation (21b) are similar to the findings I present in Table 5: more productive sectors receive higher protection, and tariffs are inversely related to import penetration and import demand elasticity. In Table 15, I replicate the estimations from Table 14 by using effective rates of protection instead of tariffs and find identical results. However, this time the positive impact of liberalization on productivity is larger by 17% when we estimate the whole system. These findings indicate that the trade policy effects on productivity might be underestimated when endogeneity is not accounted for.

7 Concluding Remarks

I show, both theoretically and empirically, that we should be concerned about the endogeneity of trade policy with respect to productivity. This has been neglected for the most part in the recent

[47] Note that α_1, α_2, β_1, β_2, β_3, γ_1, and γ_2 are scalars. α_3, α_5, and γ_3 are 2×1, α_4 and β_4 are $(N-1) \times 1$ vectors, and β_5 is a $(T-1) \times 1$ vector.

empirical literature. Studies that investigate the effect of trade policy on productivity often argue that the exogeneity of the trade liberalization shock helps to identify a linkage without worrying too much about the endogeneity of tariffs or other forms of trade policy. I account for such an argument in my theoretical and empirical models, and still obtain tariffs to be endogenous.

I employ a basic political economy of trade protection model and also introduce two different channels of protection that lead to unilateral liberalization once they are removed. The extra channels are meant to capture the perceived benefit of protection to the governments even in the absence of political economy concerns. I first keep the liberalization channel very simple to ensure that my results are not driven by any specific assumptions or complications and then give more structure to it by modeling a learning-by-doing argument. The main result from my theoretical models, simple yet compelling, is that despite an exogenous unilateral trade liberalization shock that is common across sectors, we obtain a differentiated effect across sectoral protection based on productivity. Based on my theory, I predict that more productive sectors receive more protection and that the extent of liberalization is less for sectors that experience a higher productivity increase.

Next, I test and confirm these theoretical results using production, trade, and tariff data at the 4-digit ISIC industry level for Colombia between 1983 and 1998. I keep all of my estimations closely related to my theory and account for all the potential endogeneity problems by using relevant instruments and methodologies.

Finally, I estimate a system of equations and show that by not accounting for the endogeneity of trade policy with respect to productivity, we might underestimate the positive impact of trade reform on productivity. Thus, correcting for the endogeneity bias does not overturn the results in the early empirical literature but makes them somewhat stronger for Colombia which would be interesting to test for different countries as well.

As a natural extension to this paper, it would be useful to carefully model the effect of tariffs on productivity and obtain a more structural simultaneous equations model considering all the interdependencies between tariffs, productivity, and their determinants.

A Appendix

A.1 Derivations

Equation (2)

We maximize equation (1) with respect to τ_i to obtain the following first order condition

$$\begin{aligned}\frac{\partial G}{\partial \tau_i} &= -D_i(\tau_i) + \omega A_i Q_i(\tau_i) + M_i(\tau_i) + \tau_i M_i'(\tau_i) \\ &= (\omega - 1) A_i Q_i(\tau_i) + \tau_i M_i'(\tau_i) \end{aligned} \tag{22}$$

Equating to zero and solving for τ_i, and then dividing both sides of this expression by $p_i^w = 1$ and using the following elasticity definition $\varepsilon_i \equiv -M_i' p_i^w / M_i$ yields equation (2).

Equation (6)

In order to obtain equation (6), we implicitly differentiate the specific tariff version of τ_i as expressed in equation (5) with respect to α and use the linearity assumption for M_i (so that $M_i'' = 0$), the restriction $0 < \alpha < 2 - D_i'/A_i Q_i'$ and concavity of $\sigma_i(\tau_i)$ (i.e. $\sigma_i' > 0$, $\sigma_i'' < 0$)

$$\frac{d\tau_i}{d\alpha} = -\frac{\sigma_i'}{M_i'(\tau_i) + (\omega - 1) A_i Q_i'(\tau_i) + \alpha \sigma_i''(\tau_i)} > 0 \tag{23}$$

Equation (13)

The first order condition for a solution to equation (11) is

$$\begin{aligned}\frac{\partial E_t(G_{it} + \delta G_{it+1})}{\partial \tau_{it}} &= (\omega - 1)\phi_{it} Q_{it}(\tau_{it}) + \tau_{it} M_{it}' - \delta \frac{\partial \tau_{it+1}^e(\tau_{it})}{\partial \tau_{it}} D_{it+1}(.) \\ &\quad + \delta \omega \frac{\partial}{\partial \tau_{it}} \int_0^{1+\tau_{it+1}^e} \overline{\phi}_{it+1} \lambda(\phi_{it} Q_{it}(\tau_{it})) Q_{it+1}(\tau_{it+1}) d\tau_{it+1} \\ &\quad + \delta \frac{\partial \tau_{it+1}^e(\tau_{it})}{\partial \tau_{it}} M_{it+1}(.) + \delta \frac{\partial \tau_{it+1}^e(\tau_{it})}{\partial \tau_{it}} \tau_{it+1}^e(\tau_{it}) M_{it+1}' \end{aligned} \tag{24}$$

which after a few steps of manipulation becomes

$$\begin{aligned}\frac{\partial E_t(G_{it} + \delta G_{it+1})}{\partial \tau_{it}} &= (\omega - 1)\phi_{it} Q_{it}(\tau_{it}) + \tau_{it} M_{it}' \\ &\quad + \delta \omega \left[\frac{\lambda'(\phi_{it} Q_{it}(\tau_{it}))}{\lambda(\phi_{it} Q_{it}(\tau_{it}))} \phi_{it} Q_{it}' \int_0^{1+\tau_{it+1}^e} \overline{\phi}_{it+1} \lambda(.) Q_{it+1}(\tau_{it+1}) d\tau_{it+1} \right] \\ &\quad + \delta \frac{\partial \tau_{it+1}^e(\tau_{it})}{\partial \tau_{it}} \left[(\omega - 1) \overline{\phi}_{it+1} \lambda(.) Q_{it+1}(\tau_{it+1}^e(\tau_{it})) + \tau_{it+1}^e(\tau_{it}) M_{it+1}' \right] \end{aligned} \tag{25}$$

Using equation (12) to substitute in for $\tau_{it+1}^e(\tau_{it})$ and employing the definition in equation (14),

the first order condition simplifies to

$$\frac{\partial E_t(G_{it} + \delta G_{it+1})}{\partial \tau_{it}} = (\omega - 1)\phi_{it} Q_{it}(\tau_{it}) + \tau_{it} M'_{it} + \delta\omega\Lambda_i = 0 \tag{26}$$

Dividing both sides of equation (26) by $p_i^w = 1$ and using the same elasticity term ε_i as described above yields equation (13).

Equations (16a), (16b), and (16c)

Employing the functional form given in equation (15), the LBD term can now be expressed as

$$\Lambda_i = n\phi_{it}^n Q'_{it}(Q_{it}(\tau_{it}))^{n-1} \int_0^{1+\tau_{it+1}^e} \overline{\phi}_{it+1} Q_{it+1}(\tau_{it+1}) d\tau_{it+1} \tag{27}$$

The relationships in equations (16a), (16b), and (16c) are then obtained by plugging equation (27) in equation (26) and differentiating τ_{it} in equation (26) with respect to $\overline{\phi}_{it+1}$ (implicitly), ϕ_{it} (partially), and ϕ_{it} (implicitly). For $\overline{\phi}_{it+1}$ we get

$$\frac{d\tau_{it}}{d\overline{\phi}_{it+1}}|_{n<1} = -\frac{\delta\omega n\phi_{it}^n Q'_{it}(Q_{it}(\tau_{it}))^{n-1} \int_0^{1+\tau_{it+1}^e} Q_{it+1} d\tau_{it+1}}{M'_{it} + \delta\omega n(n-1)\phi_{it}^n (Q'_{it})^2 (Q_{it})^{n-2} \int_0^{1+\tau_{it+1}^e} \overline{\phi}_{it+1} Q_{it+1} d\tau_{it+1} + (\omega - 1)\phi_{it} Q'_{it}} > 0 \tag{28}$$

