New Evidence from Brazil on Trade Liberalization and Productivity Growth*

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Abstract

This paper presents evidence on the positive effect of international trade on productivity growth using industrial level data preceding and following Brazil's trade liberalization in 1988-1990. Brazil provides a rare policy experiment to study this issue that is seldom available: it was one of the most closed economies in the world until 1988 and intra-industry data are available on an annual basis before, during and many years after liberalization. Our data reveal large and widespread productivity improvement after barriers to trade were drastically reduced. On average, total factor productivity grew at 3 percent a year and labor productivity growth rates for all but one of the 16 industries we study were above 5 percent. Econometric results confirm the association between trade liberalization and productivity growth and show that the impact was indeed substancial: the observed tariff reduction in the period brought a 6 percent estimated increase in total factor productivity growth rate and a similar impact on labor productivity.

*We gratefully acknowledge the comments of Ed Prescott, João Issler, Ajax Moreira Samuel Pessôa, Eustáquio Reis and three anonymous referees. Thanks also to Honório Kume for some of the data used, and CNPq and PRONEX for financial support.

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1 Introduction

This paper offers new evidence on the positive effect of international trade on productivity growth using industrial level data preceding and following Brazil's trade liberalization in 1988-1990.

Empirical support for the relationship between productivity and trade reform in the literature is rather weak. Results are at best ambiguous and, if any, only modest gains are predicted. For instance, in surveying the applied general equilibrium literature, Kehoe and Kehoe(1994) write that the estimated effect of NAFTA is negligible for the US and Canada, and only worth 2.2 percent of GDP for Mexico. Tybout, de Melo and Corbo(1991) found no evidence of overall productivity improvement in the Chilean manufacturing sector after trade liberalization. Results in Tybout and Westbrook(1995) for the Mexican manufacturing sector are similar, but the evidence is even weaker for trade liberalization affecting productivity. In a similar tone, Pack(1988) states that

> Comparisons of total factor productivity growth among countries pursuing different international trade orientations do not reveal systematic differences in productivity growth in manufacturing nor do the time-series studies of individual countries that have experienced alternating trade regimes allow strong conclusions in this dimension.

In fact, very few studies at the micro level have linked trade reform to increased productivity growth[1]. On the other hand, the evidence obtained from studies that rely on cross-country regressions (e.g., Edwards(1993) and Ben-David[1993]) has been attacked recently by Rodríguez and Rodrik(1999) and Rodrik(1999). Their criticism is centered on methodological issues but could be interpreted as a rejection of the recent policy consensus on the beneficial impacts of openness.

However, as stated by Srinivasan and Bhagwati (1999), cross-country regressions are not in any event the best tools for analyzing the problem of understanding the linkage between trade and growth, because of institutional and country-specific factors that are difficult to control. Moreover, when studying country experiences, the important question is what would have happened if a country had not adopted less restrictive trade policies.

One empirical approach to deal with this question is to use data from the same country before and after a policy change, which is exactly what we do in the present study (as opposed to Harrison(1995), Lee(1996) and most articles surveyed in Pack(1988)). Monthly industrial surveys in Brazil collected data before, during and after this process, providing a policy experiment. Data are available not only for the entire 1985-1997 period but also for different industries of the manufacturing sector, also allowing the study of intra-industry effects of the reforms. Hence, we have an experiment in which institutional and country

[1] Three exceptions are Harrison(1994), which works with plant level data from Cote D'Ivoire, Lee(1996), which works with industrial data at the 4-digit level from Korea and Trefler(2001), which studies Canadian industries.

factors are controlled, the data span stretches from five years before the policy change to some years later and the manufacturing industries included in the exercises comprise more than 90% of the total sector production.

Unlike most of the previous literature, we found strong evidence linking trade liberalization and productivity growth. Our data show that after declining over the 1980s, both output per worker and total factor productivity (TFP) increased after trade liberalization. For example, TFP for 16 industries at two-digit level declined at an average annual rate of 3.83 percent from 1985 to 1990, but from 1991 to 1997 increased at an average annual rate of 2.65 percent. The figures for output per worker are similar, while 10 of those 16 industries had negative growth from 1985 to 1990, all but one grew at annual rates above 5% from 1991 to 1997. In the same period, average nominal tariffs for the manufacturing sector dropped from more than 100% to less than 15%, while the effective rate of protection declined to less than one-fifth of its original level.

The relationship between these phenomena is investigated econometrically in the paper, using panel techniques. Results confirm the linkages between trade reform and productivity growth and show that the magnitude of the impact of tariff reduction on the growth rates of TFP and output per worker was substantial. According to the estimations, for instance, the observed tariff reduction in the period brought a 6 percent increase in the TFP growth rate and had a similar impact on labor productivity.

The long span of the data after trade liberalization and the panel data structure of our sample may explain the difference in findings between this and other micro-based studies. For instance, the samples of Krishna and Mitra (1998) and Tybout, de Melo and Corbo(1991) end one or two years after liberalization was completed, so that its full impact might not had been felt yet. In addition, business cycle effects are problematic to productivity measures in short data spans. A second factor that might have driven the results is that the magnitudes of protection reduction in most other countries were smaller than in Brazil. This is certainly true for Mexico, India (at least in the period studied by Krishna and Mitra [1998]) and all other Asian countries that liberalized trade recently (Kawai[1994]), although the figures for Chile are comparable. In fact, until recently Brazil was one of the most closed economies in the world: it had in the seventies the fifth smallest trade share of all countries in the Summers and Helston database and, according to Leamer's openness index, a worse ranking than the vast majority of economies, including Mexico, Colombia, Chile, India and Thailand. Hence, the gains from liberalization were potentially larger.

This article relates to the literature of political and institutional barriers to growth (e.g., Holmes and Schmitz(1995), Parente and Prescott(2000)). In these studies, sectors with some degree of monopoly power over the supply of specific factors can impose prices and block adoption of new technology. In Parente and Prescott (1999), for instance, a coalition of factor suppliers that is the monopoly seller of its input services can dictate work practices and member's wages. The monopoly right is protected by law, which makes it costly to enter the market with more productive technology. A corollary is that barriers to trade such as tariffs, quotas or any non-tariff barriers imposed by those interest groups affect the country's TFP level and growth prospects. If these barriers are destroyed the resistance to new technologies or new work practices is reduced, accelerating productivity growth. That is exactly what is shown in this paper: as barriers to trade were drastically reduced, industrial productivity soared while employment and hours worked fell substantially.

