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Trade liberalization and inter-industry productivity spillovers: a dynamic spatial panel approach

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Abstract

The use of trade liberalization to enhance manufacturing productivity has been a commonly applied policy in several developing countries since the 1980s. This paper proposes a new methodology to estimate the inter-industry productivity spillovers that may occur in such reforms. The findings from a study of the Brazilian trade liberalization episode (1989-1998) indicate that inter-industry productivity spillovers exist, are positive, and account for 70% of the increase in productivity that results from a reduction in import tariffs.

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1. Introduction

The relationship between trade liberalization and productivity in developing countries has received considerable attention from researchers because productivity is a key factor for economic growth. Several studies have found that trade liberalization appears to increase industry-level productivity—for instance, Krishna and Mitra (1998) for India, Fernandes (2007) for Colombia, and Muendler (2004a) for Brazil. The literature also indicates that trade liberalization improves firms' access to cheaper, better quality, and more diverse inputs (see Goldberg et al. 2010). More precisely, a decrease in input tariffs is found to increase industry-level productivity in Brazil (Schor, 2004) and Indonesia (Amiti and Konings, 2007).

However, the extant literature has not yet considered the effect of inter-industry productivity spillovers in analyses of the impact of tariff reductions on industry-level productivity. These spillovers may occur because of increased competition in input markets. This forces domestic input producers to not only increase their efficiency, but also upgrade the quality of their products and even to embody more knowledge in the inputs produced, for instance by imitating the newly-imported competing intermediate inputs. Such improvements will be reflected in the input producers' productivity, which will spill over to the downstream industries through linkages that can be clearly seen in an Input-Output (I-O) matrix.[1]

This paper addresses this important gap in the literature by proposing a new methodology based upon spatial dynamic panel econometric techniques to assess the magnitude of inter-industry productivity spillovers induced by trade liberalization. To explore this issue, I use data from the Brazilian trade liberalization episode (1989–1998), which offers a good benchmark because it has been studied extensively. In particular, Muendler (2004a) estimated industry-level TFP using firm-level data, and these good quality estimates are employed here.

The results of my analysis indicate that inter-industry spillovers are present, are positive, and can account for 70% of the increase in industry-level TFP due to trade liberalization. Furthermore, my results imply that when spillovers are taken into account, the contribution of input tariffs to the increase in TFP due to trade liberalization is similar to the effect of output tariffs. Finally, I find that not accounting for productivity spillovers causes the impact of trade liberalization on productivity to be overestimated by at least 25%.

The remainder of the paper is organized as follows. The next section discusses briefly the empirical specification that has been used in previous studies and develops a new econometric methodology. The data used in the empirical analysis is described in section 3. Section 4 reports my estimates and discusses the results. Finally, conclusions are presented in section 5.

2. Literature Review and Methodology

Early studies like Krishna and Mitra (1998) focused specifically on the effect of output tariffs on industry-level productivity, since a decrease in output tariffs leads to increased competition in domestic markets and thus reduces x-inefficiencies through managerial restructuring. Notice that industry-level productivity may also increase due to output reallocation from low productivity firms to high productivity firms, as outlined in the Melitz (2003) model. The measure of productivity used in these studies and the subsequent literature is the total factor productivity (TFP), which measures the change in the level of output that cannot be explained by

[1] The issue of productivity spillovers occurring through input-output linkages has been raised previously in the foreign direct investment literature, see Javorcik (2004).

changes in the quantity of factors of production, i.e. capital, intermediate inputs (materials), and labor. This residual is composed of random shocks, process innovations, managerial effort and reorganization, increases in workers' knowledge, and knowledge embodied in intermediate inputs, which are all unobservable to the researcher.

Later, the research agenda shifted toward examining the effect of input tariffs on productivity due to the following two important reasons. First, Corden (1971) predicts that a decrease in input tariffs will decrease productivity because cheaper inputs will weaken competitive pressure in the output market (i.e., the effective rate of protection will increase). Second, the theoretical models in Ethier (1982), Markusen (1989), and Grossman and Helpman (1991) predict that lower input tariffs induce higher productivity through access to a larger variety and better quality of intermediate inputs as well as knowledge spillovers. These theoretical results suggest that the overall effect of the input tariff on TFP is an empirical question. The input tariff effect is found to be negative and between two and six times larger in magnitude than the effect of the output tariff, according to Schor (2004) for Brazil and Amiti and Konings (2007) for Indonesia. Equation (1) illustrates the typical empirical specification used in these previous studies, where Δ is the time difference operator, for example, $\Delta tfp_{it} \equiv tfp_{it} - tfp_{it-1}$.

