Trade Liberalization and the Skill Premium: A Local Labor Markets Approach*

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Abstract

We develop a specific-factors model of regional economies that includes two types of workers, skilled and unskilled. The model delivers a simple equation relating trade-induced local shocks to changes in local skill premia. We apply the methodology to Brazil's early 1990s trade liberalization and find statistically significant but modest effects of liberalization on the evolution of the skill premium between 1991 and 2010. The methodology uses widely available household survey data and can easily be applied to other countries and liberalization episodes.

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Trade economists have long studied the effects of globalization on wage differences between workers with different levels of skill or education.[1] This literature has generally sought to link globalization to changes in the economy-wide skill premium. Attanasio, Goldberg and Pavcnik (2004) and Gonzaga, Filho and Terra (2006) are salient examples that investigate whether changes in sector-specific prices or tariffs, changes in skill composition within and across sectors, and movements in the skill premium are consistent with the predictions of workhorse trade models, such as the Heckscher-Ohlin model. However, there is little evidence directly establishing a causal effect of globalization on the skill premium.[2] More recently, a growing body of research has focused on trade's differential effects across local markets within a country, finding large differences across sub-national markets.[3] In this paper, we combine these two strands of literature by developing a theoretically consistent approach to studying the causal effect of trade liberalization on the skill premium at the local level.

We develop a specific-factors model of regional economies that includes two types of workers, skilled and unskilled, who are complementary with specific factors and with each other, and are mobile across industries within a region.[4] From this model, we derive a simple equation that links changes in regional skill premia to (exogenous) trade-induced regional price shocks that differentially affect skilled and unskilled workers. From the model's perspective, trade liberalization differently affects skilled and unskilled workers within a local labor market because (1) workers are imperfectly mobile across regions; (2) there was a large dispersion in tariff cuts across sectors; (3) regions were partly specialized in different industries at the onset of liberalization; and (4) industries employ skilled and unskilled workers with different intensities.

The model yields an empirically tractable approach to studying the effect of trade liberalization

[1] See Goldberg and Pavcnik (2007) and Goldberg (forthcoming) for comprehensive surveys on the effects of globalization on the skill premium and on inequality in general.

[2] Amiti and Cameron (2012) is a noteworthy exception, finding effects of input tariff changes on within-firm skill premia.

[3] See Dix-Carneiro and Kovak (2014) for an extensive list of citations.

[4] Autor, Dorn and Hanson (2013) and Kovak (2013) respectively develop monopolistic competition and specific-factors models of trade's effects on local labor markets in a context with one homogenous labor pool. Pellandra (2014) and Rodriguez Chatruc (2014) are concurrent projects examining trade's effects on local skill premia using alternate theoretical frameworks to the one we develop. It is also important to note that Topalova (2007) examined trade's effects on local consumption inequality and Costa, Garred and Pessoa (2014) study effects on local wage inequality using causal empirical frameworks, though without the theoretical foundation that we provide here.

on regional skill premia. We illustrate this methodology using four rounds of the Brazilian Census of Population from 1980 to 2010. This period covers a major trade liberalization episode that took place between 1990 and 1995. We find that trade liberalization drove small but statistically significant declines in the skill premium in the country during the post-liberalization period. Depending on the specification, up to 14% of the decline in the national average skill premium during our sample period (computed as the employment weighted average of regional skill premia) is explained by trade liberalization. Our methodology makes use of widely available household survey data and can easily be applied to liberalization episodes in other countries.

1 Regional Labor Market Model with Two Worker Types

We extend the specific-factors model of Kovak (2013) to include two types of labor. The national economy consists of many regions, r, each of which may produce goods in many industries, i. Goods are produced using three factors. Following Jones (1975), each region is endowed with a vector of industry-specific factors, T_{ri}. Skilled labor, H_r, and unskilled labor, L_r, are both costlessly mobile across industries within region. Total factor supplies are fixed in each region.[5] Production is Cobb-Douglas, and factor shares θ_{Ti}, θ_{Li}, and θ_{Hi} may vary across industries, subject to $\theta_{Ti} + \theta_{Li} + \theta_{Hi} = 1$.[6] Goods and factor markets are competitive. Hats represent proportional changes, such that $\hat{x} \equiv d \ln x$. Producers in all regions face the same national vector of liberalization-induced price changes $\hat{P}_i$.

We solve the model in Appendix A.1, using factor market clearing, cost minimization, and zero profits. These equilibrium conditions imply the following system of equations,

$$\begin{aligned} \hat{w}_r &= \frac{\sum_i \frac{\lambda_{Lri}}{\theta_{Ti}} \hat{P}_i}{1 + \sum_i \frac{\lambda_{Lri}}{\theta_{Ti}} \theta_{Li}} - \left(\frac{\sum_i \frac{\lambda_{Lri}}{\theta_{Ti}} \theta_{Hi}}{1 + \sum_i \frac{\lambda_{Lri}}{\theta_{Ti}} \theta_{Li}} \right) \hat{s}_r \\ \hat{s}_r &= \frac{\sum_i \frac{\lambda_{Hri}}{\theta_{Ti}} \hat{P}_i}{1 + \sum_i \frac{\lambda_{Hri}}{\theta_{Ti}} \theta_{Hi}} - \left(\frac{\sum_i \frac{\lambda_{Hri}}{\theta_{Ti}} \theta_{Li}}{1 + \sum_i \frac{\lambda_{Hri}}{\theta_{Ti}} \theta_{Hi}} \right) \hat{w}_r \end{aligned} \tag{1}$$

[5] See Dix-Carneiro and Kovak (2014) for a version of the model with one type of labor, but allowing specific factor and labor supplies to vary endogenously.