The paper is organized in 4 sections, in addition to this introduction. The next section presents trade reform stylized facts while Section 3 discusses the evolution of labor productivity and TFP in the manufacturing sector in the period. Section 4 tests the link between productivity and trade restrictions while at the same time estimating productivity elasticity with respect to measures of trade protection. Section 5 concludes.

2 Trade Policy

Import substitution and protection of infant industries were the foundation of industrial policy and development strategy in Brazil (and Latin America as a whole) until the end of the eighties. Up to 1979, quantitative controls, reserved market shares and outright import bans were the dominant policy instruments. The so-called "lei do similar nacional" ("law of similar domestic production") banned the importation of or imposed prohibitive tariffs on any industrial product competing with domestic goods. After 1979, tariffs were re-established as the main instrument of trade policy and quantitative controls were mostly abandoned gradually. However, to compensate for the decrease in industrial protection, nominal tariffs were raised to levels well above international standards. In 1988, a trade liberalization process began. This was rather timid at first, with the elimination of redundant tariffs, but after 1990 the pace of reform accelerated. All quantitative controls were definitively eliminated and a timetable was established for tariff reduction. By 1997, nominal tariffs were on average one-tenth as large as in 1987.

In this paper, we have a complete data set for 16 of the 21 sectors of the Brazilian manufacturing industry over a time span from 1985 to 1997 (annual observations). The output of these 16 sectors takes in something around 92% of the total output of the manufacturing industry of the country during this period. The effective rate of protection was constructed using technical coefficients from the input-output tables and nominal tariffs. The latter were simple averages of all the tariffs imposed on products of a given industry. Table 1 displays the average nominal tariff for the 16 industries between 1987 and 1997[2].

[2]The nominal tariff and effective rate of protection data are from Pinheiro and Almeida (1994) and Kume(1996). 1997 data are based on the Mercosur common tariffs. See the appendix for more information about the data set.

Table 1: Average Nominal Tariffs

Industry	Year		
	1987	1990	1997
Nonmetal mineral products	98.7	24.5	7.30
Metalworking	72.8	23.7	12.80
Machinery	62.1	39.5	13.90
Electronic and communication equipment	100.4	39.6	14.55
Transportation and motor vehicles	115.9	55.9	16.70
Paper and paper products	82.2	23.1	11.90
Rubber products	101.7	49.6	12.80
Chemicals	34.2	13.4	8.23
Pharmaceuticals	42.2	26	10.00
Perfumes, soap and candles	184.4	59.2	10.00
Plastic products	164.3	40	16.50
Textiles	161.6	38.8	15.80
Clothing, fabric products and footwear	192.2	50	19.60
Food	84.2	27.4	12.15
Beverages	183.3	75.1	14.50
Tobacco	204.7	79.6	9.00
Average	117.81	41.59	12.86
Standard Deviation	56.01	19.02	3.40

On average, pre-reform tariffs were almost ten times larger compared to post-reform tariffs in 1997. The highest tariffs were observed in consumption industries such as tobacco, beverages and textiles. The lowest tariffs were those on intermediate industries such as chemicals and machinery. Three years after the beginning of liberalization, tariffs were already only one-third of 1987 figures and dispersion (e.g., as measured by the ratio of standard deviation to average tariff) was also significantly reduced. Dispersion was further reduced until 1996 and by this time the highest average tariff, on the clothing industry, was only 19% percent.

It is interesting to note that although the fall in nominal tariffs after trade liberalization is widespread across sectors, the ordering is more or less the same as before; the consumption industries still have more protection than intermediate and capital-goods industries. Another point worth mentioning is that due to exceptions in the Mercosur agreement, protection in some industry subsectors, for instance the automobiles, computers and freezers industries, is still relatively high (e.g., more than 40 percent in the case of most automobiles) and well above figures in Table 1 for 1997.

The study of effective rates of protection rather than nominal tariff rates is certainly more important for understanding the impact of trade policy on productivity growth. This is so because the former takes into account not only the price of final products but also the price of the inputs used in their production and in principle includes the effect of all of the factors that drive a wedge between world and domestic prices. As said before, the effective rate of protection was constructed using technical coefficients from the input-output tables and nominal tariffs. Table 2 displays industry averages for the effective rate of protection for the 1985-1997 period.

Table 2: Effective Rates of Protection

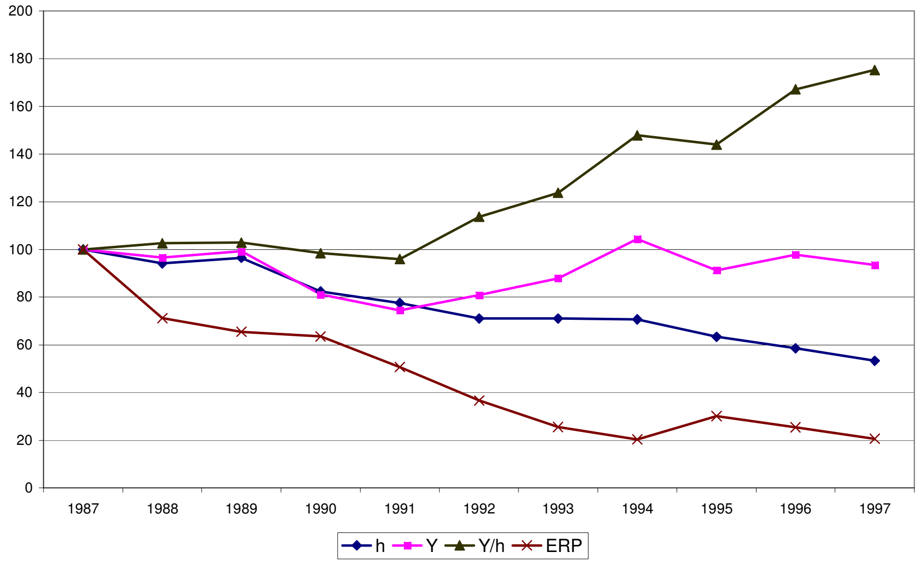
Industry	Year		
	1987	1990	1997
Nonmetal mineral products	31.5	42.2	14.5
Metalworking	59.8	34.5	17.5
Machinery	18.5	41.2	14.3
Electronic and communication equipment	108.2	53.3	16.7
Transportation and motor vehicles	43.5	178.2	33.8
Paper and paper products	31.0	22.8	12.6
Rubber products	125.0	67.1	14.7
Chemicals	64.9	21.5	10.3
Pharmaceuticals	52.3	36.3	9.9
Perfumes. soap and candles	96.1	76.0	26.1
Plastic products	427.7	54.2	22.3
Textiles	53.1	50.1	21.5
Clothing. fabric products and footwear	240.7	65.4	22.6
Food	32.7	33.5	15.7
Beverages	-7.6	93.0	19.9
Tobacco	-4.6	3.1	10.8
Average	85.8	54.5	17.7
Standard Deviation	105.6	38.5	6.2