Similarly for ϕ_{it} we get the following two

$$\frac{\partial\tau_{it}}{\partial\phi_{it}}|_{n<1} = -\frac{\delta\omega n^2\phi_{it}^{n-1} Q'_{it}(Q_{it})^{n-1} \int_0^{1+\tau_{it+1}^e} \overline{\phi}_{it+1} Q_{it+1} d\tau_{it+1} + (\omega - 1)Q_{it}}{M'_{it}} > 0 \tag{29}$$

$$\frac{d\tau_{it}}{d\phi_{it}}|_{n<1} = -\frac{\delta\omega n^2\phi_{it}^{n-1} Q'_{it}(Q_{it})^{n-1} \int_0^{1+\tau_{it+1}^e} \overline{\phi}_{it+1} Q_{it+1} d\tau_{it+1} + (\omega - 1)Q_{it}}{M'_{it} + \delta\omega n(n-1)\phi_{it}^n (Q'_{it})^2 (Q_{it})^{n-2} \int_0^{1+\tau_{it+1}^e} \overline{\phi}_{it+1} Q_{it+1} d\tau_{it+1} + (\omega - 1)\phi_{it} Q'_{it}} > 0 \tag{30}$$

Equation (17)

The actual tariff in period $t + 1$ is similar to the one in equation (12) but now its terms are not dependent on X_{it}, because I assume that the LBD process is realized to be a false perception:

$$\tau_{it+1} = (\omega - 1)\frac{\phi_{it+1} Q_{it+1}(\tau_{it+1})/M_{it+1}(\tau_{it+1})}{\varepsilon_{it+1}(\tau_{it+1})} \tag{31}$$

Now, by using equation (13) and equation (31), we can express the difference in the tariff rates

between the two periods as

$$\begin{aligned}\Delta\tau_{it+1} &= \tau_{it+1}|_{n=0} - \tau_{it}|_{n>0} = -\frac{1}{M_i'}(\omega-1)(\phi_{it+1}Q_{it+1} - \phi_{it}Q_{it}) \\ &\quad + \frac{1}{M_i'}\delta\omega n\phi_{it}^n Q_{it}'(Q_{it})^{n-1}\int_0^{1+\tau_{it+1}^e}\overline{\phi}_{it+1}Q_{it+1}dp_{it+1} \end{aligned} \tag{32}$$

Equation (17) is then obtained by implicitly differentiating equation (32) with respect to $\Delta\phi_{it+1}$.

$$\frac{d\Delta\tau_{it+1}}{d\Delta\phi_{it+1}}|_{\tau_{it},\phi_{it}} = -\frac{(\omega-1)Q_{it+1}(\tau_{it+1})}{M_i'(.) + (\omega-1)\phi_{it+1}Q_{it+1}'(\tau_{it+1})} > 0 \tag{33}$$

A.2 Import Demand Elasticity

In the theory section, I define the import demand elasticity, ε_i, as $M_i' p_i^w / M_i$ but traditionally and in the empirical data it is evaluated at the domestic prices, not the world prices. I take this into account in obtaining the elasticity adjusted inverse import penetration ratio, given the fact that ouput value is evaluated at the domestic prices, whereas imports are evaluated at the world prices. Therefore,

$$\frac{X_i/M_i}{\varepsilon_i} = \frac{X_i/M_i}{M_i' p_i^w / M_i} = \frac{p_i X_i / p_i^w M_i}{M_i' p_i / M_i} \tag{34}$$

I use the structural estimates from Kee, Nicita and Olarreaga (2004) to compute the import demand elasticities. Based on Kee et al. (2004), I obtain the import demand elasticity for sector i as

$$\varepsilon_{it} = \frac{a_i}{s_{it}} + s_{it} - 1 \tag{35}$$

where s_{it} is the negative of the imports to GDP ratio and a_i is an estimated structural price parameter from a GDP function.

A.3 Variable Definitions and Sources

Name	Definition	Source
τ_{it}	Advalorem tariff rate (%): Obtained at the 8-digit product level ("Nabandina" code) and aggregated to the 4-digit ISIC level by simple averaging	National Planning Department (DNP), Colombia
τ_{it}^{eff}	Effective rate of protection (%): Obtained at the 8-digit product level ("Nabandina" code) and aggregated to the 4-digit ISIC level by simple averaging	National Planning Department (DNP), Colombia
X_{it}	Output values in 1000 USD at the 4-digit ISIC level	UNIDO, Industrial Statistics Database
M_{it}	Import values in 1000 USD at the 4-digit ISIC level	COMTRADE, United Nations Statistics Division
ε_{it}	Import demand elasticity at the 3-digit ISIC level: obtained by combining import and GDP data with estimated structural price parameters.	Structural estimates (Kee et al. 2004), GDP (World Development Indicators, World Bank), imports (COMTRADE).
A_{it}	Total factor productivity (TFP): Obtained at the firm level by estimating production function residuals with a 2SLS model. Aggregated from the firm to the 4-digit ISIC level by using production shares as weights.	Eslava, Haltiwanger, Kugler and Kugler (2004)
Capital Share	Capital stock series obtained at the firm level using fixed assets, gross investment, "observed" depreciation rates, and a gross capital formation deflator. The ratio of capital stock to output is then aggregated to the 4-digit ISIC level by using firms' production shares as weights.	Eslava, Haltiwanger, Kugler and Kugler (2004)
Materials Prices	Obtained at the firm level using Tornqvist indices which are aggregated to the 4-digit ISIC level by using firms' production shares as weights.	Eslava, Haltiwanger, Kugler and Kugler (2004)
Scale	The ratio of total value added to the number of firms in a given 4-digit ISIC sector.	Eslava, Haltiwanger, Kugler and Kugler (2004)
Upstream TFP	Using the input-output tables at the 3-digit ISIC level, I exclude the inputs being used from the own sector, and obtain the upstream measure based on a combination of TFPs of the remaining input sectors as weighted by their share of usage.	Input-output tables (Nicita and Olarreaga 2001, originally from Global Trade Analysis Project), TFP (Eslava et al. 2004).
GDP Growth	The annual percentage change in the GDP (constant 2000 US dollars)	World Development Indicators (WDI), World Bank
Inflation	Annual percentage change in the GDP deflator	World Development Indicators (WDI), World Bank

References

[1] Baldwin, Richard E. (1985), *The Political Economy of U.S. Import Policy*, (Cambridge, MA: MIT Press.)

[2] Baldwin, Robert E. (2002), "Entry and Asymmetric Lobbying: Why Governments Pick Losers," National Bureau of Economic Research Working Paper No. 8756, February.

[3] Caves, R. E. (1976), "Economic Models of Political Choice: Canada's Tariff Structure," *Canadian Journal of Economics*, 9(2), 278-300.

[4] Cragg, J. (1983), "More Efficient Estimation in the Presence of Heteroskedasticity of Unknown Form," *Econometrica*, 51, 751-763.

[5] Edwards, S. (1997), "Trade Liberalization Reforms and the World Bank," *American Economic Review*, Papers and Proceedings of the Hundred and Fourth Annual Meeting of the American Economic Association, 87(2), 43-48.

[6] Edwards, S. (2001), *The Economics and Politics of Transition to an Open Market Economy: Colombia*, (Paris: OECD.)

[7] Eslava, M., J. Haltiwanger, A. Kugler and M. Kugler (2004), "The Effects of Structural Reforms on Productivity and Profitability Enhancing Reallocation: Evidence from Colombia," *Journal of Development Economics*, 75(2), 333-371.

[8] Fernandes, A. M. (2003), "Trade Policy, Trade Volumes and Plant-Level Productivity in Colombian Manufacturing Industries" Policy Research Working Paper No. 3064, (Washington, DC: World Bank.)