[6] We assume Cobb-Douglas because we do not have empirical estimates of elasticities of factor substitution that vary across industries, and it avoids complications arising if the two labor types were differentially substitutable with specific factors.

where λ_{Hri} and λ_{Lri} are the respective shares of regional skilled and unskilled labor allocated to industry i, and s and w are the respective wages paid to skilled and unskilled labor. The direct effect of trade-induced price changes on unskilled wages has an indirect effect on skilled wages, which in turn affects skilled wages, and so on. This system highlights how regional skilled and unskilled wages are intertwined, showing that one must consider the factors' equilibrium interactions when studying the effects of trade liberalization on skilled and unskilled wages.

Solving the system in terms of exogenous price changes yields the effect of liberalization-induced price changes on the proportional change in the regional skill premium.

$$\hat{s}_r - \hat{w}_r = \frac{\sum_i (\beta_{Hri} - \beta_{Lri}) \hat{P}_i}{\frac{1}{\sum_i \frac{\lambda_{Hri}}{\theta_{Ti}}} + \sum_i (\beta_{Hri} - \beta_{Lri}) \theta_{Hi}}, \tag{2}$$

$$\text{where} \quad \beta_{Lri} \equiv \frac{\frac{\lambda_{Lri}}{\theta_{Ti}}}{\sum_j \frac{\lambda_{Lrj}}{\theta_{Tj}}}, \qquad \beta_{Hri} \equiv \frac{\frac{\lambda_{Hri}}{\theta_{Ti}}}{\sum_j \frac{\lambda_{Hrj}}{\theta_{Tj}}},$$

β_{Lri} and β_{Hri} sum to 1 across industries, such that the numerator reflects the difference in weighted average price changes for skilled and unskilled workers. The skill premium declines (increases) more when tariff declines are more incident upon industries employing a larger (smaller) share of skilled workers. This weighted-average structure parallels the empirical approach in the literature on the local effects of trade, with each term in the numerator reflecting a skill-specific version of the literature's weighted-average shocks. Thus, in this model, changes in local inequality are driven by the *difference* in weighted average shocks for skilled and unskilled workers, rather than by standard *overall* shocks using industry weights that combine both types of workers. The denominator in (2) additionally shows that the skill premium depends not only upon the difference in weighted average price shocks across skill levels, but also on the distribution of regional industry weights, β_{Hri} and β_{Lri}, and industry factor intensities, captured in θ_{Hi} and θ_{Ti}.

To summarize the empirical content of the model, liberalization affects regional skilled and unskilled workers wages differently when workers are imperfectly mobile across regions, tariff changes vary across industries, regions initially specialize in different products, and industries employ skilled and unskilled workers with different intensities.

2 Context, Data, and Descriptives

We examine the effects of trade liberalization on regional skill premia in the context of Brazil's widely studied early 1990s trade liberalization.[7] Liberalization began in March 1990, with the sudden and unexpected abolition of a wide variety of non-tariff barriers, tariff exemptions, and trade-related taxes, replacing them with import tariffs providing equivalent protection to Brazilian producers (Kume, Piani and de Souza 2003, de Carvalho, Jr. 1992). Tariffs were then cut gradually over the following five years, falling from an average of 30.5 percent in 1990 to 12.8 percent in 1995, and remaining relatively stable thereafter.[8] Along with this large decline in average tariff rates, there was substantial variation in tariff cuts across industries, with some industries such as agriculture and mining facing small changes, and others such as apparel and rubber facing declines of more than 30 percentage points. We measure the effect of liberalization using tariff changes from 1990 to 1995, based on tariff data from Kume et al. (2003).

We then calculate regional shocks to the skill premium based on equation (2). Under a small country assumption, the proportional change in the price faced by Brazilian producers is given by the proportional change in one plus the tariff rate, $d\ln(1+\tau_i)$. We calculate factor cost shares (θ's) using IBGE national accounts data and the 1991 Census.[9] Industry distributions of skilled and unskilled labor in each region (λ_{ri}) come from the 1991 Census. We refer to the empirical measure of the right hand side of (2) as the "differential tariff shock," as it reflects the differential effect of tariff cuts on wages for skilled and unskilled workers in the relevant region.