The effective rate of protection fell in all industries but beverages and tobacco. On average, the 1997 values are one-fourth those of 1987. The decrease, however, is not uniform across industries, and is still high in the transportation industry. The largest reductions occurred in the plastic products industry and in the clothing, fabric products and footwear industry. In the first case, the current rate is less then 6 per cent of its 1985-89 average. Note also that there is a large decrease in the dispersion of effective protection: the ratio of standard error to average fell from 1.23 to 0.35 in the period.

3 Productivity growth

3.1 Labor productivity

We used two measures of productivity: one based on “total work hours employed in production” and the other “total labor force employed in production.” They were constructed using data obtained in the monthly industry surveys of IBGE, the Brazilian public statistics bureau. There is no information on value-added by industry, so we used output (in constant prices) as a proxy[3]. Figure 1 below presents the evolution of average productivity, average hours, average output and effective rate of protection for the 16 sectors for the 1987-1997 sub-period:



Labor Productivity and Effective Rate of Protection (Industry Average, 1987-1997)

In the graph above, h stands for hours, Y for output and ERP for effective rate of protection. One can see that productivity started to increase at a very fast pace in the beginning of the nineties and by 1997 it was on average 80 percent higher than in 1987. Note the contrasting behavior of protection, falling throughout the entire period

Before trade liberalization, from 1985 to 1990, labor productivity grew very little or declined in most sectors. On average, the annual rate of growth for the entire manufacturing sector was -0.282 percent in the output/hours concept. Between 1985 and 1989, output and employment increased, but the latter more than the former. After 1990, with the beginning of trade liberalization, average productivity increased at an annual rate of almost 8 percent (when using hours). In the period between 1990 and 1993, the country experienced a recession but output reduction was more then offset by employment reduction. Finally, the 1994-1997 period is one of even faster productivity growth. Employment continued its downward trend but in this case output increased in all industries.

Behavior by industry is similar, as can be seen from Table 3 below:

[3] In section 4 we present some evidence that this does not seem to be a problem.

Table 3: Labor Productivity Growth

Industry	Period	
	1985-90	1991-97
Nonmetal mineral products	-0.96%	9.08%
Metalworking	-1.20%	7.65%
Machinery	0.35%	8.17%
Electronic and communication equipment	1.33%	10.78%
Transportation and motor vehicles	-4.25%	11.19%
Paper and paper products	0.21%	8.08%
Rubber products	-0.63%	8.87%
Chemicals	-0.30%	8.05%
Pharmaceuticals	-1.65%	2.89%
Perfumes, soap and candles	1.23%	5.29%
Plastic products	-3.30%	8.85%
Textiles	-3.85%	8.21%
Clothing, fabric products and footwear	-0.97%	6.58%
Food	-0.33%	6.91%
Beverages	3.99%	8.76%
Tobacco	5.86%	8.21%
average	-0.28%	7.97%

After trade liberalization, all 16 sectors experienced rapid productivity growth, with the fastest rates occurring in the transportation (11.19 percent annual growth rate) and electronics (10.78 percent annual growth rate) industries. In contrast, in the first sub-period, all but 5 industries experienced negative annual labor productivity growth rates, textiles having the worst record (-3.86 percent annual growth). Note that in the period after trade liberalization, the growth rate of labor productivity in all but two industries is above 6.5 percent, an impressive performance.

3.2 Total Factor Productivity

Total factor productivity is measured in the standard way. Assume a Cobb-Douglas production function:

$$Y_{it} = A_{it}.K_{it}^{\alpha}.L_{it}^{\gamma}, \quad i = 1, ..., N; \quad t = 1, ..., T, \tag{1}$$

where Y_{it} denotes output of sector i at time t, K, and L stand for physical capital and labor, respectively. Hence, in this formulation the residual A_{it} is equivalent to the TFP. Taking logarithms and differentiating with respect to time, we obtain:

$$d\ln Y_{it} = dTFP_{it} + \alpha.d\ln K_{it} + \gamma.d\ln L_{it} \tag{2}$$

where $d\ln X_{it} = \ln X_{it} - \ln X_{it-1}$. The productivity term can be decomposed into two terms $dTFP_{it} = \varpi_{it} + \varepsilon_{it}$, where the term ϖ_{it} is known by the firm but not by the econometrician and the second term, ε_{it}, is unknown by both. Therefore, the model allows the rate of productivity growth to vary over industries.The equation to be estimated is then:

$$d\ln Y_{it} = \alpha.d\ln K_{it} + \gamma.d\ln L_{it} + \varpi_{it} + \ \varepsilon_{it} \tag{3}$$

Physical capital was constructed from investiment data using the perpetual inventory method and it is corrected for the rate of utilization of sector capacity[4].

As emphasized by the literature, the use of OLS is inappropriate because capital and labor are correlated with the residual. More productive firms are willing to invest more, therefore they are able to hire more workers or contract more capital. One can assume that the unobserved plant-specific productivity to be time-invariant and estimate (3) using the fixed-effects (within estimation). This seems to be a strong assumption for times of large structural changes as emphasized by Pavnick(2000). Another way to estimate (3) is using an instrumental variable (IV) estimation. The IV estimator is difficult to implementat because it is necessary to find instrumental variables that are correlated with the regressors but not with productivity. For IV estimation, we used input prices as instruments: the rental rate of capital and real wages. For more information about the data, see the appendix. Table 4 shows the results for this range of estimators using total hours as a proxy for labor[5].

