Minimum Wage, Trade Policy, and Informality: Evidence from Colombia

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Abstract

This paper studies how trade liberalization and the minimum wage interact and jointly determine informality and welfare. Colombia has one national minimum wage but large regional differences in pay, so it binds more tightly in some local labor markets than in others. Combining industry-level tariff cuts from the 2010–2011 reform with pre-reform differences in the minimum-wage bite, I find that a one-percentage-point larger tariff reduction raises informality by 0.8 percentage points where the minimum wage binds more tightly, and has no detectable effect where it binds less tightly. I then estimate a spatial general-equilibrium model with heterogeneous firms and export selection, employer wage-setting power, and endogenous formality and self-employment. I find that the tariff cuts reduce informality in the aggregate, while the regional loss of labor demand that reduced-form designs measure raises it. Yet informality responds far more to the minimum wage than to tariffs, and a higher minimum wage weakens the formalization that tariff cuts bring. Evaluating trade liberalization therefore requires accounting for domestic labor-market policies. Finally, I find that worker welfare is maximized at a minimum wage of about 54 percent of the current level, which would lower informality by 11 percentage points.

Keywords: Minimum wage, trade liberalization, informality, monopsony, Colombia.
JEL Codes: F13, F16, J38, J42, O17.

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1 Introduction

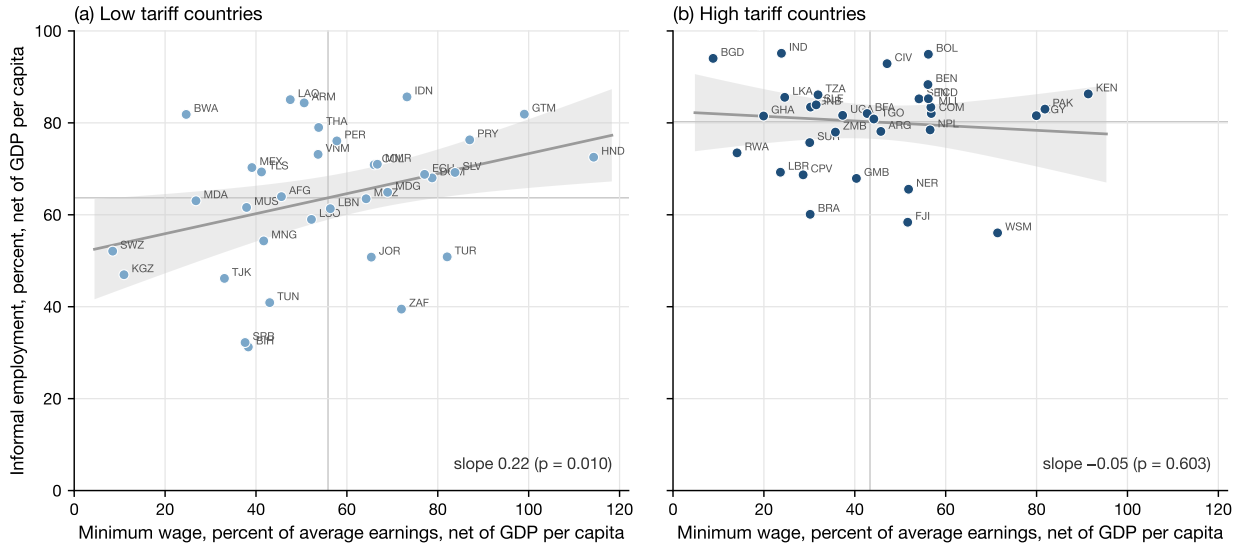
Over the past decades, many developing countries have lowered trade barriers while informal employment has remained widespread. Although informal employment serves as a buffer against unemployment, informal firms are less productive than formal firms, informal workers lack the social insurance attached to formal jobs, and informal firms and jobs lie outside the tax base (Ulyssea, 2020). Trade liberalization expands firms' access to foreign markets and intensifies product-market competition. Regions facing larger tariff cuts have experienced lasting increases in informality, and the opening of developing countries to trade coincided with rising inequality (Goldberg and Pavcnik, 2007). These effects differ across countries and depend on the labor-market institutions in place. In much of Latin America, one such institution is a high minimum wage. Separate empirical literatures provide evidence that trade reforms reshape formal and informal employment and that minimum wages affect informal employment and wages.[1]