[9] Ferreira, P. C. and G. Facchini (2005), "Trade Liberalization and Industrial Concentration: Evidence from Brazil," *Quarterly Review of Economics and Finance*, 45, 432-446.

[10] Ferreira, P. C. and J. L. Rossi (2003), "New Evidence from Brazil on Trade Liberalization and Productivity Growth," *International Economic Review*, 44(4), 1383-1405.

[11] Gawande, K. and U. Bandyopadhyay (2000), "Is Protection for Sale? Evidence on the Grossman-Helpman Theory of Endogenous Protection," *Review of Economics and Statistics*, 82(1), 139-152.

[12] Goldberg, P. K. and G. Maggi (1999), "Protection for Sale: An Empirical Investigation," *American Economic Review*, 89(5), 1135-1155.

[13] Grossman, G. M. and E. Helpman (1994), "Protection for Sale," *American Economic Review*, 84(4), 833-850.

[14] Grossman, G. M. and E. Helpman (1995), "Technology and Trade," in G. Grossman and K. Rogoff (eds.), *Handbook of International Economics, Vol. III*, 1279-1337 (Amsterdam: North-Holland.)

[15] Grossman, G. M. and H. Horn (1988), "Infant-Industry Protection Reconsidered: The Case of Informational Barriers to Entry," *Quarterly Journal of Economics*, 103(4), 767-787.

[16] Harrison, A. (1994), "Productivity, Imperfect Competition and Trade Reform: Theory and Evidence," *Journal of International Economics*, 36(1-2), 53-73.

[17] Harrison, A. (1996), "Openness and Growth: A Time-Series, Cross-Country Analysis for Developing Countries" *Journal of Development Economics*, 48, 419-447.

[18] Helpman, E. (1997), "Politics and Trade Policy," in D. M. Kreps and K. F. Wallis (eds.), *Advances in Economics and Econometrics: Theory and Applications*, (New York, NY: Cambridge University Press.)

[19] Johnson, H. G. (1955), "Economic Expansion and International Trade," *Manchester School of Economic and Social Studies*, 23, 95-112.

[20] Karacaovali, B. and N. Limão (2005a), "The Clash of Liberalizations: Preferential vs. Multilateral Trade Liberalization in the European Union," Policy Research Working Paper No. 3493, (Washington, DC: World Bank.)

[21] Karacaovali, B. and N. Limão (2005b), "The Clash of Liberalizations: Preferential vs. Multilateral Trade Liberalization in the European Union," CEPR Discussion Paper No. 4973, (London: Centre for Economic Policy Research.)

[22] Kee, H. L., A. Nicita and M. Olarreaga (2004), "Import Demand Elasticities and Trade Distortions," Policy Research Working Paper No. 3452, (Washington, DC: World Bank.)

[23] Krishna, P. and D. Mitra (1998), "Trade Liberalization, Market Discipline and Productivity Growth: New Evidence from India," *Journal of Development Economics*, 56(2), 447-462.

[24] Krueger, A. O. and B. Tuncer (1982), "An Empirical Test of the Infant Industry Argument," *American Economic Review*, 72, 1142-1152.

[25] Levinsohn, J. and A. Petrin (2003), "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, 70, 317-341.

[26] Magee, S., W. Brock and L. Young (1989), *Black Hole Tariffs and Endogenous Policy Theory: Political Economy in General Equilibrium*, (Cambridge: Cambridge University Press.)

[27] Marvel, H. P. and E. J. Ray (1983), "The Kennedy Round: Evidence on the Regulation of International Trade in the United States," *American Economic Review*, 73(1), 190-197.

[28] Mitra, D., D. D. Thomakos and M. A. Ulubasoglu (2002), "Protection for Sale in a Developing Country: Democracy vs. Dictatorship," *Review of Economics and Statistics*, 84(3), 497-508.

[29] Melendez, M., K. Seim and P. Medina (2003), "Productivity Dynamics of the Colombian Manufacturing Sector," Documento CEDE 2003-23, Universidad de los Andes.

[30] Melitz, M. J. (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity," *Econometrica*, 71(6), 1695-1725.

[31] Muendler, M. (2004), "Trade, Technology, and Productivity: A Study of Brazilian Manufacturers, 1986-1998," mimeo, University of California, San Diego.

[32] Nicita, A. and M. Olarreaga (2001), "Trade and Production, 1976-99," Policy Research Working Paper No. 2701, (Washington, DC: World Bank.)

[33] Olley, S. and A. Pakes (1996), "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64(6), 1263-1297.

[34] Olson, M. (1965), *The Logic of Collective Action: Public Goods and the Theory of Groups*, (Cambridge, MA: Harvard University Press.)

[35] Ozler S. and K. Yilmaz (2003), "Does Trade Liberalization Improve Productivity? Plant Level Evidence from Turkish Manufacturing Industry," in *Regional Development: Reality or Myth?* Selected Papers from the Ninth ERF Annual Conference, (Cairo: Economic Research Forum.)

[36] Pack, H. (1988), "Industrialization and Trade," in H. Chenery and T.N. Srinivasan (eds.) *Handbook of Development Economics, Volume I*, 333-380 (Amsterdam: North-Holland.)

[37] Pagan, A. R. and D. Hall (1983), "Diagnostic Tests as Residual Analysis," *Econometric Reviews*, 2(2), 159-218.

[38] Pavcnik, N. (2002), "Trade liberalization, Exit, and Productivity Improvements: Evidence from Chilean Plants," *Review of Economic Studies*, 69(1), 245-76.

[39] Roberts, M. J. (1996), "Colombia, 1977-85: Producer Turnover, Margins, and Trade Exposure," in M. J. Roberts and J. R. Tybout (eds.), *Industrial Evolution in Developing Countries: Micro Patterns of Turnover, Productivity, and Market Structure*, (New York, NY: Oxford University Press), 227-258.

[40] Rodriguez, F. and D. Rodrik (2001), "Trade Policy and Economic Growth: A Skeptic's Guide to the Cross-National Evidence," in B. Bernanke and K. Rogoff (eds.), *NBER Macroeconomics Annual 2000*, (Cambridge, MA: MIT Press.)

[41] Schor, A. (2004), "Heterogeneous Productivity Response to Tariff Reduction. Evidence from Brazilian Manufacturing Firms," *Journal of Development Economics*, 75, 373-396.

[42] Shea, J. (1997), "Instrument Relevance in Multivariate Linear Models: A Simple Measure," *Review of Economics and Statistics*, 49(2), 348-352.

[43] Srinivasan, T.N. and J. Bhagwati (2001), "Outward Orientation and Development: Are Revisionists Right?" in D. Lal and R. Snape (eds.), *Trade, Development and Political Economy: Essays in Honour of Anne O. Krueger*, (Basingstoke, UK: Palgrave.)

[44] Topalova, P. (2004), "Trade Liberalization and Firm Productivity: The Case of India," IMF Working Paper WP/04/28, (Washington, DC: International Monetary Fund.)

[45] Tovar, P. (2004), "The Effects of Loss Aversion on Trade Policy and the Anti-Trade Bias Puzzle," mimeo, University of Maryland.