Table 4 - Estimation Results

	OLS	FE	IV
K	0.309	0.323	0.341
	(0.056)	(0.058)	(0.103)
L	0.406	0.368	0.752
	(0.051)	(0.049)	(0.156)
Wald Test: CRS	21.166	23.262	0.380
p-value:	0.0001	0.0001	0.537
Hausman Test		7.195	8.565
		0.027	0.014
R^2	0.39	0.46	0.36
Observations	192	192	192

Note: Estimation using robust standard errors (White heteroskedasticity consistent covariance matrix)

First, the results show that endogeneity is a problem for our estimation. A Hausmann test of specification rejected the hypothesis that OLS estimation is consistent. Second, a well-known problem of the fixed-effects estimation appears. If average differences across industries are well-measured, but the within

[4] The initial capital stock was constructed according to $K_0 = I_0/(g_I + \delta)$, where K_0 is the initial capital stock, I_0 is the initial investment expenditure, g_I is the growth rate of investment in the period, and δ is the depreciation rate.

[5] Because heteroskedasticity is a problem when panel data is used, all parameters were estimated using robust standard errors (White heteroskedasticity consistent covariance matrix).

industry fluctuations are badly measured, the estimators for shares decline after the fixed-effects transformation is applied, so that there appear to be large decreasing returns to scale. This represents bias toward zero that is caused by mismeasurement. The Wald test confirms this fact, when the hypothesis of constant returns to scale is rejected for OLS and fixed-effects estimation.

Third, the result from IV estimation is near to what is assumed as acceptable in the literature, with the labor share close to 2/3 and the capital share equal to 1/3. Moreover, a Wald test does not reject the hypothesis of constant returns to scale. In addition, real wages and rental rate of capital have all the qualities of good instrumental variables. The variables are correlated with the regressors, but not with the error term, and both have enough variability to estimate the parameters.

From all these facts, it is possible to conclude that simultaneity is an important issue and the data reject the within and OLS estimation. Therefore, we used IV for the estimation of the total factor productivity. Another important fact is that the result with respect to TFP estimation is not dependent on whether we use total hours(h) or labor force(n). Both TFP series are highly correlated and there is no significant change in the estimation of the factor shares. Results for labor force (n) are shown in the appendix.

Regardless of the labor series used, TFP growth rate behaves the same: between 1985 and 1990, the period prior trade liberalization, the TFP declined in all sixteen industries, in some cases by more than 3 percent per year (with a maximun fall of 9 percent in transportation and motor vehicles industry. After the trade liberalization, from 1991 to 1997, this trend reverted, as there was positive productivity growth in every industry but one. The average growth rate jumped from -3.83% in the previous period to +2.65 percent, and in almost half the sectors annual growth rates were above 3 percent. Note also that the evolution of labor productivity in the period is very similar, although magnitudes vary. Table 5 below displays TFP annual growth rates by industry in the 2 sub-periods and the 1994-1997 sub-period, for the case in which hours were used as the labor variable. In the 1994-1997 period there was an acceleration of TFP growth in most industries and average growth across industries is even higher.

Table 5: TFP Annual Growth Rates

Industry	Period		
	1985-90	1991-97	1994-1997
Nonmetal mineral products	-3.03%	3.22%	5.42%
Metalworking	-2.89%	4.01%	4.44%
Machinery	-2.11%	3.39%	0.57%
Electronic and communication equipment	-2.93%	4.34%	2.72%
Transportation and motor vehicles	-9.08%	4.64%	5.67%
Paper and paper products	-4.28%	2.70%	1.98%
Rubber products	-4.56%	1.63%	4.67%
Chemicals	-5.01%	3.53%	4.80%
Pharmaceuticals	-4.15%	-1.28%	-0.36%
Perfumes. soap and candles	-0.40%	1.78%	1.37%
Plastic products	-6.43%	2.83%	8.44%
Textiles	-5.72%	3.60%	1.49%
Clothing. fabric products and footwear	-5.34%	0.69%	3.01%
Food	-3.26%	2.78%	3.36%
Beverages	-1.10%	2.68%	2.14%
Tobacco	-1.07%	1.77%	3.47%
average	-3.83%	+2.65%	+3.32%

note: TFP estimated by IV.

Note that the observed increase in the growth rate of total factor productivity and labor productivity across industries in the period coincides with the reduction of protection to domestic industry. In the next section we test this relationship econometrically.

4 Productivity Change and Trade Liberalization

Table 6 below presents simple correlations between trade protection measures and productivity variables in our data set as first and casual evidence of the relationship between these series.

Table 6: Productivity Growth and Tariffs Correlations

	NT	ERP	$\widehat{(Y/L)}$	$\widehat{TFP}$
NT	1	0.50	-0.34	-0.32
ERP		1	-0.23	-0.21
$\widehat{(Y/L)}$			1	0.79
$\widehat{TFP}$				1

NT stands for nominal tariff, ERP for effective rate of protection and Y/L for labor productivity, and a hat above variables represent growth rates. The correlations presented above indicate a negative relationship between trade protection variables and productivity growth, as we observe negative correlation coeficient between all measures of protection and of productivity[6].

An important question we must deal before proceeding is whether we can rule out the possibility that the productivity increase that is documented here is the result of other macroeconomic policy and/or institutional changes that occurred in the period, and not trade liberalization. Privatization, for example, that was going on by this time, perhaps exerted an influence in the path the productivity. It is impotant to note, however, that privatization in the manufacturing sector was essentially restricted to two of the sixteen industries we study, Metalworking and Chemicals. Moreover, although the numbers on output per type of firm are not available, we can infer that the participation of government owned companies in these industries, although relevant, was always below or about half of total production. First, we know that out of all sub-sectors of the Chemicals industry, only firms in the Fertilizer and the Petrochemical sub-sectors were privatized. Second, the share of output of these sub-sectors in the industry output in 1990 was less than 20 percent, and in the total manufacturing industry, less than 3 percent. In the Metalworking industry these numbers are higher but they were around 50 percent of total industry output and 6 percent of total manufacturing output. Finally, given that there were private companies in these sub-sectors, the numbers above overestimate the importance of government owned companies in the industry.

Timing is also an important factor: the first privatization episode in the Metalworking industry occurred by November of 1991, but its TFP that year was already 8.5 percent higer than in 1988. In the Chemicals industry the first privatization was in 1992, but by that year its TFP was already 5.7 percent above the 1988 level. Finally, as we will see in the next section, excluding these two industries from the sample used in the econometric exercises did not change results.

Besides privatization, the sucessive stabilization plans can affect our productivity measures, we can cite the Collor plan that caused a deep recession during 1990 and the Real Plan that finally controled inflation in the country after 1994[7]. As we will see below, we deal econometrically with these questions including a vector of time dummies and also excluding in some regressions the industries affected by privatization.