Yet research and policy debates typically treat the two policies as separate instruments. In this paper, I study how the effect of trade liberalization on informality depends on the minimum wage, and how trade policy and minimum wage policy jointly determine aggregate outcomes, welfare, and optimal policies in developing countries. Trade policy and minimum-wage policy affect the same firms and workers through different economic margins. A tariff cut changes firms' labor demand and a binding minimum wage limits their wage adjustment. When import competition reduces demand, firms constrained by the minimum wage may instead ration formal jobs or operate informally, and displaced workers may move into informal employment or self-employment. The minimum wage can therefore mediate the effects of trade liberalization on informality and inequality, and on who gains and loses from liberalization. Across developing countries, the relationship between the minimum wage and informality differs with trade exposure. Figure 1 offers descriptive splits of 67 low and middle income countries at their median applied tariff and plots informal employment against the minimum wage relative to average earnings, conditioning on income per capita. Among the more open economies, those with a higher minimum wage have more informal employment, whereas among the more protected economies the relationship is absent.

Lowering or not having the minimum wage is not an obvious remedy for informality. Minimum wages seek to raise earnings and redistribute income and, in imperfectly competitive labor markets, may also improve efficiency by limiting employers' wage-setting power, which

[1] On trade and informality, see Goldberg and Pavcnik (2003), McCaig and Pavcnik (2018), Dix-Carneiro and Kovak (2019), Ponczek and Ulyssea (2022), and Dix-Carneiro et al. (2026). On minimum wages and informality, see Mora and Muro (2017), Arango and Flórez (2021), Corcuera (2024), Derenoncourt et al. (2025), and Parente et al. (2026).

Figure 1: Informal employment and the minimum wage, by trade exposure



Notes: 67 low and middle income countries, split at the median applied tariff of 9.3 percent. Both axes are net of log GDP per capita within each panel, so the slope of each line is the coefficient on the minimum wage controlling for income. Shaded areas are 95 percent confidence bands, and thin lines mark panel means. *Sources:* ILOSTAT, WDI (averages over the years available in 2015–2022).

is substantial in developing countries and which trade liberalization itself might strengthen by raising labor-market concentration.[2] Setting either policy well requires evaluating the two jointly.

My empirical setting is Colombia, where a uniform and high national minimum wage binds much more tightly in some local labor markets than in others because of large regional differences in pay. Informal employment accounts for roughly 70 percent of employment, with self-employment constituting an important component.[3] Colombia's 2010–2011 trade reform also generated large and heterogeneous tariff cuts across industries. Because the minimum wage is set nationally but binds with different intensity across local labor markets, I can compare the same tariff cuts across labor markets within one country, where trade policy and other national institutions are the same. I ask how the informality response varied with how tightly the minimum wage bound in each local labor market, whether the Colombian minimum wage is set at its optimal level, and how the optimal level changes with trade policy.

I answer these questions in two steps. First, using the household survey, I relate changes in informality around the reform to industry-level tariff reductions and allow the response to

[2]On employer wage-setting power in developing countries, see Amodio and de Roux (2024) and Felix (2026). On minimum wages under employer wage-setting power, see Manning (2003). On minimum wages and inequality, see Engbom and Moser (2022) and Parente et al. (2026).

[3]In the 2015 household survey, 69.9 percent of workers are informal and self-employment accounts for 51.3 percent of employment (Appendix A.3).

vary with the pre-reform minimum-wage bite across regions and education groups. The tariff reductions were driven largely by pre-reform tariff levels as the reform rounded down the existing tariff schedule, rather than by contemporaneous labor-market conditions. I then examine the entire wage distribution, following Cengiz et al. (2019), to see where in the distribution employment changed.

I find that the relationship between tariff reductions and informality differs sharply with the initial minimum-wage bite. A one-percentage-point larger tariff reduction is associated with a 0.8-percentage-point increase in informality in labor markets where the minimum wage is more binding, while the corresponding estimate where it is less binding is statistically indistinguishable from zero. Looking at the wage distribution, in industries receiving larger tariff cuts, formal employment near the minimum wage declines and informal employment below the minimum wage rises, relative to industries receiving smaller cuts. A one-percentage-point larger tariff reduction lowers the formal employment share by 0.25 percentage points in the wage bin at the minimum wage, with smaller declines in the adjacent bins and no change well above it, while raising informal employment below the minimum wage by 0.64 percentage points. The increase in informality is concentrated in self-employment rather than informal wage employment.