$$\Delta tfp_{it} = \gamma_1 \Delta output\_tariff_{it} + \gamma_2 \Delta input\_tariff_{it} + \beta \Delta upstream\_tfp + \Sigma_t\, \theta_t + \Delta u_{it} \qquad (1)$$

Equation (1) is in first-difference because this difference eliminates time invariant industry effects that are correlated with tariff changes. One example of such industry-specific characteristics is labor or environmental regulations that affect industries differently and may constrain adjustment in some factors of production. Another reason for the first-difference is that TFP levels are expressed in conceptual units that are not comparable across industries. Thus, identification of the tariff effects has to come from within-industry variation obtained by also employing year effects. Moreover, year effects (θ_t) are also included in the specification to control for economy-wide shocks (i.e., variables that increase or decrease together in different industries during the same business cycle). For instance, if firms are prone to conduct managerial reorganizations during a recession, but at the same time the government raises tariffs in response to the recession, a spurious relationship will be found between tariffs and productivity unless year effects are used.

Fernandes (2007) argues that the estimated TFP series exhibits time persistence since the TFP estimation methodology in Olley and Pakes (1996) assumes that plant productivity follows a first-order Markov process. Unless the econometric specification accounts for this time persistence, the estimates based on equation (1) are inconsistent due to the autocorrelated error term. Hence, it is necessary to use the Arellano-Bond estimator and to incorporate Δtfp_{it-1} as a regressor in equation (1). Its coefficient, λ, is expected to be positive because current TFP depends positively on the last-period TFP. This augmented model is hereafter called the baseline specification.

Now, I develop a methodology that allows for the estimation of inter-industry TFP spillovers. The existence of linkages across industries can be seen clearly in the I-O matrix through the amount of inputs that one industry purchases from other industries. This makes industry-level productivity dependent on the productivity of other industries, which works through two channels. The first channel is learning transfer (or technological diffusion), since technological knowledge can be embodied in intermediate goods.[2] The second channel is the upgrading of the quality of inputs purchased, due either to new requirements from buyers or imitation of newly-imported competing products.

The literature has controlled for such spillovers by adding a regressor that consists of the TFP of upstream industries aggregated according to their shares in the I-O table. However, this approach does not provide consistent estimates because the industries are interdependent, so that upstream industry TFPs are simultaneously determined with the downstream industry TFP. To address this simultaneity problem, I use spatial econometrics techniques to explicitly model how much one industry interacts with another. The amount of interaction between the N industries is reflected in the weights matrix $\boldsymbol{W}$, which is an $N \times N$ matrix with rows normalized to sum one and zeroes in the main diagonal.[3] The last requirement is needed to allow for identification in the estimated model. Intuitively, the elements of $\boldsymbol{W}$ should be larger for industries that have larger interactions. One way to measure this interaction is to use the share of inputs purchased by industry i from industry j (given by the I-O matrix) as the weights.[4] This new specification is shown in equation (2), where $\boldsymbol{tfp}_t$ is an $N\times1$ vector of observations on the TFP (dependent variable).

$$\Delta \boldsymbol{tfp}_t = \lambda\Delta \boldsymbol{tfp}_{t-1} + \delta \boldsymbol{W}_N \Delta \boldsymbol{tfp}_t + \gamma_1 \Delta \boldsymbol{output\_tariff}_t + \gamma_2 \Delta \boldsymbol{input\_tariff}_t + \boldsymbol{\theta}_t + \Delta \boldsymbol{u}_t \qquad (2)$$

Some features of this specification merit further discussion. First, the spatial lag ($\boldsymbol{W}\Delta \boldsymbol{tfp}_t$) is the term that captures the inter-industry spillover. Its estimated coefficient (δ) is interpreted as the percentage of the total change in $\Delta \boldsymbol{tfp}_t$ that is due to the TFP spillovers from other industries. From the discussion above, I expect the productivity spillovers to be positive ($\delta > 0$). To calculate the total change in productivity due to both the direct and the indirect (spillover) effects, Anselin (2003) introduces the spatial multiplier. It is calculated as $(1-\delta)^{-1}-1$. Hence, the total effect is the product between the multiplier and the direct effects.[5]

The second issue concerns the potential endogeneity of $\boldsymbol{W}$. I address it by using the 1985 I-O matrix, which is five years before the start of the trade liberalization. It is worth mentioning that the 1985 I-O matrix is very similar to the 1990 and 1995 I-O matrices. This means that if there is indeed endogeneity, it appears to be time invariant, and as discussed earlier, the assumption that the input mix is stable over time seems reasonable. Thus, in this case, using the variables in first difference solves the problem.