In order to investigate the relationship between trade liberalization and productivity growth econometrically, we use the following model:

[6] Both measures of productivity were constructed using hours worked but results do not change if we use employment. Note that we do not mean that the correlations between opening up to trade and rising productivity indicate causation. This would not be the case, for instance, if trade reforms were endogenous. The correlations above are just an indication of a potential relationship. Endogeneity problems will be studied later on.

[7] Note however, with respect to the Real Plan, that in 1993 labor productivy was on average already 20 percent higher than in 1988, while TFP was 15 percent higher. Moreover, there is no statistical evidence of inflation affecting productivity.

$$\hat{prod}_{it} = \beta_i + \sigma_t + \phi.Z_{it} + \gamma.R_{it} + \varepsilon_{it}, \qquad i = 1, ..., 16, \quad t = 1985, ..., 1997 \quad (4)$$

where $\hat{prod}_{it}$ is the growth rate of productivity (either labor productivity or TFP), β_i is the industry-specific fixed effect, Z_{it} are variables used as proxies for trade liberalization, σ_t is a vector of time dummies and ε_{it} is the error term. The term β_i represents possible different unobeserved industry specific factors - e.g., different managerial abilities - that might affect productivity growth and σ_t is a vector of time dummies included to capture common institutional and macoeconomic factors that affect productivity growth. We expect that the vector of time-dummies should capture all the events - privatization and stabilization plans, for instance - commented on above.

The term Z_{it} represents a set of trade liberalization proxies including tariffs, effective rate of protection and import ratio. All variables are industry-specific indices. One of the strengths of the paper is that besides quantity figures we use tariffs and the effective rate of protection as measures of trade liberalization. The import ratio is defined as the ratio of total imports to total national output. They may be considered direct measures of openness but also, especially in the case of imports, indirect measures of technological adoption (see, for instance, Coe, Helpman and Hoffmaister(1995) and Holmes and Schmitz (1995)).

The term R_{it} is a set of control variables, for example, inflation. The negative impact of inflation on growth is well documented (e.g., Fischer(1993)). One possible channel would be the increase in uncertainty brought about by higher price volatility (Ramey and Ramey (1996)). For our regressions, 16 industry sector inflation rates were constructed from industry wholesale price indices.

Note that it is possible that estimation suffers from an endogeneity problem. The political economy literature of international trade emphasizes that less productive industries might be more likely to lobby and receive higher protection. Another possibility is that, as argued by Mundler (2002), when setting tariffs, government favors less productive sectors in order to boost their productivity.

Our argument is that none of these factors influenced the path of trade liberalization in Brazil, which means that productivity shocks are not correlated with tariffs or efffective rate of protection, and therefore endogeneity is not a problem with respect to tariff determination. Table 1 shows that tariffs were reduced proportionally across industries, keeping the same pattern of protection, an indication that neither lobbying nor a selectivity reduction are features of our dataset. Moreover, there is no dynamic model that can highlight the problem of the simultaneous determination of protection and productivity in order to choose appropriate instruments. As cited, political economy variables could be good instruments, but these variables could not be collected or are not available at this aggregation level . On the other hand, it is hard to argue that the import ratio as defined is an exogenous variable, since less productive sectors are more attractive to foreign firms, causing more imports. In order to test our conjectures, we proceed in the following way: First, we estimate equation (4) by fixed effects. Second, we estimate it using instrumental variables, so we test our different specifications. We use as instrumental variables determinants of the terms of trade such as nominal exchange rate and weighted price index of the main Brazilian trade partners.

4.1 Productivity Growth Regressions

Table 7 presents the results of the estimations of equation (4) with (log)TFP growth rate as the dependent variable. M stands for import ratio.

Table 7: Total Factor Productivity Growth Regressions

Variable	FE	FE	FE	FE	FE	FE
NT	-0.073 (0.010)	-0.049 (0.009)	-0.047 (0.011)			
ERP				-0.046 (0.011)	-0.019 (0.009)	-0.018 (0.009)
M			4.386** (3.840)			5.308** (4.012)
$Time$	No	Yes	Yes	No	Yes	Yes
R^2	0.120	0.413	0.420	0.120	0.413	0.525
N	192	192	192	192	192	192
Hausman Test	0.001	0.114	3.148	1.397	0.075	0.609
P-Value	1.000	1.000	0.207	0.999	1.000	0.737

Note: Estimation using robust standard errors (White heteroskedasticity consistent covariance matrix) * - significant at 10% level of significance; ** - Not significant

Whether trade barriers are measured by the effective rate of protection (ERP) or nominal tariffs (NT), the estimated effect on total factor productivity growth is negative, robust to control variables and always significant. The Hausman test does not reject the consistence of the fixed effects for all specifications. Therefore, we conclude that endogenity is not a problem for all estimations. In the appendix, the results for IV estimation are shown. Trade liberalization in Brazil can explain a large part of TFP growth: the decrease in the effective rate of protectiom observed in the period implies, according to our estimations, an increase of 3 to 6 percent in the TFP growth rate. If we use nominal tariffs, the estimated impact is even larger (between 8 to 12 percent), as tariff reduction is more dramatic than the drop in the effective rate of protection and the estimated elasticity is also higher in absolute value[8]. Results for import ratio are not robust; if we include time dummies, the import ratio variable is not significant at 10%, which means that this variable is capturing some macroeconomic disturbance. Export ratio and inflation (not shown) are not significant in all estimations. Finally, comparing columns 1 and 2 or columns 4 and 5, we

[8] Due to the large variation of tariffs and effective rates of protection, we used the arc-elasticity definition to calculate these values.

see that using time dummies does not change the significance of the tariffs and the effective rate of protection, although the magnitude adding time trend is lower. This means that macroeconomic disturbances were important, but they did not drive the results for tariffs or effective rate of protection[9].

In the appendix we show the results using labor productivity instead of TFP growth as dependent variable. Given the high correlation between the two labor productivity measures constructed, we opted to present only the results of the estimations that used total hours in production, but regression results with total labor were very similar, as expected. The results reported confirm the negative relationship between labor productivity and trade barriers. The inclusion of control variables and/or time dummies did not change the results, although the estimated coefficients were smaller in general, which demonstrates that macroeconomic factors were important to changes in productivity growth. The results of the regressions with effective rate of protection are also significant and robust to changes in controls. They also show that increases in protection imply slower productivity growth.