Figure 1 panel (a) shows the distribution of differential tariff shocks across Brazilian microregions.[10] Regions are outlined in gray while states are outlined in black. Note that the vast majority of the population lives in the eastern part of the country, where regions are geographically smaller, but much more populous. Lighter regions faced more negative shocks to the regional skill premium. The shocks range from a 4 percent decline to a 0.5 percent increase, and the regional employment-

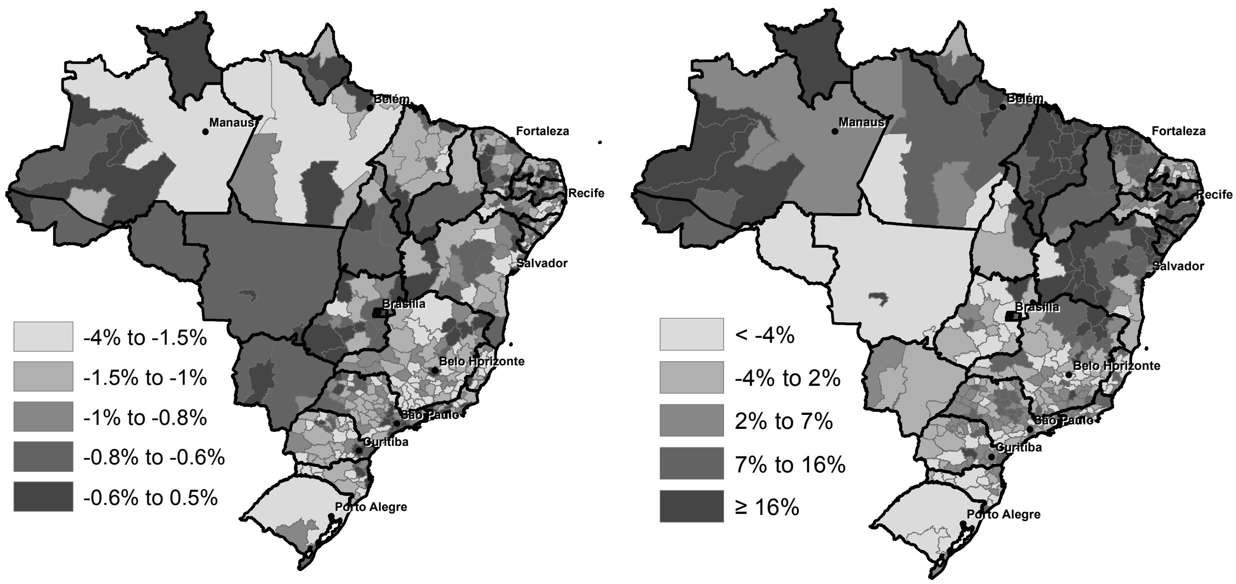
[7] See Dix-Carneiro and Kovak (2014) for a more detailed description of Brazil's liberalization and a discussion of the exogeneity of tariff changes to counterfactual industry performance.

[8] Raw average tariff rates across industries, as reported in Kume et al. (2003)

[9] The specific factor cost shares (θ_{Ti}) reflect gross operating surplus as a share of total factor costs in the 1990 IBGE national accounts. The remaining cost share of labor is divided between skilled and unskilled labor (θ_{Li} and θ_{Hi}) based on the industry skilled and unskilled labor wagebills in the 1991 Census.

[10] See Dix-Carneiro and Kovak (2014) for details on this time-consistent definition of local labor markets.

Figure 1: Differential Tariff Shocks and Changes in Skill Premia



(a) Differential Tariff Shocks (b) Change in Skill Premium 1991-2000

Dark lines are state borders and gray lines are microregion borders. Panel (a) presents regional differential tariff shocks based on equation (2). Panel (b) presents the change in skill premium for all regional workers from 1990-2000, with skill defined as high-school or more.

weighted mean shock is a decline of 0.8 percent. Thus, in most regions trade liberalization is expected to drive a decline in the skill premium, relative to a no-liberalization counterfactual.

We measure changes in skill premia using the Brazilian Decennial Census for 1980, 1991, 2000, and 2010, and restrict the sample to employed individuals outside public administration, age 18-64, earning a positive wage, and not enrolled in school. We define skill as completing high-school or more (11+ years of education), and present results for an alternative definition based on college completion in Appendix A.3. Skill premia in each region are calculated using individual-level log wage regressions, separately for each Census year. We estimate linear returns to years of education, allowing these returns to vary arbitrarily across regions and controlling for national returns to various other observable worker characteristics, including age, sex, and industry. We then evaluate the returns to education using the average number of years of education for skilled (12.4 years) and unskilled (3.7 years) workers, and define the regional skill premium as the difference in predicted

Table 1: Descriptive Statistics: Regional Skill Premia

	hourly wages		earnings	
	mean	std. dev.	mean	std. dev.
Levels				
1991	0.961	0.132	0.932	0.118
2000	0.994	0.107	0.954	0.103
2010	0.716	0.099	0.732	0.107
Changes				
1991-2000	0.033	0.096	0.022	0.090
1991-2010	-0.245	0.120	-0.200	0.119

411 microregion observations, weighted by 1991 share of national workers in our sample. Skill is defined as having completed high school. Regional skill premium calculated based on the returns to education, as described in the text.

wages for the two groups in each region.[11] We present results using skill premia based on hourly wages or monthly earnings.

Table 1 shows descriptive statistics on the regional skill premium in each year, for both hourly wage and monthly earnings measures, which yield quite similar results. We weight each region by its 1991 share of national workers in our sample. In all cases, skilled workers earn much more than unskilled workers on average. In 1991, skilled workers' wages were 96 log points higher than those for unskilled workers on average. The average skill premium remained relatively steady from 1991 to 2000, with an average increase of only 3 log points. However, even during this period of relatively constant skill premium, the standard deviation across regions was quite large, indicating substantial differences in the skill premium's evolution in different local markets. Panel (b) of Figure 1 shows the regional variation in the change in skill premium from 1991 to 2000. In the 2000s, the skill premium fell sharply to 72 log points in 2010, but again there was quite a bit of variation across regions in the skill premium's evolution. In the subsequent section, we seek to explain this regional variation using the differential tariff shocks shown in Panel (a) of Figure 1.