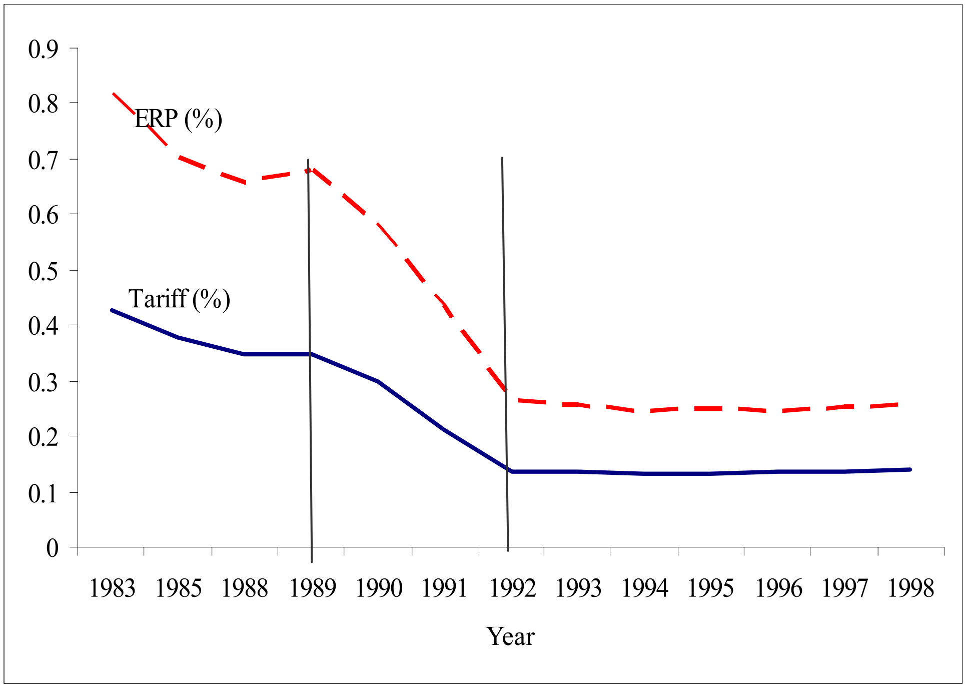
[46] Trefler, D. (1993), "Trade Liberalization and the Theory of Endogenous Protection: An Econometric Study of U.S. Import Policy," *Journal of Political Economy*, 101(1), 138-160.

[47] Tybout, J. (1991), "Linking Trade and Productivity: New Research Directions," *The World Bank Economic Review*, 6(2), 189-211.

[48] Tybout, J. (1996), "Heterogeneity and Productivity Growth: Assessing the Evidence" in M. J. Roberts and J. R. Tybout (eds.), *Industrial Evolution in Developing Countries: Micro Patterns of Turnover, Productivity, and Market Structure*, (New York, NY: Oxford University Press), 43-72.

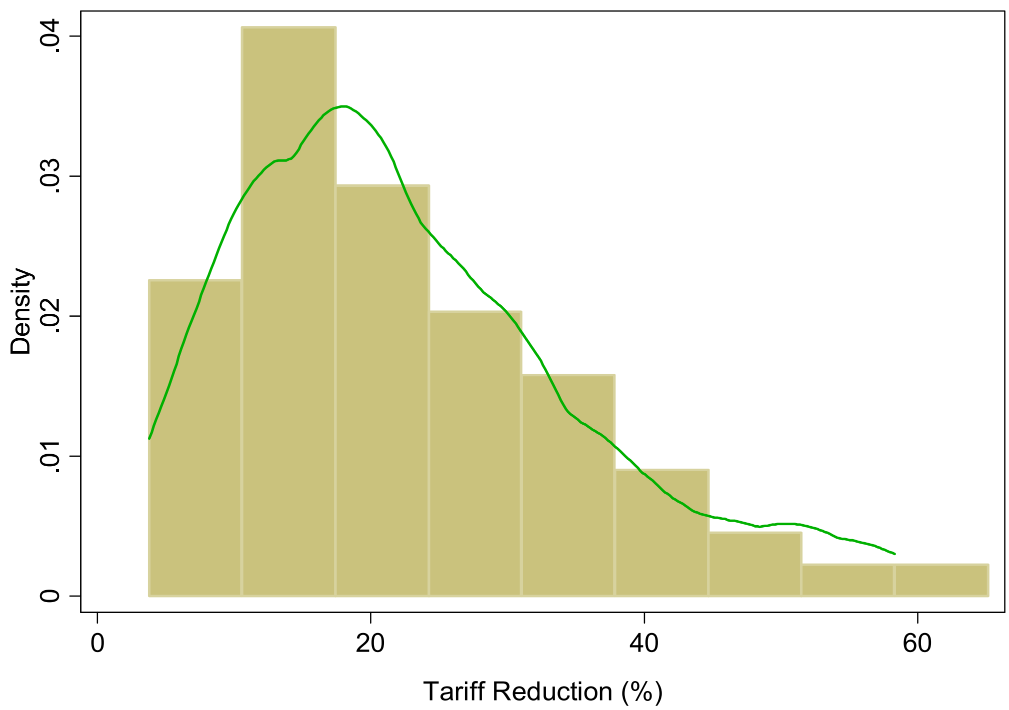
[49] Tybout, J. and M. Westbrook (1995), "Trade Liberalization and the Dimensions of Efficiency Change in Mexican Manufacturing Industries," *Journal of International Economics*, 39(1-2), 53-78.

FIGURE 1. Average Tariffs and Effective Rates of Protection in Colombia 1983-1998



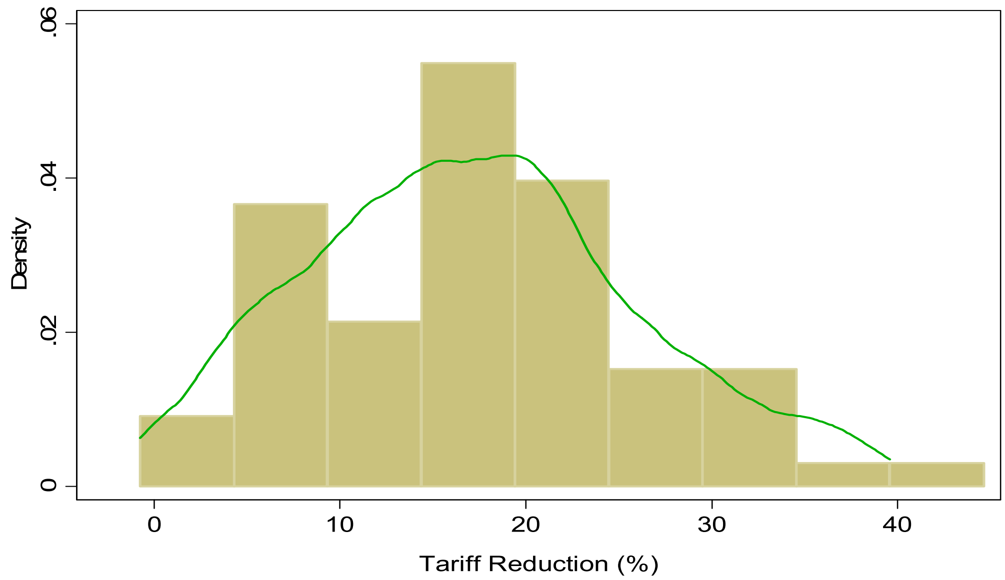
Source: DNP and author's own calculations.

FIGURE 2. Histogram of the Percentage Decline in Tariffs between 1983 and 1995 at the 4-digit ISIC Level



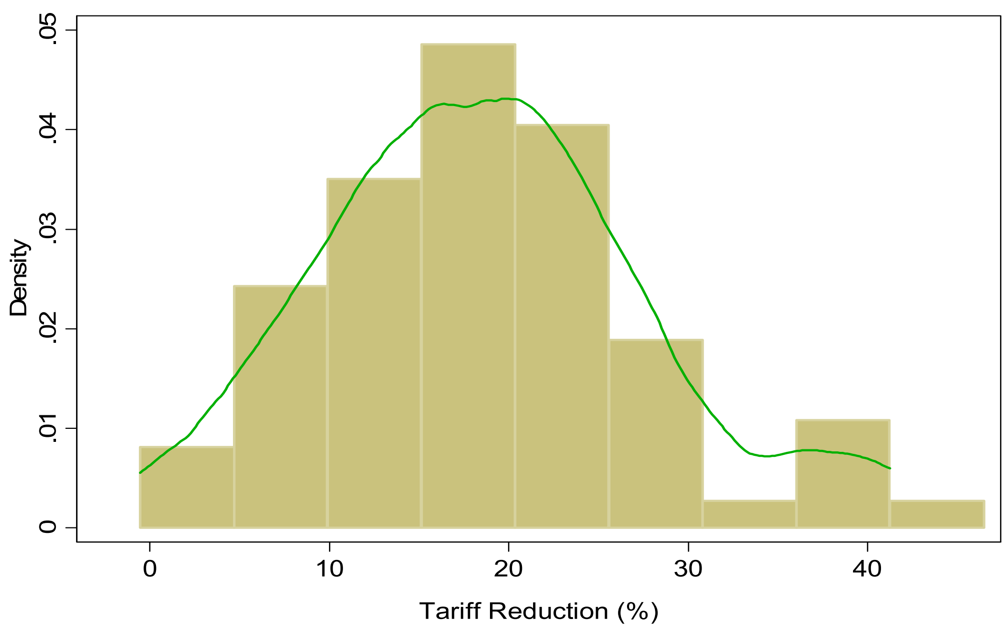
Note: Tariff reduction is calculated as $[\log(1+\tau_{i1983})-\log(1+\tau_{i1995})]*100$
Source: DNP and author's own calculations.