We repeated these regressions excluding from the sample two industries, Chemicals and Metalworking, in which privatization was relevant. We obtained results very close to those in Table 7. The estimated coefficient of ERP was a bit smaller without the time dummies, -0.035, but that of NT was almost equal, and both were significant at the 5% level. For the labor productivity regressions, results without these two industries were also very similar. Hence, we have further evidence that privatization is not driving the results.

4.2 Output Growth Regressions

A potential restriction to the previous regressions is that when we first estimate the TFP and then the effect of trade barriers on it, the errors of the two sets of regressions might compound each other. The final estimated elasticity, hence, might be estimated less precisely than if we just estimate a production function directly, substituting it in the trade variable. In other words, we have been assuming the following relationship between productivity growth and, for instance, nominal tariffs:

$$d\ln TFP = \beta_i + \delta_t + \phi NT_i + \varepsilon_{it}$$

where β_i is the country-specific fixed effect and ε_{it} is the disturbance term. So we could plug the above expression in (2) and obtain:

$$d\ln Y_{it} = \beta_i + \delta_t + \phi NT_i + \alpha.d\ln K_{it} + \gamma.d\ln L_{it} + \varepsilon_{it} \tag{5}$$

This type of model was used, for instance, in Harrison(1995) for panel data of developing countries. In this case, the effect of trade barriers on output growth when directly controlling for factor growth was estimated. Table 8 below

[9] Note that this and other tables do not present all regressions used to test robustness. The total number is much larger, as it includes not only exports but also combinations of exports, imports and inflation. The resulting estimations, however, are very similar.

presents the results of the estimation of equation (5) using our panel of Brazilian industries:

After testing, we used the 2SLS-FE method using the rental rate of capital and the real wages as instruments for the factors of production. We ran regressions using both hours and labor force as the labor variable. The results are quite similar, so we decided to show the results using houra as our labor proxy. As can be seen from the regressions below, the estimated effect of trade restriction measures on output growth is significant and has the expected sign in all regressions.

Table 8: Output Growth Regressions

Variable	2SLS-FE	2SLS-FE
K	0.306	0.309
	(0.071)	(0.070)
L	0.456	0.423
	(0.085)	(0.083)
NT	-0.0453	
	(0.0142)	$--$
ERP		-0.0211
	$-$	(0.0108)
R^2	0.603	0.577
N	192	192

Note: Estimation using robust standard errors

4.3 Alternative Frameworks

One common limitation of TFP regressions is that business cycle fluctuations that affect the behavior of output and factors may also affect the productivity measurement, although those fluctuations have no long-run impact on the productivity trend. This is the case if labor hoarding is relevant or if capital services are measured by the stock of capital and not by the stock of capital effectively used in production. In this case, during a recession, for instance, while output falls input levels are kept constant. Consequently, measured TFP would also decrease. The opposite would occur during a recovery. In the present study the capital series used to construct TFP was already corrected by the capacity utilization rate . However, we may have a problem in the labor series, especially with the "labor force used in production" series. To check for this fact, we ran a series of regressions with 3-year averages, in order to reduce potential problems caused by business fluctuations. Table 9 presents a sample of the results:

Table 9: TFP Growth Regressions (Correcting Cyclical Effects)

Variable						
	FE	FE	FE	FE	FE	FE
NT	-0.077	-0.080	-0.068			
	(0.008)	(0.008)	(0.006)			
ERP				-0.038	-0.040	-0.027
				(0.008)	(0.008)	(0.007)
M			12.930			20.861
			(4.415)			(6.227)
$Time$	No	Yes	Yes	No	Yes	Yes
R^2	0.723	0.767	0.886	0.483	0.544	0.604
N	64	64	64	64	64	64

Note: Estimation using robust standard errors (White heteroskedasticity consistent covariance matrix) * - significant at 10% level of significance; ** - Not significant

The results are robust to the inclusion or exclusion of control variables. The comparison with Table 7 shows that the results are similar. The estimated coefficients of the effective rate of protection and tariffs are close to those presented in Table 7, although the results in Table 8 are slightly higher and do not change with the inclusion of time dummies. This similarity can be explained either because we had already taken into account business cycle and short-term fluctuations when constructing the productivity series or because cyclical effects do not have a relevant effect on the correlation between trade protection and growth in the present context.

We constructed a second measure of TFP using human capital. Note, however, that there is no detailed information at the industry level of education available. There is only aggregated information of average schooling years of the labor force for two main industrial groups, "modern" and "traditional" industries, one including five of our sixteen industries and the other eleven. Instead of discarding this incomplete information we opted to perform some additional regressions as a weak robustness test of the previous results. Human capital was incorporated in the production function as a specific input separated from raw labor, so that the new production function is $Y_{it} = A_{it}.K_{it}^{\alpha}.H_{it}^{\beta}.L_{it}^{\gamma}$. We reproduced the steps of Section 3.2 to construct the TFP measure and those of Section 4 to test its relationship with nominal and effective tariffs. Results did not change considerably: increases of 20 percent in NT and ERP imply, according to these estimates, decreases of the TFP growth rate of 0.6 percent and 0.5 percent, respectively. These values are smaller than estimations in Table 7, but are still robust and very significant.

One potential caveat to our results is that output is used as a proxy for value-added in the regressions that construct the industry specific TFP growth. Similarly, labor productivity measure does not control for the change in intermediate input. So, given that the value of nominal tariffs and effective protection rates are negatively correlated to imports, the estimated trade reform effect on productivity may have captured the effect of trade reform on the increasing level of imported materials in the production of the industries.

There are no value-added data collected in any survey, but there is a (poor) proxy, *value of industrial transformation* (VIT), obtained in the Annual Industry Survey ("Pesquisa Industrial Anual") of the IBGE ("Brazilian Bureau of Geography and Statistics"). It subtracts from gross output the value of most materials and some services used. There are some serious methodological problems with this series[10] and, in general, data obtained from the annual survey is not as trustworthy as the monthly survey data used in this paper. Nonetheless, we could gain some insights from studying the behavior of the VIT series.