[11] We measure the skill premium based on returns to education as opposed to differences in average wages between skilled and unskilled workers because the educational composition of the Brazilian force changed dramatically over the course of the 1990s and 2000s, even within our skilled and unskilled categories (see Menezes-Filho, Fernandes and Picchetti (2006) and Menezes-Filho and Tavares (2013)). We use parametric returns to education rather than a more nonparametric approach as in Katz and Murphy (1992) because we often have small samples for particular education levels in sparsely populated regions.

3 Liberalization's Effects on Regional Skill Premia

We now examine the effects of trade liberalization on regional skill premia, testing the model's prediction that regions facing more negative differential tariff shocks experienced larger relative declines in the observed regional skill premium. We regress the change in regional skill premium shown in Panel (b) of Figure 1 on the differential tariff shocks shown in Panel (a) of Figure 1. Our sample consists of 411 time-consistent microregions.[12] Since the dependent variables are themselves estimates, we weight by the inverse of their standard errors to account for heteroskedasticity. We also calculate cluster-robust standard errors at the more aggregate mesoregion level to account for potential spatial correlation in outcomes across neighboring regions.[13] In closely related work, we find substantial differences in the regional labor market effects of liberalization for formally and informally employed workers.[14] Hence, we present findings for both all workers and formally employed workers.[15] We also present results calculating skill premia based on hourly wages and monthly earnings, and for the 1991-2000 and 1991-2010 time periods. In each case, we estimate a simple bivariate regression and additional specifications adding state fixed effects and 1980-1991 pre-liberalization trends in the regional skill premium.

The results appear in Table 2. Panels A and B examine the skill premium for all workers irrespective of their formal status, while Panels C and D restrict attention to formally employed workers. The coefficient of 1.297 in column (1) of Panel A indicates that, on average, regions facing a 1 percentage point more negative differential tariff shock experienced a 1.3 percentage point larger decline in the regional skill premium between 1991 and 2000. This is quite close to the coefficient of 1 that would be observed if the data precisely followed the model in Section 1. Column (2) adds a vector of 26 state fixed effects to account for any state-level policy changes such as minimum wages that might have affected the skill premium in that state's microregions.

[12] We drop the region containing the free trade zone of Manaus, since it was exempt from tariffs and unaffected by the tariff changes occurring during liberalization.

[13] There are 112 time-consistent mesoregions during our sample period.

[14] See Dix-Carneiro and Kovak (2014) for details, and for a discussion of the nature of formal and informal employment in Brazil. We define formal employment as having a work card signed by one's employer.

[15] When examining skill premia for formally employed workers, we construct an alternate version of the differential tariff shock in which λ_{Hri} and λ_{Lri} reflect the industry distributions of formally employed workers. See Dix-Carneiro and Kovak (2014) for a discussion of this approach, justified by the fact that workers are able to transition out of formal employment relatively easily, but transitioning into formal employment appears quite difficult.

Table 2: Liberalization's Effect on Regional Skill Premia

dependent variable: proporional change in regional skill premium from 1991 to listed year

	2000			2010		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: All workers - wages						
Differential tariff shock	1.297	0.050	0.797	1.908	0.280	1.005
	(1.522)	(0.944)	(0.644)	(1.759)	(1.404)	(1.039)
Skill premium pre-trend (80-91)			-0.363***			-0.462***
			(0.044)			(0.051)
State fixed effects (26)		✓	✓		✓	✓
Panel B: All workers - earnings						
Differential tariff shock	2.014	0.747	1.389**	3.759**	2.090	2.797**
	(1.408)	(0.791)	(0.610)	(1.811)	(1.410)	(1.134)
Skill premium pre-trend (80-91)			-0.303***			-0.415***
			(0.041)			(0.047)
State fixed effects (26)		✓	✓		✓	✓
Panel C: Formally employed - wages						
Differential tariff shock	1.049	1.165*	1.494***	0.521	0.288	0.606
	(1.585)	(0.628)	(0.558)	(1.302)	(0.811)	(0.661)
Skill premium pre-trend (80-91)			-0.387***			-0.488***
			(0.056)			(0.049)
State fixed effects (26)		✓	✓		✓	✓
Panel D: Formally employed - earnings						
Differential tariff shock	1.513	1.767***	2.074***	2.037	1.841**	2.155***
	(1.522)	(0.530)	(0.515)	(1.544)	(0.798)	(0.699)
Skill premium pre-trend (80-91)			-0.362***			-0.466***
			(0.054)			(0.046)
State fixed effects (26)		✓	✓		✓	✓

Dependent variable is the proportional change in regional skill premium from 1991 to the year listed, calculated as described in the text. Independent variable is the differential tariff shock for skilled and unskilled workers, defined in (2). Worker skill defined as having completed 11 or more years of education. 411 microregion observations when including all workers in the sample. 397 microregion observations when including only formally employed workers, those with a signed work card. Skill premium pre-trends calculated for 1980-1991 period based on monthly earnings. Observations weighted by the inverse of the squared standard error of the estimated proportional change in regional skill premium. Standard errors (in parentheses) adjusted for 112 mesoregion clusters. *** Significant at the 1 percent, ** 5 percent, * 10 percent level.

