Online Appendix

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. 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. 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

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

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

Zero profits implies

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

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

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

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

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

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.

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

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

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

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

Note that $\mathbf{\Theta}$ 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.

(A15)

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

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

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.

2. Supplemental Results

Table A1 estimates pre-liberalization placebo regressions, using the 1980-1991 change in regional skill premium as the dependent variable while maintaining the same independent variable as in Table 2, the differential tariff shock. Since the 1980 Census is missing information on hours, we can only calculate pre-liberalization skill premium trends for earnings. In all cases pre-existing trends in the regional skill premium were not significantly related to the differential tariff shocks.

Table A1—: Pre-liberalization Placebo Regressions

dependent variable: proporional change in regional skill premium 1980-1991

	11+ skill defn.	15+ skill defn.
	(1)	(2)
Panel B: All workers - earnings		
Differential tariff shock	2.130	2.100
	(1.295)	(1.564)
State fixed effects (26)	✓	✓
Panel D: Formally employed - earnings		
Differential tariff shock	0.939	0.885
	(0.638)	(0.716)
State fixed effects (26)	✓	✓

Note: Dependent variable is the proportional change in regional skill premium from 1980 to 1991, 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 or 15 or more years of education, as listed in the column titles. 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. 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 A2 shows liberalization's effect on regional skill premia using an alternate measure of the differential trade shock based upon changes in the effective rate of protection rather than nominal tariffs. Effective rates of protection also come from Kume et al. (2003). The coefficients are quite similar to those for nominal tariffs in Table 2, though the scale is somewhat smaller. This feature results from the fact that changes in effective rates of protection span a wider range than changes in nominal tariffs, such that the regression coefficients are scaled down proportionately.

Table A2—: Liberalization's Effect on Regional Skill Premia - Effective Rate of Protection Tariff Measure

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	0.818	-0.0332	0.423	1.257	0.169	0.591
	(0.957)	(0.574)	(0.376)	(1.129)	(0.880)	(0.625)
Skill premium pre-trend (80-91)			-0.361***			-0.460***
			(0.0434)			(0.0500)
State fixed effects (26)		✓	✓		✓	✓
Panel B: All workers - earnings						
Differential tariff shock	1.253	0.411	0.803**	2.385**	1.311	1.725**
	(0.873)	(0.475)	(0.357)	(1.144)	(0.870)	(0.679)
Skill premium pre-trend (80-91)			-0.300***			-0.411***
			(0.0410)			(0.0459)
State fixed effects (26)		✓	✓		✓	✓
Panel C: Formally employed - wages						
Differential tariff shock	0.720	0.639*	0.790**	0.551	0.194	0.318
	(0.887)	(0.354)	(0.321)	(0.799)	(0.480)	(0.382)
Skill premium pre-trend (80-91)			-0.381***			-0.485***
			(0.0562)			(0.0494)
State fixed effects (26)		✓	✓		✓	✓
Panel D: Formally employed - earnings						
Differential tariff shock	0.974	1.011***	1.150***	1.380	1.082**	1.205***
	(0.832)	(0.312)	(0.314)	(0.900)	(0.464)	(0.404)
Skill premium pre-trend (80-91)			-0.353***			-0.458***
			(0.0539)			(0.0457)
State fixed effects (26)		✓	✓		✓	✓

Note: 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), and using the effective rate of protection as the tariff measure. Worker skill defined as having completed 11 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 A3 shows the predicted changes in the skill premium resulting from trade liberalization, as described in Section III. Each prediction applies to the corresponding entry in Table 2.

Table A3—: 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

Note: 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.

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 A4 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 A4—: 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

Note: 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 A5 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 A5—: Liberalization's Effect on Regional Skill Premia - 15+ Year Skill Definition

dependent variable: proporional change in regional skill premium between listed years

	1991-2000			1991-2010		
	(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)		✓	✓		✓	✓

Note: 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 A6 calculates predicted changes in the skill premium resulting from trade liberalization, as described in Section III. Each prediction applies to the corresponding entry in Table A5. Note that the employment-weighted average shock is -0.003 when calculated for formal sector workers. As an example, consider columns (3) and (6) of Panel B, which yield predicted skill premium changes of -0.0043 and -0.0100, respectively. From Table A4, the realized change in the earnings-based skill premium in 1991-2000 was 0.028. In the absence of liberalization, our results suggest that the average skill premium would have grown by 0.032 during that period. The realized change in skill premium in 1991-2010 was -0.245, so our liberalization shocks explain 4.1 percent of the observed average decline in skill premium.

Table A6—: 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

Note: 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.