FIGURE 3. Histogram of the Percentage Decline in Tariffs between 1988 and 1995 at the 4-digit ISIC Level



Note: Tariff reduction is calculated as [log(1+τ_{i1988})-log(1+ τ_{i1995})]*100
Source: DNP and author's own calculations.

FIGURE 4. Histogram of the Percentage Decline in Tariffs between 1983-1989 average and 1992-1998 average at the 4-digit ISIC Level



Note: Tariff reduction is calculated as [log(1+avg$\tau_{i1983\text{-}1988}$)-log(1+avg$\tau_{i1992\text{-}1998}$)]*100
Source: DNP and author's own calculations.

FIGURE 5. Tariffs and Productivity: Whole Sample

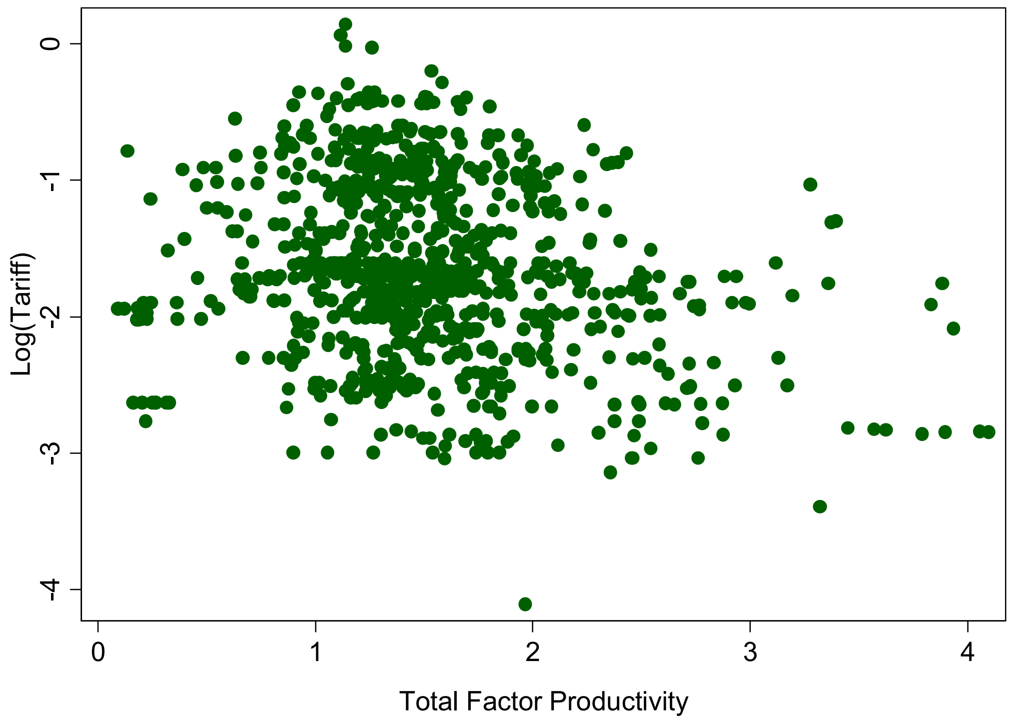


FIGURE 6. Tariffs and Productivity: By Year

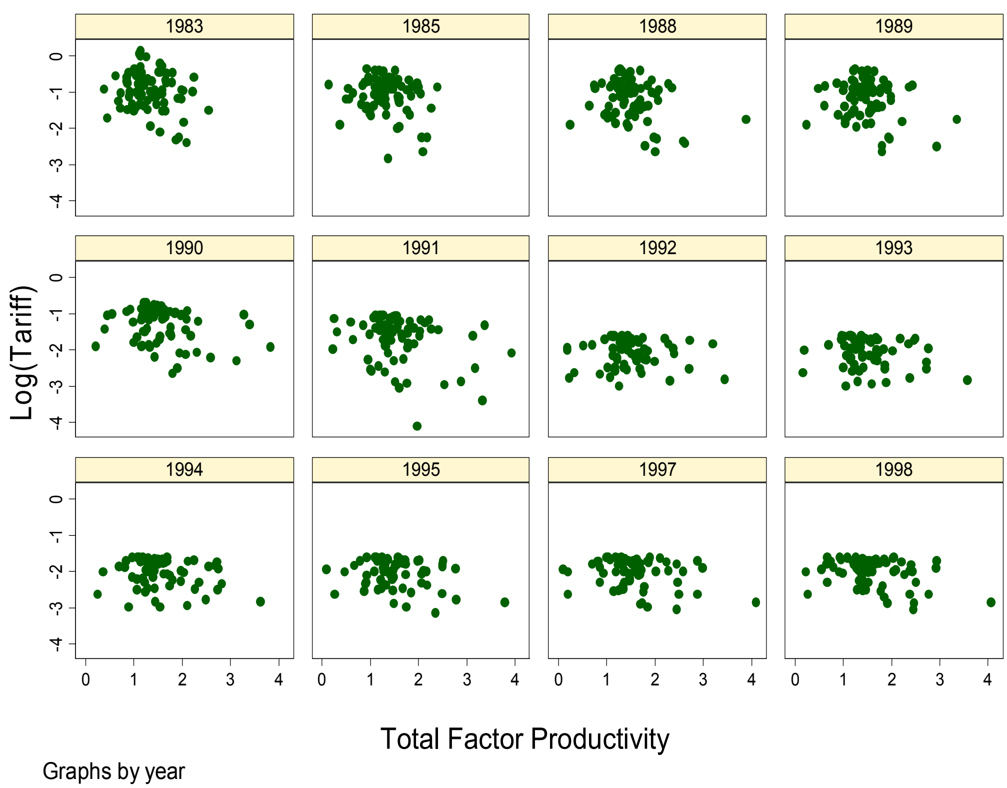


TABLE 1. Spearman's Rank Correlation Matrix for Tariffs over Time

	τ_{1983}	τ_{1985}	τ_{1988}	τ_{1989}	τ_{1990}	τ_{1991}	τ_{1992}	τ_{1993}	τ_{1994}	τ_{1995}	τ_{1996}	τ_{1997}
τ_{1985}	0.928	1										
τ_{1988}	0.861	0.953	1									
τ_{1989}	0.862	0.954	0.997	1								
τ_{1990}	0.806	0.925	0.952	0.954	1							
τ_{1991}	0.733	0.823	0.830	0.847	0.893	1						
τ_{1992}	0.688	0.764	0.771	0.768	0.795	0.866	1					
τ_{1993}	0.700	0.761	0.773	0.770	0.779	0.861	0.993	1				
τ_{1994}	0.688	0.763	0.777	0.778	0.797	0.876	0.997	0.991	1			
τ_{1995}	0.720	0.794	0.801	0.807	0.828	0.898	0.986	0.978	0.989	1		
τ_{1996}	0.727	0.847	0.874	0.882	0.897	0.857	0.885	0.874	0.887	0.922	1	
τ_{1997}	0.732	0.852	0.882	0.882	0.907	0.859	0.887	0.876	0.889	0.925	0.999	1
τ_{1998}	0.724	0.845	0.874	0.882	0.899	0.856	0.888	0.877	0.889	0.924	0.998	0.999

Note: τ_t stands for the average 4-digit ISIC level tariff in year *t*.