Column (3) additionally includes a skill premium pre-trend based on monthly earnings, calculated identically to the dependent variable, but covering the pre-liberalization 1980-1991 time period. This control ensures that our results are not driven by ongoing trends in regional skill premia that were already in progress before liberalization.[16]

[16]We use monthly earnings rather than hourly wage pre-trends because hours are unavailable in 1980.

In all panels and specifications, the point estimates are positive, and many are significantly different from zero. Only one coefficient (Panel D column (3)) is significantly different from the model's predicted value of 1. Results for earnings tend to be larger and more precisely estimated than those for hourly wages, which is consistent with employers adjusting on the hours margin along with the wage margin we focus on in the model. Results for formally employed workers are somewhat larger and more precisely estimated than those for all workers, but are otherwise qualitatively similar. There is no distinct time pattern in liberalization's effects on regional skill premia; liberalization's effect is realized by 2000, with no noticeable increase by 2010. This finding is in contrast to the steadily growing regional formal wage and employment effects of liberalization documented in Dix-Carneiro and Kovak (2014). Together, the two papers' results imply that although regions facing larger tariff declines during liberalization experience steadily deteriorating relative formal labor market outcomes during the 2000s, outcomes for skilled and unskilled workers evolve similarly during that time period.

To get a sense of the economic importance of our results, we examine what fraction of the realized average change in skill premium can be explained by our estimates. For each specification, we multiply the coefficient estimate on the differential tariff shock by the employment-weighted average shock of -0.008 to yield the predicted change in skill premium accounted for by liberalization. For reference, the resulting predictions appear in Appendix Table A1. We then compare these predicted skill premium changes to the observed changes presented in Table 1. As an example, consider the estimates in columns (3) and (6) of Table 2, which correspond to predicted skill premium changes of -0.0104 and -0.0210, respectively. From Table 1, the realized change in the earnings-based skill premium in 1991-2000 was 0.022. Hence, in the absence of liberalization, our results suggest that the average skill premium would have grown by 0.032 in 1991-2000. The realized change in skill premium in 1991-2010 was -0.200, so liberalization explains 11 percent of the observed average decline in skill premium. Performing the same exercise across the other specifications in Table 2, liberalization can explain at most 14 percent of the 1991-2010 decline in skill premium. Hence, although liberalization had a statistically significant effect on the evolution of the skill premium, it explains only a modest portion of the aggregate decline.

4 Conclusion

We develop a specific-factors model of regional economies that includes two types of workers, skilled and unskilled, who are complementary with specific factors and with each other, and are mobile across industries within a region. The model delivers a simple equation relating trade-induced local shocks to changes in local skill premia. We apply the methodology to Brazilian data to explore the country's early 1990s trade liberalization. We find statistically significant but modest effects of trade liberalization on the evolution of the skill premium in Brazil between 1991 and 2010. The methodology uses widely available household survey data and can easily be applied to other countries and liberalization episodes.

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A Appendix

A.1 Model Solution

The national economy consists of many regions, r, each of which may produce goods in many industries, i. Goods are produced using three factors. Following Jones (1975), each region is endowed with a vector of industry-specific factors, T_{ri}. Skilled labor, H_r, and unskilled labor, L_r, are both costlessly mobile across industries within region. Total factor supplies are fixed in each region.[17] Production is Cobb-Douglas, and factor shares θ_{Ti}, θ_{Li}, and θ_{Hi} may vary across industries, subject to $\theta_{Ti} + \theta_{Li} + \theta_{Hi} = 1$. Goods and factor markets are competitive. Producers in all regions face the same national vector of liberalization-induced price changes $\hat{P}_i$.

Suppress regional subscripts on all terms, and let a_{Ti}, a_{Li} and a_{Hi} be the respective quantities of specific factor, unskilled labor, and skilled labor used to produce one unit of industry i output. Letting Y_i be output in each industry, the factor market clearing conditions are

$$a_{Ti}Y_i = T_i \quad \forall i, \tag{A1}$$

$$\sum_i a_{Li}Y_i = L, \tag{A2}$$

$$\sum_i a_{Hi}Y_i = H. \tag{A3}$$

Holding regional factor supplies constant and letting hats represent proportional changes, such that $\hat{x} \equiv d \ln x$, factor market clearing implies the following.

$$\sum_i \lambda_{Li}(\hat{a}_{Li} - \hat{a}_{Ti}) = 0 \tag{A4}$$

$$\sum_i \lambda_{Hi}(\hat{a}_{Hi} - \hat{a}_{Ti}) = 0, \tag{A5}$$

where λ_{Li} and λ_{Hi} are the share of regional employment in industry i for unskilled and skilled labor, respectively. Cost minimization with Cobb-Douglas production implies

$$\hat{a}_{Li} - \hat{a}_{Ti} = \hat{R}_i - \hat{w} \quad \forall i, \tag{A6}$$

$$\hat{a}_{Hi} - \hat{a}_{Ti} = \hat{R}_i - \hat{s} \quad \forall i, \tag{A7}$$

where R_i, w, and s are the respective wages of specific factors, unskilled labor, and skilled labor. Combining these with the factor market clearing conditions in (A4) and (A5), we have

$$\sum_i \lambda_{Li}(\hat{R}_i - \hat{w}) = 0, \tag{A8}$$

$$\sum_i \lambda_{Hi}(\hat{R}_i - \hat{s}) = 0. \tag{A9}$$

[17] see Dix-Carneiro and Kovak (2014) for a version of the model with one type of labor, but allowing specific factor and labor supplies to vary endogenously.