The first point worth noting is that the average ratio of VIT to output is relatively stable, decreasing slightly from 56% to 51% over the whole 1988-1995 interval, after reaching 60% in 1992. This decrease in the VIT-output ratio, although not irrelevant, is not large enough to affect productivity trends calculated with output data. Hence, the growth rate of output used in previous sections is not a bad proxy for the growth rate of value added. Second, we constructed new measures of TFP using data from the annual survey (at a different aggregation level, now closer to the 4-digit classification) and repeated the estimations of Table 7 with the corresponding values of nominal tariffs and effective rate of protection[11]. In the model that used nominal tariff, the estimated coefficient was only significant at 9%, but in the case of effective rate of protection, results were very similar to those in the previous sections, the estimated coefficient being significant at the usual levels and close to -0.10. Although we have to be cautious here, given the worse quality of the VIT data and some other factors that may be influencing our productivity measures, such as contracting-out labor, the estimated trade reform effect on productivity of previous sections does not seem to depend on a particular series or proxy for output.

5 Concluding Remarks

All the estimated measures of productivity growth for the industries studied in this article display a common pattern of behavior in the years between 1985 and 1997: they fall or stagnate until 1990 and then increase remarkably after that. In the same period, Brazil moved to liberalize its international trade, reducing tariffs, definitively eliminating import quotas and reserved market shares and

[10] For instance: expenses for transport, publicity, maintenance, communication and rents, among others, were not deducted from the VIT series. Another serious problem is the valuation of inventories variation, which is calculated as the difference between the inventories at the end and beginning of period. As the inflation rates were very high up to 1993, year-end inventories always tend to have much higher valuations to those at the start of the year, due to rise of prices, even if in physical terms they are smaller. This distortion tends to grow with the inflation rate but does not affect the monthly data used in the paper. Moreover, PIA methodology changed in 1996, so that we can only use data up to 1995.

[11] The fixed-effect method was used after testing. The data set consists of 45 industries and 7 time-series observations.

consequently decreasing the protection of domestic production.

Results in this article allow us to conclude that there is a significant and robust relation between these two facts, so that trade reform had an important impact on industrial performance. In the cross-sectional dimension, the estimations imply that the higher the protection the lower the growth rate of TFP and labor productivity of a given industry. These results are robust to changes in the data used, in the controls and in the methodology and do not depend on any restrictive assumption.

The framework used here has some advantages with respect to most of the existing literature. First, our sample years comprise data before and after (and during) trade reform, providing a flavor of natural experiment to the analysis. Second, this large time span also allows sufficient variation in the data. Third, our study centers on a single country, avoiding institutional and country-specific factors that are difficult to control. Finally, Brazil is a relatively large economy and until the nineties was one of the most closed economies in the world, increasing the prospective gains from trade. Moreover, Latin America and most of the developing world adopted similar policy patterns (i.e., import substitution followed by trade liberalization) so that results in this study may hint at a comparable relationship between trade reform and productivity gains in these countries as well.

Of course, the policy and institutional environment in Brazil, as in most developing countries, is not as stable as in the developed world, so that we do not have a perfectly controlled setting. Trefler(2001), for instance, when studying the impact of the Canada-US Free Trade Agreement on Canadian industry, can affirm with great security that there was no other important change going on in the country that could affect productivity significantly. In Brazil, this is not the case, as other important policy and institutional changes, such as privatization and price stabilization, took place in the nineties. However, due to timing and/or the inclusion of few sectors or firms, we have reasons to believe that these phenomena did not have a determining impact on the productivity behavior of the industries we study, and the econometric evidence confirms this.

Indirect evidence that the productivity increases in the 16 industries examined in the paper were brought on by trade liberalization and not by general policy changes is the contrasting pattern of productivity between these industries and non-tradable sectors such as services. Data from input-output tables show that in 3 sub-sectors of the latter - "Services to Firms, Services to Families and Non-Market Private Services" - labor productivity decreased between 1990 and 1998 and in Transportation and Retail, labor productivity growth was below or close to one percent a year. Actually, the average annual productivity growth of the 9 service sub-sectors in the period, 2.03 percent, is less than half of the industry average, 5.07 percent, in the input-output tables. If we eliminate one outlier, Telecomunications, the 8 remaining service sectors grew at only 0.97 percent a year. Another non-tradable sector, Construction, grew at half the industry rate. Hence, although most of the sectors experienced positive growth after trade liberalization, the performance figures of the 16 industries we use in the paper are well above those of non-tradable sectors such as construction and services.

Another caveat is contracting-out of labor, although the evidence is that in both labor series used in the paper this was not a major problem. Finally, using output and not value-added in most regressions could also be partly driving our results. Even with these qualifications, there is little doubt that industry productivity increased notably after trade liberalization and that there is a strong correlation between both facts.

One could think that the productivity increases documented in this paper were caused by some other factor common to specific industries in Latin America countries such as Chile, Argentina and Mexico. It might be the case that there were differences in exogenous technological change across industries, so that those industries that expected to have large increases in exogenous technology growth might be less willing to lobby for protection. In this case the relationship between tariffs and productivity growth would be spurious. Evidence in Katz (1999), however, shows that productivity growth rates of the dimensions observed in the Brazilian manufacturing industry were not a general phenomena in the region. In Mexico, for instance, it went down slightly in the nineties while in Colombia and Chile it increased by just one and one and half percent, respectively, while in Brazil it goes from less than one percent from 1970 to 1989 to 8.6 percent in the nineties. Moreover, Katz (1999) also shows that while the productivity gap with respect to U.S firms in the cement, textiles, rubber, transportation, electric equipment and other 6 industries decreased in Brazil in the whole period, it increased in Chile.

The results in this study, and evidence from other sources, provide some indication of the nature of productivity growth brought about by trade liberalization. First, foreign competition pressured firms to adopt more efficient production and business processes. This is a channel stressed by Muendler(2001)[12] and Carvalho(2001). The estimated effect on productivity of the nominal tariffs in the firms' output market presented in Section 4 is strong evidence of this fact. Carvalho(2000) presents some casual evidence of changing work practices in specific firms and industries that also indicates that international competition played an important role in raising production efficiency. Among other factors, these modifications meant that by the end of the period of study employment decreased in all but two of the sixteen industries studied while output increased in all but two (not the same two) industries. Another indication is the increase in import penetration (measured by *imports/(imports+domestic production-exports)*) observed in the period in all industries. Moreira(1999) shows that imports increased from 4.5% of total supply of the manufacturing industry in 1989 to 18.4% in 1997. In some industries the numbers are even more impressive: import penetration went from 11.6% to 62% in the Electronic

[12] Muendler (2001) works with a balanced panel of firms from 1986 and 1998 and uses a different source of raw data than ours. The fact that he eliminates from his data set firms for which there are no observations during the whole period may explain why the growth rate of productivity in his data seems slower than in our paper. Less efficient firms displaced by competition and highly efficient entrants were not part of his sample, but are part of our (industry level) dataset.

and Communication Equipment industry; from 13.3% to 55.7% in the Machinery and Industrial Equipment industry and from 6.3% to 31.3% in the Resins, Fibers and Elastomers industry.