The third issue is the reverse causality between TFP and tariffs. Interestingly, Muendler (2004a) found that one of the key goals of the Brazilian trade liberalization was to improve productivity in lagging industries. Thus, the potential future increase in TFP induced the tariff cuts. This is in line with Karacaovali's (2011) theoretical model predictions. In such model, the initial tariff level is set taking into account not only the present but also the expected future productivity. As a result, the larger the industry current or expected future productivity the higher will be the initial tariff. Therefore, the initial tariff is not a valid instrument for tariff changes.

[2] Keller (2009) provides a very good literature review on this topic and also discusses evidence that supports the argument that imports are an important channel of technology diffusion.
[3] This guarantees that δ will belong to (-1,1) and allows it to be interpreted as a spatial multiplier (Anselin, 2003).
[4] The I-O matrix has been used previously in this way by Moreno et al. (2004) among others.
[5] See Paz (2013) for a different econometric approach to estimate the inter-industry productivity spillovers.

To address this problem, I use Colombia's import tariffs during its trade liberalization episode (1984–1993) as an instrument for Brazil's import tariff.[6] Prior to their trade liberalization episodes, both the Colombian and Brazilian governments believed that their import substitution industrialization policies (which implied high levels of trade protection) were welfare enhancing, in addition to the fact that import substitution was viewed as an institution or even a historical legacy that could not be changed due to political concerns. At a certain point, however, governments realize that the gains from import substitution may not be as large as expected, and change their development policies by decreasing trade protection across all industries.[7] This means that the Brazilian and Colombian tariffs should exhibit a positive correlation, and thus move in the same direction (downward) as a result of this change to a trade liberalization policy.

I believe that using Colombia's import tariffs as an instrument for Brazil's import tariffs is valid for the following reasons. First, Colombian tariffs are not affected by future Brazilian tariffs, since trade between these two countries is very small relative to their other partners. Second, the pre-reform protection patterns in Brazil and Colombia are different.[8] If the pattern of protection across industries were the same in both countries, the pre-reform tariff levels in both countries would also be correlated. Accordingly, Colombian tariff changes would then be correlated with Brazilian initial tariffs. Consequently, Colombian tariffs would not be a valid instrument for the same reason discussed earlier. Therefore, the effect of Colombia's productivity on its tariffs is uncorrelated with the possible effect of Brazil's productivity on its tariffs.[9]

The last issue is the endogeneity of the spatial lag. I follow the suggestion in Kelejian and Prucha (1998) to use $\boldsymbol{W}_N\boldsymbol{h}_{it}$ and $\boldsymbol{W}^2{}_N\boldsymbol{h}_{it}$ as instruments for the spatial lag, where $\boldsymbol{h}_{it}$ is a vector of exogenous regressors (included instruments) and Colombian tariffs (excluded instruments). The other excluded instruments are the Arellano-Bond instruments, since I estimate equation (2) by means of a spatial Arellano-Bond estimator (that is, generalized method of moments). According to Elhorst (2010), the advantage of using GMM is that it imposes a significantly smaller computational burden and prevents serious numerical problems when finding the eigenvalues of the weights matrix, which is required in the maximum likelihood estimator.

3. Policy Background and Data Description

This section provides some historical background on the 1989–1998 Brazilian trade liberalization and presents the data used in the econometric analysis of this episode. Until the end of the 1980s, Brazil's trade policy was dictated by an import substitution development policy and the country's balance of payments deficits.[10] This trade policy started to change in 1988 when Brazil unilaterally decided to decrease the level of redundant protection. Tariffs were reduced to a level that would still curb imports. In 1990, Brazil's new president drastically reduced NTBs and adopted nominal tariff reductions scheduled to start in 1990 and end in 1994. The actual decrease in tariffs was not identical across industries. Moreover, the tariff reductions did not