Zero profits implies

$$\theta_{Li}\hat{w} + \theta_{Hi}\hat{s} + \theta_{Ti}\hat{R}_i = \hat{P}_i \quad \forall i. \tag{A10}$$

We can then express the equilibrium factor market clearing and zero profit conditions in (A8), (A9), and (A10) in matrix form.

$$\left[\begin{array}{cccc|cc} \theta_{T1} & 0 & \dots & 0 & \theta_{L1} & \theta_{H1} \\ 0 & \theta_{T2} & & \vdots & \theta_{L2} & \theta_{H2} \\ \vdots & & \ddots & 0 & \vdots & \vdots \\ 0 & \dots & 0 & \theta_{TN} & \theta_{LN} & \theta_{HN} \\ \hline \lambda_{L1} & \lambda_{L2} & \dots & \lambda_{LN} & -1 & 0 \\ \lambda_{H1} & \lambda_{H2} & \dots & \lambda_{HN} & 0 & -1 \end{array}\right] \left[\begin{array}{c} \hat{R}_1 \\ \hat{R}_2 \\ \vdots \\ \hat{R}_N \\ \hline \hat{w} \\ \hat{s} \end{array}\right] = \left[\begin{array}{c} \hat{P}_1 \\ \hat{P}_2 \\ \vdots \\ \hat{P}_N \\ \hline 0 \\ 0 \end{array}\right] \tag{A11}$$

To solve this system for the change in skill premium, first rewrite it in more compact matrix notation.

$$\left[\begin{array}{c|c} \boldsymbol{\Theta} & \boldsymbol{\theta} \\ \hline \boldsymbol{\lambda}' & -\mathbf{I} \end{array}\right] \left[\begin{array}{c} \hat{\mathbf{R}} \\ \hline \hat{\mathbf{w}} \end{array}\right] = \left[\begin{array}{c} \hat{\mathbf{P}} \\ \hline \mathbf{0} \end{array}\right] \tag{A12}$$

Then use Cramer's rule and the rule for the determinant of a partitioned matrix to solve for the changes in unskilled and skilled wages.

$$\hat{w} = \frac{\det(\mathbf{X}_w - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\hat{\mathbf{P}}_w)\cdot\det\boldsymbol{\Theta}}{\det(-\mathbf{I} - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\boldsymbol{\theta})\cdot\det\boldsymbol{\Theta}} = \frac{\det(\mathbf{X}_w - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\hat{\mathbf{P}}_w)}{\det(-\mathbf{I} - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\boldsymbol{\theta})} \tag{A13}$$

$$\text{where} \qquad \mathbf{X}_w \equiv \begin{bmatrix} 0 & 0 \\ 0 & -1 \end{bmatrix} \qquad \hat{\mathbf{P}}_w \equiv \begin{bmatrix} \hat{P}_1 & \theta_{H1} \\ \hat{P}_2 & \theta_{H2} \\ \vdots & \vdots \\ \hat{P}_N & \theta_{HN} \end{bmatrix}$$

$$\hat{s} = \frac{\det(\mathbf{X}_s - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\hat{\mathbf{P}}_s)\cdot\det\boldsymbol{\Theta}}{\det(-\mathbf{I} - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\boldsymbol{\theta})\cdot\det\boldsymbol{\Theta}} = \frac{\det(\mathbf{X}_s - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\hat{\mathbf{P}}_s)}{\det(-\mathbf{I} - \boldsymbol{\lambda}'\boldsymbol{\Theta}^{-1}\boldsymbol{\theta})} \tag{A14}$$

$$\text{where} \qquad \mathbf{X}_s \equiv \begin{bmatrix} -1 & 0 \\ 0 & 0 \end{bmatrix} \qquad \hat{\mathbf{P}}_s \equiv \begin{bmatrix} \theta_{L1} & \hat{P}_1 \\ \theta_{L2} & \hat{P}_2 \\ \vdots & \vdots \\ \theta_{LN} & \hat{P}_N \end{bmatrix}$$

Note that $\boldsymbol{\Theta}$ is a diagonal matrix, so its inverse is a diagonal matrix with each element inverted. Calculate the determinants in (A13) and (A14) to yield the change wage as a function of price changes.