TABLE 2. Summary Statistics for Tariffs over Time

	Observations	Mean	Standard Deviation	Coefficient of Variation	Minimum	Maximum
τ_{1983}	78	0.427	0.221	0.516	0.09	1.15
τ_{1985}	78	0.377	0.148	0.393	0.059	0.70
τ_{1988}	78	0.347	0.155	0.448	0.07	0.70
τ_{1989}	75	0.344	0.155	0.451	0.07	0.70
τ_{1990}	76	0.297	0.115	0.386	0.07	0.50
τ_{1991}	74	0.211	0.093	0.442	0.016	0.35
τ_{1992}	68	0.134	0.045	0.334	0.05	0.20
τ_{1993}	65	0.135	0.046	0.343	0.05	0.20
τ_{1994}	63	0.136	0.045	0.333	0.05	0.20
τ_{1995}	65	0.136	0.046	0.334	0.043	0.20
τ_{1996}	67	0.139	0.046	0.333	0.048	0.20
τ_{1997}	66	0.140	0.046	0.332	0.048	0.20
τ_{1998}	67	0.140	0.045	0.323	0.048	0.20

Note: τ_t stands for the average 4-digit ISIC level tariff in year *t*.

TABLE 3. Correlation Matrix for Tariffs and Productivity over Time

	$\log\tau_{1983}$	$\log\tau_{1985}$	$\log\tau_{1988}$	$\log\tau_{1989}$	$\log\tau_{1990}$	$\log\tau_{1991}$	$\log\tau_{1992}$	$\log\tau_{1993}$	$\log\tau_{1994}$	$\log\tau_{1995}$	$\log\tau_{1996}$	$\log\tau_{1997}$	$\log\tau_{1998}$
$\log A_{1983}$	**-0.187**	-0.153	-0.064	-0.071	-0.049	0.003	-0.100	-0.117	-0.073	-0.088	-0.007	-0.014	0.007
$\log A_{1985}$	-0.233**	**-0.179**	-0.108	-0.116	-0.104	-0.076	-0.085	-0.097	-0.076	-0.108	0.012	0.008	0.028
$\log A_{1988}$	-0.220*	-0.237**	**-0.269****	-0.211*	-0.249**	-0.198*	-0.144	-0.151	-0.158	-0.226*	-0.241**	-0.244**	-0.239*
$\log A_{1989}$	-0.208*	-0.217*	-0.197*	**-0.199***	-0.233**	-0.206*	-0.141	-0.125	-0.129	-0.196	-0.219*	-0.223*	-0.220*
$\log A_{1990}$	-0.223*	-0.241**	-0.235**	-0.229**	**-0.260****	-0.253**	-0.138	-0.135	-0.146	-0.198	-0.233*	-0.231*	-0.233*
$\log A_{1991}$	-0.177	-0.195*	-0.238**	-0.224*	-0.234**	**-0.268****	-0.127	-0.124	-0.132	-0.203	-0.205	-0.204	-0.208*
$\log A_{1992}$	-0.145	-0.156	-0.158	-0.162	-0.163	-0.251**	**-0.039**	-0.054	-0.074	-0.199	-0.113	-0.112	-0.115
$\log A_{1993}$	-0.170	-0.193	-0.200	-0.204	-0.229*	-0.265**	-0.161	**-0.148**	-0.163	-0.201	-0.257**	-0.258**	-0.260**
$\log A_{1994}$	-0.195	-0.251**	-0.263**	-0.262**	-0.308**	-0.362***	-0.185	-0.161	**-0.175**	-0.218*	-0.275**	-0.271**	-0.277**
$\log A_{1995}$	-0.179	-0.225*	-0.239*	-0.238*	-0.269**	-0.346***	-0.154	-0.132	-0.147	**-0.227***	-0.225*	-0.225*	-0.227*
$\log A_{1996}$	-0.180	-0.217*	-0.245**	-0.245**	-0.257**	-0.297**	-0.141	-0.125	-0.144	-0.213*	**-0.241****	-0.244**	-0.247**
$\log A_{1997}$	-0.167	-0.194	-0.226*	-0.231*	-0.241*	-0.294**	-0.146	-0.126	-0.143	-0.220*	-0.225*	**-0.232***	-0.234*
$\log A_{1998}$	-0.206*	-0.229*	-0.272**	-0.271**	-0.294**	-0.337***	-0.223*	-0.205	-0.219*	-0.265**	-0.302**	-0.307**	**-0.311****

Note: $\log\tau_t$ stands for the natural logarithm of the average 4-digit ISIC level tariff in year *t*, and $\log A_t$ stands for the natural logarithm of the average 4-digit ISIC level total factor productivity in year *t*

TABLE 4. Summary Statistics for All the Variables in the Estimations

	Observations	Mean	Standard Deviation	Minimum	Maximum
$\log\tau_{it}$	920	-1.646	0.641	-4.107	0.140
$\Delta\log\tau_{it}$	840	-0.093	0.228	-1.971	1.583
$\log\tau_{it}^{eff}$	902	-1.128	0.884	-4.294	1.556
$\Delta\log\tau_{it}^{eff}$	821	-0.113	0.526	-12.613	2.377
$\log(Q_{it}/M_{it}\varepsilon_{it})$	920	0.248	2.376	-6.139	11.470
$\Delta\log(Q_{it}/M_{it}\varepsilon_{it})$	840	-0.098	0.641	-6.025	3.201
$\log A_{it}$	920	1.508	0.590	0.091	4.097
$\Delta\log A_{it}$	840	0.031	0.270	-1.951	2.154
log*Capital Share*	920	-1.765	0.777	-5.549	0.598
Δlog*Capital Share*	840	0.027	0.324	-3.714	1.771
log*Materials Prices*	920	-0.067	0.267	-1.488	0.929
Δlog*Materials Prices*	840	-0.018	0.134	-0.777	1.338
log*Scale*	920	11.726	1.489	5.595	16.264
Δlog*Scale*	830	0.050	0.528	-5.107	3.488
log*Upstream TFP*	920	1.523	0.140	1.206	2.096
Δlog*Upstream TFP*	840	0.017	0.067	-0.205	0.490
GDP growth	920	3.445	1.621	0.570	6.042
Inflation	920	24.037	7.158	14.773	45.357

Notes: The tariff data are not available for 1982, 1986, and 1987 so we start out with 1310 4-digit ISIC tariff lines. When we take into account the missing output figures (not present for the whole year of 1984), the sample reduces to 1004 observations. Finally, considering the other missing observations on the right-hand-side, the sample further declines to around 920 for the main estimations.

TABLE 5. The Effect of Productivity on Tariffs

	(1)	(2)	(3)
$\log(Q_{it}/M_{it}\varepsilon_{it})$	0.390***	0.606***	0.864***
($\beta_1>0$)	(0.073)	(0.142)	(0.173)
$\log A_{it}$	0.271***	0.386***	0.551***
($\beta_2>0$)	(0.066)	(0.097)	(0.116)
$UNILIB_t$	-0.533***		
($\beta_3<0$)	(0.065)		
REF_t		-0.492***	
($\rho_1<0$)		(0.035)	
$POSTREF_t$		-0.306**	
($\rho_2<0$)		(0.154)	
Constant	-1.536***	-1.884***	-2.186***
	(0.190)	(0.269)	(0.296)
Year Effects	No	No	Yes
Observations	920	920	920
Chi^2-test p-val for all μ_i=0 [a]	0.000	0.000	0.000
Chi^2-test p-val for all θ_t=0 [b]	n/a	n/a	0.000
Hansen's J p-val [c]	0.144	0.180	0.933

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) The dependent variable is the natural logarithm of the advalorem tariff rate ($\log\tau_{it}$). (4) The predicted signs for the coefficients of the regressors are indicated in parentheses below them. (5) All the regressions include 4-digit ISIC industry dummies as regressors but are not reported. (6) List of the instruments (all in logs): Capital share, materials prices (deviated from the producer price index), measure of scale economies (value added/number of firms), and the TFP of upstream sectors.