The import boom in the nineties also points to a second channel from openness to productivity growth: the increasing use of foreign inputs, supposedly more efficient and of better technology/quality than domestic inputs. Embodied technology in imported machines could also be a factor here. The estimated effect of effective rate of protection on productivity, presented in Section 4, points in this direction given that this measure takes into account input tariffs. The impact of imports on TFP growth (Table 7 and especially Table 9) is another (mild) indication. One also must note that imports increased more decisively in the industrial goods sector, where import penetration went from 14.4 % in 1989 to 54.8% in 1997. The same is true with respect to intermediate industries such as the already mentioned Resins, Fibres and Elastomers industry.

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A Appendix A - Data

- Labor and Output: Labor productivity and output series were constructed using information obtained in the "Pesquisas Industrial Mensal - Produção Física" (Monthly Industry Survey - Physical Production) and "Pesquisas Industrial Mensal-Dados Gerais" (Monthly Industry Survey - General Data), both from the IBGE, the public statistics bureau of Brazil. We constructed two measures of productivity: one used "total work hours employed in production" and the other "total labor force employed in production.". These series do not include administrative workers and services such as security or cleaning, so that the corresponding productivity measure is not affected by the observed trend of sub-contracting some of these services. Contracting out labor directly employed in production was not observed in the period.

- Physical Capital: The capital series was constructed from investment data obtained in the "Pesquisa Industrial Anual ("Annual Industry Survey") of the IBGE. We used the perpetual inventory method, assuming a constant annual depreciation rate of 5% per year, and investment values were deflated by the gross capital deflator calculated in the national account. In order to remove possible effects of business cycle fluctuations on TFP, the stock of capital obtained was multiplied by the rate of utilization of sector capacity (which is calculated by the Fundação Getulio Vargas) to obtain the fraction of physical capital effectively used in production. The initial capital stock was constructed according to $K_0 = I_0 / (g_I + \delta)$, where K_0 is the initial capital stock, I_0 is the initial investment expenditure, g_I is the growth rate of investment in the period, and δ is the depreciation rate.

- Human Capital: As for human capital, there is no detailed information at the industry level, only aggregated information of average schooling years of the labor force for the two main groups, "modern" and "traditional" industries, surveyed by the IBGE. The first group includes the following sectors: transportation equipment, electronic and communication equipment, mechanical machinery, plastic products and metalworking. The remaining sectors are classified as traditional. Consequently, most of the variation is in the time-series dimension, given that for each year there are only two observations of the human capital stock.

- The rental rate of capital was calculated summing the real interest rate for goverment bonds(CDB) plus the estimated depreciation rate. The nominal interest rate was deflated using the wholesale price index (IPA-OG).

- The "Pesquisas Industrial Mensal-Dados Gerais" (Monthly Industry Survey - General Data) contains an index of real wages for all sectors.

- The import-ratio is the ratio of total imports and GDP in dollars obtained from FUNCEX. .

- Effective Rate of Protection and Nominal Tariff: the first variable was constructed using the following formula:

$$ERP_j = (t_j - \sum a_{ij}^{lc}.t_i)/(1 - \sum a_{ij}^{lc})$$

where $a_{ij}^{lc} = a_{ij}^{d}.(1 + t_j)/(1 + t_i)$ is the free-trade technical coefficient, measuring input i participation in final price of industry j (both at international prices); a_{ij}^{d} is the distortionary technical coefficient, measuring input i participation in final price of industry j, at domestic prices; t_j is the nominal tariff in industry j and t_i is the nominal tariff of input i. The coefficient a_{ij}^{d} is taken from the input-output tables and tariffs are calculated by the simple average of all the tariffs imposed on products of a given industry, which is also the methodology used to construct the nominal tariffs used in the paper.

B Appendix B - Additional regressions

B.1 Factor Shares Using Labor Force

Table B1 - Estimation Results

Variable	OLS	FE	IV
K	0.330	0.340	0.395
	(0.057)	(0.061)	(0.100)
L	0.396	0.357	0.728
	(0.057)	(0.055)	(0.165)
Wald Test: CRS	17.530	20.095	0.558
p-value:	0.0004	0.0001	0.455
Hausman Test		12.704	7.403
		0.0017	0.0246
R^2	0.398	0.444	0.435
N	192	192	192

Note: estimation using robust standard errors (White heteroskedasticity consistent covariance matrix)

B.2 Labor productivity

Table B2: Labor Productivity Growth Regressions

Variable	FE	FE	FE	FE	FE	FE
NT	-0.019	-0.013	-0.012			
	(0.003)	(0.003)	(0.003)			
ERP				-0.013	-0.006	-0.005
				(0.003)	(0.002)	(0.002)
M			1.59**			1.82*
			(0.96)			(0.98)
$Time$	No	Yes	Yes	No	Yes	Yes
R^2	0.285	0.485	0.491	0.162	0.440	0.450
N	192	192	192	192	192	192

Note: Estimation using robust standard errors (White heteroskedasticity consistent covariance matrix) * - significant at 10% level of significance; ** - Not significant

B.3 Total Factor Productivity

Table B.3: Total Factor Productivity Growth Regressions

Variable	2SLS-FE	2SLS-FE	2SLS-FE	2SLS-FE	2SLS-FE	2SLS-FE
NT	-0.073	-0.058	-0.056			
	(0.014)	(0.015)	(0.015)			
ERP				-0.059	-0.016**	-0.013**
				(0.015)	(0.011)	(0.011)
M			5.758**			6.593**
			(4.231)			(4.428)
$Time$	No	Yes	Yes	No	Yes	Yes
R^2	0.151	0.437	0.439	0.120	0.413	0.525
N	192	192	192	192	192	192

Note: Estimation using robust standard errors (White heteroskedasticity consistent covariance matrix) * - significant at 10% level of significance; ** - Not significant