[6] I match the year preceding the trade liberalization in Colombia (1984) to the year preceding trade reform in Brazil (1989). Hence, the 1984 Colombian tariff level is used as an instrument for the 1989 Brazilian tariff, and so on.
[7] For example, governments that adopted import substitution development policies may have observed that countries with trade-oriented development policies, like South Korea, have experienced higher levels of economic growth.
[8] Colombia protected more the low productivity light manufacturing sector (e.g. apparel and footwear), while Brazil offered more protection to high productivity capital good industries (e.g. machinery and transportation equipment).
[9] Paz (2012) was the first paper to employ Colombian tariffs as instruments for Brazilian tariffs.
[10] Kume et al. (2003) provide a comprehensive description of Brazil's trade policy in the 1980s and 1990s.

follow the planned schedule. Nonetheless, the tariff reductions had real effects on the economy, as imports of manufactured goods increased by more than 200% and import penetration increased from 5.7% to 11.6% between 1990 and 1998. The 1987–1998 Brazilian import tariff data set comes from Kume et al. (2003). The instrument for Brazilian import tariffs was constructed using Colombian import tariff data for the 1982–1993 period (from the Colombian National Planning Department).

The industry-level TFP series are from Muendler (2004a), who used firm-level data from the Pesquisa Industrial Annual, an annual survey conducted by the Instituto Brasileiro de Geografia e Estatística (IBGE).[11] His dataset consists of an unbalanced panel of roughly 9,500 medium- and large-sized firms. Muendler (2004a) estimated the TFP for the 1986–1998 period using two methods. The first TFP measure (OLS-TFP) is the estimated OLS residual of a simplified production function. The second TFP measure (OP-TFP) is estimated using an extended version of the Olley and Pakes (1996) methodology that takes into account the investment decision concerning the two types of capital (equipment and structures) and endogenous firm entry and exit.[12] The two measures are calculated using the unbalanced panel sample of all firms. The correlation between the two TFP measures is 0.921, and their descriptive statistics are presented in Table 1.

The I-O table is used to calculate the input tariff, the upstream TFP variable, and the weighting matrix. I use the 1985 I-O table for Brazil from IBGE (2006). The non-manufacturing sectors and all final use consumption columns are excluded. This procedure leads to an I-O matrix (Γ) of dimensions 16x16. The weighting matrix used in the estimation of the spillovers ($\boldsymbol{W}$) has zeroes in its main diagonal, and the other entries (w_{ij}) are the share of inputs purchased from industry j by industry i for $i \neq j$, as displayed by equation (3).

$$w_{ij} = \frac{\Gamma(\mathrm{i,j})}{\sum_{\mathrm{k}=1}^{16} \Gamma(\mathrm{k,j})}, \text{ with } i, j = 1,\ldots,16 \tag{3}$$

The input tariff is the weighted average of the tariff imposed on the intermediate inputs consumed by the industry, including those purchased from other firms in the same industry, as done in Schor (2004). The instrument for the Brazilian input tariffs is calculated similarly but now using Colombian tariffs. Following Karacaovali (2011), the upstream TFP variable is calculated using the share of each upstream industry in the I-O matrix multiplied by the respective upstream industry TFP.

4. Empirical Results

In this section, I first present estimates from the baseline specification concerning the effects of output and input tariffs on industry-level productivity. I then estimate the specification that addresses productivity spillovers across industries. My results confirm the existence of (large) TFP spillovers. Moreover, these consistent estimates indicate that the effect of output tariffs on TFP is smaller relative to the specifications that ignore the existence of spillovers.

I estimated equation (1) using instrumental variables and the results are shown in Table 2. Columns (1)-(3) contain the estimates for the OLS-TFP measure and columns (4)-(6) contain the

[11] The survey was not conducted in 1991 due to budget cuts, so I used linear interpolation to build the TFP for 1991. More details about the survey and its variables can be found in Muendler (2003).
[12] The interested reader can refer to Van Beveren (2011) for a survey on TFP estimation.

estimates for the OP-TFP measure. All specifications have a negative and statistically significant coefficient for output tariffs. The estimated coefficient of output tariff in column (6) means that a 10 percentage point decrease in output tariff leads to a 1.39 percent increase in TFP, which is similar to the results in Schor (2004).