$$\hat{w} = \frac{\sum_i \lambda_{Li}\frac{1}{\theta_{Ti}}\hat{P}_i + \left(\sum_i \lambda_{Li}\frac{1}{\theta_{Ti}}\hat{P}_i\right)\left(\sum_i \lambda_{Hi}\frac{\theta_{Hi}}{\theta_{Ti}}\right) - \left(\sum_i \lambda_{Li}\frac{\theta_{Hi}}{\theta_{Ti}}\right)\left(\sum_i \lambda_{Hi}\frac{1}{\theta_{Ti}}\hat{P}_i\right)}{1 + \sum_i \lambda_{Li}\frac{\theta_{Li}}{\theta_{Ti}} + \sum_i \lambda_{Hi}\frac{\theta_{Hi}}{\theta_{Ti}} + \left(\sum_i \lambda_{Li}\frac{\theta_{Li}}{\theta_{Ti}}\right)\left(\sum_i \lambda_{Hi}\frac{\theta_{Hi}}{\theta_{Ti}}\right) - \left(\sum_i \lambda_{Li}\frac{\theta_{Hi}}{\theta_{Ti}}\right)\left(\sum_i \lambda_{Hi}\frac{\theta_{Li}}{\theta_{Ti}}\right)} \tag{A15}$$

$$\hat{s} = \frac{\sum_i \lambda_{Hi}\frac{1}{\theta_{Ti}}\hat{P}_i + \left(\sum_i \lambda_{Li}\frac{\theta_{Li}}{\theta_{Ti}}\right)\left(\sum_i \lambda_{Hi}\frac{1}{\theta_{Ti}}\hat{P}_i\right) - \left(\sum_i \lambda_{Li}\frac{1}{\theta_{Ti}}\hat{P}_i\right)\left(\sum_i \lambda_{Hi}\frac{\theta_{Li}}{\theta_{Ti}}\right)}{1 + \sum_i \lambda_{Li}\frac{\theta_{Li}}{\theta_{Ti}} + \sum_i \lambda_{Hi}\frac{\theta_{Hi}}{\theta_{Ti}} + \left(\sum_i \lambda_{Li}\frac{\theta_{Li}}{\theta_{Ti}}\right)\left(\sum_i \lambda_{Hi}\frac{\theta_{Hi}}{\theta_{Ti}}\right) - \left(\sum_i \lambda_{Li}\frac{\theta_{Hi}}{\theta_{Ti}}\right)\left(\sum_i \lambda_{Hi}\frac{\theta_{Li}}{\theta_{Ti}}\right)} \tag{A16}$$

Subtract these two expressions to yield the change in skill premium, and simplify the expression using the fact that $\theta_{Li} = 1 - \theta_{Ti} - \theta_{Hi}$.

$$\hat{s} - \hat{w} = \frac{\left(\sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\right)\left(\sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\hat{P}_i\right) - \left(\sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\right)\left(\sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\hat{P}_i\right)}{\left(\sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\right)\left(1 + \sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\theta_{Hi}\right) - \left(\sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\right)\left(\sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\theta_{Hi}\right)} \tag{A17}$$

This expression is still difficult to interpret, though the numerator resembles the difference in weighted-average price shocks for skilled and unskilled weights. However the sums involving $\hat{P}_i$ have weights that do not sum to 1, so we divide through by the sum of the weights, and define

$$\beta_{Li} \equiv \frac{\frac{\lambda_{Li}}{\theta_{Ti}}}{\sum_j \frac{\lambda_{Lj}}{\theta_{Tj}}} \qquad \beta_{Hi} \equiv \frac{\frac{\lambda_{Hi}}{\theta_{Ti}}}{\sum_j \frac{\lambda_{Hj}}{\theta_{Tj}}}. \tag{A18}$$

Then the change in skill premium can be written as

$$\hat{s} - \hat{w} = \frac{\sum_i (\beta_{Hi} - \beta_{Li})\hat{P}_i}{\frac{1}{\sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}} + \sum_i (\beta_{Hi} - \beta_{Li})\theta_{Hi}}, \tag{A19}$$

which is equation (2) in the main text.

It is instructive to return to the equilibrium system in (A11). The top portion of the system can be expressed as

$$\hat{\mathbf{R}} = \mathbf{\Theta}^{-1}\left(\hat{\mathbf{P}} - \boldsymbol{\theta}\hat{\mathbf{w}}\right), \tag{A20}$$

while the bottom portion implies

$$\hat{\mathbf{w}} = \boldsymbol{\lambda}'\hat{\mathbf{R}}. \tag{A21}$$

Substituting out $\hat{\mathbf{R}}$ and simplifying the matrix operations yields the following system of equations.

$$\begin{aligned} \hat{w} &= \frac{\sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\hat{P}_i}{1 + \sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\theta_{Li}} - \left(\frac{\sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\theta_{Hi}}{1 + \sum_i \frac{\lambda_{Li}}{\theta_{Ti}}\theta_{Li}}\right)\hat{s} \\ \hat{s} &= \frac{\sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\hat{P}_i}{1 + \sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\theta_{Hi}} - \left(\frac{\sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\theta_{Li}}{1 + \sum_i \frac{\lambda_{Hi}}{\theta_{Ti}}\theta_{Hi}}\right)\hat{w} \end{aligned} \tag{A22}$$

This system is equation (1) in the main text.

A.2 Supplemental Results

Table A1 shows the predicted changes in the skill premium resulting from trade liberalization, as described in Section 3. Each prediction applies to the corresponding entry in Table 2.

Table A1: Predicted Change in Skill Premium

	2000			2010		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: All workers - wages						
	-0.0098	-0.0004	-0.0060	-0.0144	-0.0021	-0.0076
Panel B: All workers - earnings						
	-0.0151	-0.0056	-0.0104	-0.0283	-0.0157	-0.0210
Panel C: Formally employed - wages						
	-0.0036	-0.0040	-0.0052	-0.0018	-0.0010	-0.0021
Panel D: Formally employed - earnings						
	-0.0052	-0.0061	-0.0072	-0.0070	-0.0064	-0.0074

Predicted changes in skill premia using coefficient estimates for the differential tariff shocks in Table 2 and the employment-weighted average value of the differential tariff shock of -0.008.