[a] "Chi^2-test p-val for all μ_i=0" provides the probability value for the Chi-squared test of H_0: All μ_i (industry fixed effects) are jointly insignificant.

[b] "Chi^2-test p-val for all θ_t =0" provides the probability value for the Chi-squared test of H_0: All θ_t (year effects) are jointly insignificant.

[c] "Hansen's J p-val" provides the probability value for the Hansen-Sargan test of overidentifying restrictions for H_0: Excluded instruments are uncorrelated with the error term and correctly excluded from the estimated equation.

TABLE 6. The Effect of Productivity Differences on Tariff Differences

	(1)	(2)	(3)
$\Delta\log(Q_{it}/M_{it}\varepsilon_{it})$	0.190	0.514*	0.449**
(β_1>0)	(0.726)	(0.290)	(0.213)
$\Delta\log A_{it}$	0.231	0.519**	0.476**
(β_2>0)	(0.658)	(0.263)	(0.209)
$\Delta UNILIB_t$	-0.120***		
(β_3<0)	(0.031)		
REF_t		-0.185***	-0.231***
(φ <0)		(0.069)	(0.045)
Constant			0.031*
			(0.016)
Observations	676	676	676
Hansen's J p-val [a]	0.572	0.929	0.958

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) The dependent variable is the one year change in the natural logarithm of the advalorem tariff rate ($\log\tau_{it}$). (4) The predicted signs for the coefficients of the regressors are indicated in parentheses below them. (5) List of the instruments (all in logs): First differences of capital share, materials prices (deviated from the producer price index), measure of scale economies (value added/number of firms), and the TFP of upstream sectors. (6) All estimations allow for arbitrary intra-industry correlation over time.
[a] "Hansen's J p-val" provides the probability value for the Hansen-Sargan test of overidentifying restrictions for H_0: Excluded instruments are uncorrelated with the error term and correctly excluded from the estimated equation.

TABLE 7. The Effect of Productivity on the Effective Rates of Protection

	(1)	(2)	(3)
$\log(Q_{it}/M_{it}\varepsilon_{it})$	0.333***	0.270*	0.303**
(β_1>0)	(0.084)	(0.142)	(0.139)
$\log A_{it}$	0.261***	0.190**	0.198**
(β_2>0)	(0.070)	(0.091)	(0.096)
$UNILIB_t$	-0.598***		
(β_3<0)	(0.079)		
REF_t		-0.500***	
(ρ_1<0)		(0.045)	
$POSTREF_t$		-0.715***	
(ρ_2<0)		(0.165)	
Year Effects	No	No	Yes
Constant	-0.415**	-0.207	-0.066
(α>0)	(0.198)	(0.363)	(0.342)
Observations	887	887	887
Chi^2-test p-val for all μ_i=0 [a]	0.000	0.000	0.000
Chi^2-test p-val for all θ_t=0 [b]	n/a	n/a	0.000
Hansen's J p-val [c]	0.004	0.001	0.000

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) The dependent variable is the natural logarithm of the effective rate of protection ($\log\tau_{it}^{eff}$). (4) The predicted signs for the coefficients of the regressors are indicated in parentheses below them. (5) All the regressions include 4-digit ISIC industry dummies as regressors but are not reported. (6) List of the instruments (all in logs): Capital share, materials prices (deviated from the producer price index), measure of scale economies (value added/number of firms), and the TFP of upstream sectors.

[a] "Chi^2-test p-val for all μ_i=0" provides the probability value for the Chi-squared test of H_0: All μ_i (industry fixed effects) are jointly insignificant.

[b] "Chi^2-test p-val for all θ_t =0" provides the probability value for the Chi-squared test of H_0: All θ_t (year effects) are jointly insignificant.

[c] "Hansen's J p-val" provides the probability value for the Hansen-Sargan test of overidentifying restrictions for H_0: Excluded instruments are uncorrelated with the error term and correctly excluded from the estimated equation.

TABLE 8. The Effect of Productivity Differences on the Effective Rate of Protection Differences

	(1)	(2)	(3)
$\Delta\log(Q_{it}/M_{it}\varepsilon_{it})$	0.337	0.553	0.519*
(β_1>0)	(0.838)	(0.337)	(0.269)
$\Delta\log A_{it}$	0.297	0.504*	0.490*
(β_2>0)	(0.758)	(0.294)	(0.251)
$\Delta UNILIB_t$	-0.105***		
(β_3<0)	(0.040)		
REF_t		-0.182**	-0.223***
($\varphi<0$)		(0.089)	(0.065)
Constant			0.032
			(0.021)
Observations	652	652	652
Hansen's J p-val [a]	0.482	0.695	0.765

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) The dependent variable is the one year change in the natural logarithm of the effective rate of protection ($\log\tau_{it}^{eff}$). (4) The predicted signs for the coefficients of the regressors are indicated in parentheses below them. (5) List of the instruments (all in logs): First differences of capital share, materials prices (deviated from the producer price index), measure of scale economies (value added/number of firms), and the TFP of upstream sectors. (6) All estimations allow for arbitrary intra-industry correlation over time.

[a] "Hansen's J p-val" provides the probability value for the Hansen-Sargan test of overidentifying restrictions for H_0: Excluded instruments are uncorrelated with the error term and correctly excluded from the estimated equation.

TABLE 9. The Effect of Past Productivity on Current Tariffs

	(1)	(2)	(3)
$\log(Q_{it}/M_{it}\varepsilon_{it})$	0.586***	0.518***	0.351***
(β_1>0)	(0.116)	(0.118)	(0.101)
$\log A_{it-1}$	0.186**	0.168**	0.205***
(β_2>0)	(0.088)	(0.080)	(0.067)
$UNILIB_t$	-0.361***		
(β_3<0)	(0.104)		
REF_t		-0.494***	
(ρ_1<0)		(0.044)	
$POSTREF_t$		-0.381***	
(ρ_2<0)		(0.139)	
Constant	-2.207***	-2.058***	-1.610***
	(0.289)	(0.293)	(0.239)
Year Effects	No	No	Yes
Observations	895	895	895
Chi^2-test p-val for all μ_i=0 [a]	0.000	0.000	0.000
Chi^2-test p-val for all θ_t=0 [b]	n/a	n/a	0.000
Hansen's J p-val [c]	0.406	0.061	0.056

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) The dependent variable is the natural logarithm of the advalorem tariff rate ($\log\tau_{it}$). (4) The predicted signs for the coefficients of the regressors are indicated in parentheses below them. (5) All the regressions include 4-digit ISIC industry dummies as regressors but are not reported. (6) List of the instruments (all in logs): Capital share, materials prices (deviated from the producer price index), one period lag of the measure of scale economies (value added/number of firms), and one period lag of the TFP of upstream sectors.

[a] "Chi^2-test p-val for all μ_i=0" provides the probability value for the Chi-squared test of H_0: All μ_i (industry fixed effects) are jointly insignificant.

[b] "Chi^2-test p-val for all θ_t =0" provides the probability value for the Chi-squared test of H_0: All θ_t (year effects) are jointly insignificant.

[c] "Hansen's J p-val" provides the probability value for the Hansen-Sargan test of overidentifying restrictions for H_0: Excluded instruments are uncorrelated with the error term and correctly excluded from the estimated equation.