Although the coefficients of upstream TFP are positive, they are not statistically significant at the 5% level in any of the specifications. The coefficients of input tariff are negative and not statistically significant at the 5% level. Schor (2004) also found a negative input tariff coefficient but hers was statistically significant and also larger in magnitude; however, she used a different time period and TFP measure for Brazil. The null hypothesis that both output and input tariffs are zero is rejected at the 5% level in all specifications.

In the first stage regression for columns (1) and (4), the Colombian tariff coefficients in Table 2 are positive and statistically significant at the 5% level. The upstream TFP is positive and statistically significant at the 10% level in column (1). The Colombian tariff cannot be considered a weak instrument in columns (1) and (4) because the Kleibergen-Paap rK Wald F-statistic is at least 34, which is much larger than the Stock-Yogo 10% maximum IV relative bias critical value of 16.38. This is also the case for the remaining columns, which have a Kleibergen-Paap statistic of at least 8.98 and a Stock-Yogo critical value of 7. Exogeneity of the output tariff is rejected at the 10% level by the Hausman test for the OLS-TFP specification in column (1). For the OP-TFP specification in column (4), the p-value is 20%. These results provide some support for the approach of treating import tariff as an endogenous regressor. For columns (2), (3), (5), and (6) the null hypothesis of the endogeneity test is that both output and input tariffs are exogenous is not rejected at the 5% level.

The concern that TFP is likely to be autocorrelated in the Brazilian data is addressed by estimating equation (1) with a one-period lagged TFP as a regressor by means of the Arellano-Bond estimator, which uses lags of the endogenous regressors as instruments (hereafter called Arellano-Bond instruments) as well as Colombian tariffs. The results are reported in Table 3. The time-lagged TFP coefficient is positive and statistically significant only in columns (1) and (4), when the Arellano-Bond instruments consist of the 2nd, 3rd, and 4th lags of the endogenous regressor (tfp_{it-1}), in which the import tariff coefficients are not statistically significant. On the other hand, the time-lagged TFP is not statistically significant when the Arellano-Bond instruments use the 3rd and the 4th lags of the endogenous regressors (columns (2), (3), (5), and (6)). In this case, the output tariff coefficient is always negative and statistically significant. The upstream and input tariff coefficients are positive and not statistically significant at the 10% level. The null hypothesis that both output and input tariffs are equal to zero is not rejected at the 5% level of confidence for columns (3) and (6). The output tariff coefficient is larger than the IV coefficient for the specification in first difference when input tariff is not a regressor and smaller than the IV coefficient when input tariffs is a regressor.

Some of the lags used for the Arellano-Bond instruments may be invalid instruments if the error term still displays autocorrelation. The first type of test to detect this problem is a specification test known as an over-identification test. The null hypothesis of the over-identification test is not rejected at the 5% level only for column (5). However, this is not sufficient evidence to conclude that all the estimates are invalid because in small samples this test has the tendency to over-reject the null hypothesis. In addition, this test result does not offer any insight concerning the problematic lag(s).

Another type of specification test checks directly for the presence of autocorrelation in the estimated residual, and the order of the autocorrelation in the null hypothesis can be chosen by the researcher. Interestingly, the null hypothesis that the error term is not an AR(1) process is rejected whenever the second lag of the endogenous regressors is used as an excluded instrument, whereas the null hypothesis that the error term is not an AR(2) process is never rejected. In particular, the rejection of the null hypothesis of the AR(1) implies that the second lag of the endogenous regressor is correlated with the residual and therefore is an invalid instrument. This means that only instruments using the third lag and beyond are valid. This supports the conclusion that the estimates that should be seriously considered are those that use the third and fourth lags, which provide no evidence of time persistence for the Brazilian TFP.

Finally, Table 4 accounts for both TFP spillovers across industries and time dependence by estimating equation (2) using a Spatial Arellano-Bond estimator (cf. Elhorst et al. 2010).[13] As shown in Table 4, the TFP time lag is positive and statistically significant at the 5% level in columns (1) and (3), as is the case in Table 3. The spatial lag TFP is always positive and statistically significant. The output tariff coefficient is always negative, but in the OLS-TFP specifications it is significant only in column (2) and at the 10% level in columns (1) and (3). In the OP-TFP specifications it is statistically significant at the 5% level only in columns (4) and (5) and at the 10% level in column (6). The results in Table 4 column (5) suggest that the spillover effect accounts for 70% of the total effect of tariffs on TFP. In particular, a 10% decrease in all tariffs would lead to an increase in TFP of 1.78% through the direct effect of tariffs and an increase of 4.04% through the inter-industry spillover effect, so the total effect is a 5.82% increase in TFP. The null hypothesis that both output and input tariffs are zero cannot be rejected at the 10% level for column (3) but is rejected at the 10% level for column (6), which suggests that they both matter in determining TFP. However, they cannot be precisely estimated.