A.3 Alternate Skill Definition

In the main text, we define skill as having completed high school, i.e. completing 11 or more years of education. Here, we present results for an alternate skill definition of having completed college, i.e. completing 15 or more years of education. We again evaluate the returns to education using the average number of years of education for skilled (15.4 years) and unskilled (4.7 years) workers. Table A2 presents summary statistics for the skill premium calculated using this approach. Not surprisingly, the returns to skill are higher when using the college definition of skill rather than the high school definition, as in Table 1. Otherwise, the results are quite similar, with roughly constant average returns to skill in the 1990s and a sharp decline in the 2000s, and substantial regional heterogeneity in skill premium growth during both time periods.

Table A2: Descriptive Statistics: Regional Skill Premia - 15+ Year Skill Definition

	hourly wages		earnings	
	mean	std. dev.	mean	std. dev.
Levels				
1991	1.181	0.163	1.145	0.145
2000	1.221	0.132	1.173	0.127
2010	0.880	0.122	0.900	0.131
Changes				
1991-2000	0.040	0.118	0.028	0.111
1991-2010	-0.301	0.147	-0.245	0.146

411 microregion observations, weighted by 1991 share of national workers in our sample. Regional skill premium reflects returns to education, as described in the text.

Table A3 shows the results for liberalization's effect on regional skill premia using the college skill definition, paralleling those in Table 2. The results for all workers in Panels A and B are very similar to those using the high-school skill definition. There are a few specifications for the formally employed sample in Panels C and D that differ substantially from Table 2. This likely results from the fact that many regions have few individuals with a college education or more, and restricting attention to formally employed workers further limits that sample.

Table A3: Liberalization's Effect on Regional Skill Premia - 15+ Year Skill Definition

dependent variable: proporional change in regional skill premium from 1991 to listed year

	2000			2010		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: All workers - wages						
Differential trade shock	1.057	0.093	0.717	1.727	0.719	1.249
	(1.827)	(1.012)	(0.768)	(2.100)	(1.424)	(1.137)
Skill premium pre-trend (80-91)			-0.346***			-0.456***
			(0.044)			(0.049)
State fixed effects (26)		✓	✓		✓	✓
Panel B: All workers - earnings						
Differential trade shock	1.643	0.626	1.159	3.474	2.175	2.714**
	(1.719)	(0.873)	(0.748)	(2.360)	(1.527)	(1.354)
Skill premium pre-trend (80-91)			-0.281***			-0.397***
			(0.041)			(0.048)
State fixed effects (26)		✓	✓		✓	✓
Panel C: Formally employed - wages						
Differential trade shock	-0.613	0.534	0.861	-0.553	-0.069	0.253
	(1.375)	(0.745)	(0.663)	(1.219)	(0.819)	(0.669)
Skill premium pre-trend (80-91)			-0.373***			-0.491***
			(0.061)			(0.054)
State fixed effects (26)		✓	✓		✓	✓
Panel D: Formally employed - earnings						
Differential trade shock	0.040	1.324*	1.621**	0.841	1.487*	1.819**
	(1.325)	(0.673)	(0.628)	(1.433)	(0.883)	(0.780)
Skill premium pre-trend (80-91)			-0.342***			-0.464***
			(0.061)			(0.053)
State fixed effects (26)		✓	✓		✓	✓

Dependent variable is the proportional change in regional skill premium from 1991 to the year listed, calculated as described in the text. Independent variable is the differential tariff shock for skilled and unskilled workers, defined in (2). Worker skill defined as having completed 15 or more years of education. 411 microregion observations when including all workers in the sample. 338 microregion observations when including only formally employed workers, those with a signed work card. Skill premium pre-trends calculated for 1980-1991 period based on monthly earnings. Observations weighted by the inverse of the squared standard error of the estimated proportional change in regional skill premium. Standard errors (in parentheses) adjusted for 112 mesoregion clusters. *** Significant at the 1 percent, ** 5 percent, * 10 percent level.

Table A4 calculates predicted changes in the skill premium resulting from trade liberalization, as described in Section 3. Each prediction applies to the corresponding entry in Table A3. Note that the employment-weighted average shock is -0.003 when calculated for formal sector workers.

Table A4: Predicted Change in Skill Premium - 15+ Year Skill Definition

	2000			2010		
	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: All workers - wages						
	-0.0039	-0.0003	-0.0026	-0.0064	-0.0027	-0.0046
Panel B: All workers - earnings						
	-0.0061	-0.0023	-0.0043	-0.0128	-0.0080	-0.0100
Panel C: Formally employed - wages						
	0.0005	-0.0004	-0.0007	0.0004	0.0001	-0.0002
Panel D: Formally employed - earnings						
	-0.0000	-0.0011	-0.0013	-0.0007	-0.0012	-0.0015

Predicted changes in skill premia using coefficient estimates for the differential tariff shocks in Table 2 and the employment-weighted average value of the differential tariff shock of -0.003.