TABLE 10. The Effect of Productivity on Tariffs and Effective Rates of Protection: OLS Results

	(1) $\log\tau_{it}$	(2) $\log\tau_{it}^{eff}$
$\log(Q_{it}/M_{it}\varepsilon_{it})$	0.125***	0.134***
(β_1>0)	(0.015)	(0.019)
$\log A_{it}$	0.046	0.071
(β_2>0)	(0.032)	(0.046)
$UNILIB_t$	-0.731***	-0.741***
(β_3<0)	(0.024)	(0.031)
Constant	3.418***	0.199**
(α>0)	(0.078)	(0.092)
Observations	920	887
R^2	0.823	0.842
Wald test p-val [a]	0.000	0.000

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) $\log\tau_{it}$ is the natural logarithm of the advalorem tariff rate, and $\log\tau_{it}^{eff}$ is the natural logarithm of the effective rate of protection. (4) The predicted signs for the coefficients of the regressors are indicated in parentheses below them. (5) The estimates include 4-digit ISIC industry dummies as regressors but are not reported.

[a] Wald test p-val provides the probability value for the F-test of H_0: The regressors are jointly insignificant.

TABLE 11. The Effect of Productivity Differences on Tariff and Effective Rate of Protection Differences: OLS Results

	(1) $\Delta\log\tau_{it}$	(2) $\Delta\log\tau_{it}^{eff}$
$\Delta\log(Q_{it}/M_{it}\varepsilon_{it})$	0.076***	0.084***
(β_1>0)	(0.022)	(0.031)
$\Delta\log A_{it}$	0.079*	0.071
(β_2>0)	(0.046)	(0.066)
$\Delta UNILIB_t$	-0.128***	-0.113***
(β_3<0)	(0.017)	(0.031)
Observations	676	652
R^2	0.056	0.042
Wald test p-val [a]	0.000	0.021

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) $\Delta\log\tau_{it}$ is the one year change in the natural logarithm of the advalorem tariff rate, and $\Delta\log\tau_{it}^{eff}$ is the one year change in the natural logarithm of the effective rate of protection. (4) The predicted signs for the coefficients of the regressors are indicated in parentheses below them. (5) All estimations allow for arbitrary intra-industry correlation over time.

[a] Wald test p-val provides the probability value for the F-test of H_0: The regressors are jointly insignificant.

TABLE 12. First Stage Regressions: Table 5 Column 1 Specification

	$\log(Q_{it}/M_{it}\varepsilon_{it})$	$\log A_{it}$
$UNILIB_t$	-0.686***	0.097***
	(0.0672)	(0.020)
log*Capital Share*	-0.109	-0.334***
	(0.069)	(0.020)
log*Materials Prices*	0.432***	0.008
	(0.159)	(0.047)
log*Scale*	-0.139***	0.187***
	(0.0458)	(0.013)
log*Upstream TFP*	-0.901***	0.435***
	(0.303)	(0.088)
Constant	4.531***	-2.164***
	(0.703)	(0.205)
Observations	920	920
R^2	0.897	0.858
Adjusted R^2	0.887	0.844
Shea's partial R^2	0.033	0.434
F statistic	86.67	59.96
Wald test p-val [a]	0.000	0.000
F statistic for excluded instruments	7.02	160.72
Wald test p-val excluded instruments [b]	0.000	0.000

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) These first stage regressions refer to the main tariff specification in column 1 of Table 5. (4) The dependent variables are indicated in the header row of each column.

[a] Wald test p-val provides the probability value for the F-test of H_0: The instruments are jointly insignificant.

[b] Wald test p-val provides the probability value for the F-test of H_0: The excluded instruments are jointly insignificant.

TABLE 13. First Stage Regressions: Table 6 Column 1 Specification

	$\Delta\log(Q_{it}/M_{it}\varepsilon_{it})$	$\Delta\log A_{it}$
$\Delta UNILIB_t$	-0.064	0.053**
	(0.075)	(0.026)
$\Delta\log$*Capital Share*	0.379***	-0.405***
	(0.085)	(0.030)
$\Delta\log$*Materials Prices*	0.017	-0.061
	(0.183)	(0.064)
$\Delta\log$*Scale*	-0.077*	0.103***
	(0.045)	(0.016)
$\Delta\log$*Upstream TFP*	0.345	0.004
	(0.377)	(0.132)
Observations	676	676
R^2	0.041	0.289
Adjusted R^2	0.034	0.283
Shea's partial R^2	0.002	0.014
F statistic	85.09	58.11
Wald test p-val [a]	0.000	0.000
F statistic for excluded instruments	6.80	155.58
Wald test p-val excluded instruments [b]	0.000	0.000

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) These first stage regressions refer to the main first-differenced tariff specification in column 1 of Table 6. (4) The dependent variables are indicated in the header row of each column.

[a] Wald test p-val provides the probability value for the F-test of H_0: The instruments are jointly insignificant.

[b] Wald test p-val provides the probability value for the F-test of H_0: The excluded instruments are jointly insignificant.

TABLE 14. Tariffs and Productivity: A System of Equations

	OLS	3SLS		
	$\log A_{it}$	$\log A_{it}$	$\log \tau_{it}$	$\log(Q_{it}/M_{it}\varepsilon_{it})$
$\log \tau_{it}$	-0.066***	-0.067***		1.869***
	(0.022)	(0.021)		(0.107)
$\log(Q_{it}/M_{it}\varepsilon_{it})$			0.362***	
			(0.096)	
$\log A_{it}$			0.198***	
			(0.057)	
log*Capital Share*				1.038***
				(0.082)
log*Materials Prices*				1.041***
				(0.241)
log*Scale*	0.246***	0.245***		
	(0.029)	(0.014)		
log*Upstream TFP*	0.260***	0.257***		
	(0.092)	(0.096)		
Constant	-1.842***	-1.828***	-1.612***	5.227***
	(0.321)	(0.219)	(0.229)	(0.239)
Observations	920	920	920	920
R^2	0.812	0.812	0.770	0.338
Wald test p-val	0.000	0.000	0.000	0.000

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) The dependent variables are indicated in the header row of each column. (4) The $\log A_{it}$ equations include industry dummies, GDP growth, and inflation as controls which are not reported here. The $\log \tau_{it}$ equation includes both industry and year dummies which are not reported.

[a] Wald test p-val provides the probability value for the Chi-squared-test of H_0: The regressors are jointly insignificant.

TABLE 15. Effective Rates of Protection and Productivity: A System of Equations

	OLS	3SLS		
	$\log A_{it}$	$\log A_{it}$	$\log\tau_{it}^{eff}$	$\log(Q_{it}/M_{it}\varepsilon_{it})$
$\log\tau_{it}^{eff}$	-0.059***	-0.069***		1.513***
	(0.022)	(0.020)		(0.080)
$\log(Q_{it}/M_{it}\varepsilon_{it})$			0.468***	
			(0.127)	
$\log A_{it}$			0.320***	
			(0.074)	
log*Capital Share*				1.074***
				(0.082)
log*Materials Prices*				0.966***
				(0.239)
log*Scale*	0.247***	0.247***		
	(0.029)	(0.014)		
log*Upstream TFP*	0.265***	0.247**		
	(0.092)	(0.098)		
Constant	-1.767***	-1.729***	-0.545*	3.906***
	(0.332)	(0.229)	(0.302)	(0.183)
Observations	887	887	887	887
R^2	0.809	0.809	0.756	0.363
Wald test p-val	0.000	0.000	0.000	0.000

Notes: (1) Standard errors are in parentheses. (2) *, **, and *** indicate significance at a 10%, 5%, and 1% level, respectively. (3) The dependent variables are indicated in the header row of each column. (4) The $\log A_{it}$ equations include industry dummies, GDP growth, and inflation as controls which are not reported here. The $\log\tau_{it}^{eff}$ equation includes both industry and year dummies which are not reported.

[a] Wald test p-val provides the probability value for the Chi-squared-test of H_0: The regressors are jointly insignificant.