The null hypothesis of the overidentification test is rejected at the 5% level for column (1) and at the 10% level for columns (2) and (4). Furthermore, similar to the results in Table 3, the null hypothesis of the AR(1) test is rejected at the 5% level for the specifications using the 2nd, 3rd, and 4th lags of variables as instruments, which are reported in columns (1) and (4). The null of the AR(2) test is never rejected. The results of the AR tests imply that only instruments based on the 3rd and 4th lags of regressors could be considered valid. In the end, column (3) for the OLS-TFP measure and columns (5) and (6) for the OP-TFP measure are the only estimates that are not rejected in the diagnostic tests. The most important results are that the spatial lag of TFP is positive and statistically significant and the time lag of TFP is not statistically significant in these three specifications.

5. Summary and Conclusions

Several developing countries have used trade liberalization to boost productivity, and there has been a significant amount of research evaluating the relationship between trade liberalization and productivity. In several cases, the findings indicate that reductions in both output and input tariffs caused an increase in industry-level productivity—see, for instance, Schor (2004), Amiti and Konings (2007).

In this paper I proposed a new methodology to assess the magnitude of the inter-industry productivity spillovers by means of spatial econometric techniques. Applying this methodology to data for the Brazilian trade liberalization episode (1989–1998), I find that inter-industry spillovers not only exist but also have a positive effect on industry-level productivity. And they can account for 70% of the increase in industry-level TFP due to trade liberalization. When the

[13] The second spatial lag of Colombian tariffs was not used due to collinearity in the instruments matrix.

spillovers are ignored, the estimates of the impact of trade liberalization on productivity are biased upward by at least 25%.

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Table 1 – Descriptive Statistics

Variable	Number of Observations	Mean	Std. Dev.	Minimum	Maximum
OLS-TFP	160	0.9849	0.0375	0.9127	1.0973
OP-TFP	160	0.9981	0.0307	0.9177	1.0781
Brazilian output tariff	160	0.2031	0.1212	0.040	0.750
Brazilian input tariff	160	0.2193	0.0998	0.0914	0.6818
Colombian output tariff	160	0.3193	0.1850	0.0649	1.199

All TFP variables are expressed in natural logarithms. OLS-TFP is the TFP obtained through the use of an OLS estimator, while OP-TFP is obtained by the Muendler (2004a, b) extended Olley-Pakes methodology.

Table 2 – The effect of tariff changes on TFP estimated using equation (1) by instrumental variables.

	Dependent variable					
	OLS-TFP	OLS-TFP	OLS-TFP	OP-TFP	OP-TFP	OP-TFP
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
ΔOutput Tariff	-0.197**	-0.194**	-0.189**	-0.141**	-0.144*	-0.139*
	(0.074)	(0.095)	(0.093)	(0.058)	(0.075)	(0.073)
ΔUpstream TFP	0.002		0.002	0.001		0.001
	(0.001)		(0.001)	(0.001)		(0.001)
ΔInput Tariff		-0.020	-0.022		-0.003	-0.005
		(0.116)	(0.114)		(0.091)	(0.090)
Observations	160	160	160	160	160	160
1st Stage						
ΔColombian Tariff	0.331**			0.332**		
	(0.056)			(0.056)		
ΔUpstream TFP	0.004*			0.004		
	(0.003)			(0.003)		
Weak id. Kleibergen-Paap rk Wald F statistic	34.84	8.985	9.387	34.84	8.985	9.390
Stock-Yogo 10% max IV relative bias critical values	16.38	7.03	7.03	16.38	7.03	7.03
Endogeneity test	2.728*	3.227	3.013	1.647	1.371	1.182
	[0.099]	[0.199]	[0.222]	[0.199]	[0.504]	[0.554]

All TFP variables are expressed in natural logarithms. Year dummy variables included in all specifications. Colombian tariffs and input tariffs calculated using Colombian tariffs (if Brazilian input tariffs included in the estimated specification), which are used as excluded instruments. Robust standard errors are reported in parentheses. *p*-values are reported in brackets. **, * indicates statistical significance at the 5% and 10% levels, respectively. Endogeneity test null hypothesis is that import tariff and input import tariff (if included in the estimated specification) are exogenous regressors.

Table 3 – Estimates of the baseline specification using the Arellano-Bond estimator to account for TFP time persistence.

	Dependent variable					
	OLS-TFP	OLS-TFP	OLS-TFP	OP-TFP	OP-TFP	OP-TFP
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
ΔTime Lag TFP	0.202**	-0.041	-0.040	0.370**	0.150	0.162
	(0.099)	(0.154)	(0.138)	(0.104)	(0.175)	(0.149)
ΔOutput Tariff	-0.016	-0.214**	-0.113*	-0.049	-0.282**	-0.153**
	(0.043)	(0.091)	(0.067)	(0.036)	(0.108)	(0.070)
ΔUpstream TFP	0.001	0.002	0.002	0.001	0.002	0.002
	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)
ΔInput Tariff			0.095			0.014
			(0.141)			(0.126)
Overidentification test	59.19**	30.30**	44.69**	47.47**	15.73	29.05**
	[0.000]	[0.017]	[0.000]	[0.006]	[0.472]	[0.024]
Test for AR(1) error	-3.945**	-0.528	-0.697	-4.026**	-0.857	-1.480
	[0.000]	[0.598]	[0.486]	[0.000]	[0.391]	[0.139]
Test for AR(2) error	0.007	-1.036	-0.810	-0.155	-1.465	-1.045
	[0.995]	[0.300]	[0.418]	[0.877]	[0.143]	[0.296]
Arellano-Bond instruments lags used	2 to 4	3 to 4	3 to 4	2 to 4	3 to 4	3 to 4
Observations	128	128	128	128	128	128

All TFP variables are expressed in natural logarithms. Colombian tariffs and input tariffs calculated using Colombian tariffs (if Brazilian input tariffs included in the estimated specification), which are used in addition to the traditional Arellano-Bond instruments. Year dummies included in all regressions. Standard errors are reported in parentheses. *p*-values are reported in brackets. **, * indicates statistical significance at the 5% and 10% levels, respectively.

Table 4 – Spillovers and time persistence of TFP accounted for by estimating equation (2) using the spatial Arellano-Bond estimator.

	Dependent variable					
	OLS-TFP	OLS-TFP	OLS-TFP	OP-TFP	OP-TFP	OP-TFP
Independent variables	(1)	(2)	(3)	(4)	(5)	(6)
Time Lag ΔTFP	0.210**	-0.006	-0.020	0.372**	0.190	0.153
	(0.105)	(0.148)	(0.161)	(0.109)	(0.159)	(0.183)
Spatial Lag ΔTFP	0.764**	0.725**	0.791***	0.564**	0.694**	0.798**
	(0.220)	(0.221)	(0.258)	(0.238)	(0.272)	(0.325)
ΔOutput Tariff	-0.051	-0.136*	-0.129	-0.065*	-0.178**	-0.160*
	(0.047)	(0.073)	(0.080)	(0.039)	(0.075)	(0.087)
ΔInput Tariff			-0.119			-0.148
			(0.180)			(0.166)
Overidentification test	40.46**	26.12*	22.15	38.72*	17.16	12.98
	[0.035]	[0.052]	[0.104]	[0.052]	[0.375]	[0.604]
Test for AR(1) error	-3.181**	-0.986	-1.104	-3.237**	-1.247	-1.351
	[0.001]	[0.324]	[0.270]	[0.001]	[0.212]	[0.177]
Test for AR(2) error	0.011	-0.375	0.0742	-0.244	-0.809	0.0652
	[0.991]	[0.707]	[0.941]	[0.807]	[0.418]	[0.948]
Arellano-Bond instruments lags used	2 to 4	3 to 4	3 to 4	2 to 4	3 to 4	3 to 4
Observations	128	128	128	128	128	128

All TFP variables are expressed in natural logarithms. Colombian tariffs and input tariffs calculated using Colombian tariffs (if Brazilian input tariffs included in the estimated specification), which are used in addition to the traditional Arellano-Bond instruments. Year dummies included in all regressions. Standard errors are reported in parentheses. *p*-values are reported in brackets. **, * indicates statistical significance at the 5% and 10% levels, respectively.