Second, to interpret these patterns and evaluate aggregate welfare and policy, I develop and estimate a spatial general-equilibrium model. The reduced-form estimates are relative differences across labor markets. Therefore, they do not answer whether the tariff reform increased or decreased informality in aggregate. Since the same national minimum wage binds differently across rich and poor regions and worker groups, the model is spatial, which lets me measure the distributional motive for the minimum wage. The model combines heterogeneous firms that select into exporting and formality, monopsonistic competition in local labor markets, and a national minimum wage, and it links 24 regions through domestic and international trade with tradable and nontradable sectors, college and noncollege workers, and self-employment. Workers choose among formal wage employment, informal wage employment, and self-employment, and housing prices and government transfers determine how nominal income changes translate into welfare.

In the model, heterogeneous firms choose whether to export and operate formally (Melitz, 2003; Ulyssea, 2018), and they compete monopsonistically for workers. Because workers substitute imperfectly across jobs, each firm faces an upward-sloping labor supply curve and pays a wage that is a constant markdown below the marginal revenue product of labor, so in the absence of a minimum wage firms employ too few workers.[4] More productive firms

[4]Under oligopsonistic competition, markdowns vary across firms and rise with a firm's share of local employment (Berger et al., 2022, 2025; Gutiérrez, 2023; Felix, 2026). I assume a constant markdown because

pay higher wages, so the same statutory minimum wage binds on different firms in different places. A minimum wage does not affect high-productivity firms that would pay above it, raises wages and employment at intermediate-productivity firms by limiting employer wage-setting power, and reduces employment at low-productivity firms whose labor demand cannot support the mandated wage. Firms can avoid the minimum wage and other formal regulations by operating informally, and export selection gives productive firms access to foreign demand. Trade moves firms across these regimes through two channels. The first is the level of the minimum wage relative to market wages, which depends on how the minimum wage is adjusted. The second is firms' market access. In a simplified version of the model in which the minimum wage keeps pace with wages and binds on the marginal exporter, liberalization shrinks from both ends the range of firms at which the minimum wage raises employment. Exporters outgrow the minimum wage at the top, and the weakest formal firms may become informal at the bottom.[5] The model has three implications, and the reduced-form patterns are consistent with each. Where enough minimum-wage employment is at firms that ration jobs, the bite amplifies the informality response to import competition, formal employment losses are concentrated at the minimum wage, and informal employment rises below it.

I bring the model to Colombian household surveys, customs records, and an interregional input-output table. Estimation by simulated method of moments targets regional labor-market, firm, and trade moments in 2015. The differential response of informality to the 2010–2011 tariff reform is not among these targets, so comparing the model's response with the reduced-form evidence provides an untargeted test of its central mechanism.

I simulate the 2010–2011 reform in two ways. As Dix-Carneiro et al. (2026) and Adão et al. (2026) point out, reduced-form estimates that compare regions or industries exposed to different tariff cuts identify the differential effect of a trade-induced negative labor-demand shock, not the aggregate effect of trade. The common effects of the reform are absorbed by the time effects, so its national effects are not what the reduced-form estimates measure. In the first exercise, I simulate the actual tariff reductions. National informality falls slightly, by 0.13 percentage points, and worker welfare falls by 0.4 percent. In the second exercise, I follow their approach and simulate the labor-demand shock alone. Each region's tradable productivity falls by the equivalent of the domestic demand its tradable firms lose from the region's actual 2010–2011 tariff cut, so the shock has the size and regional pattern of the actual reform. The regional loss of labor demand raises tradable-sector informality by 0.5

the variation that oligopsony adds appears small in Colombia and other developing countries (Amodio and de Roux, 2024; Kusaka, 2023; Felix, 2026), as the footnote in Section 3.4 explains.

[5] See Appendix C.

percentage points per percentage point of a region's tariff cut, the same sign and order of magnitude as the reduced-form estimate of 0.8. Therefore, the tariff cuts reduce informality in the aggregate, while the regional loss of labor demand that reduced-form designs measure raises it. In both simulations the effect on national informality is small.

I then consider how informality responds to alternative levels of the national minimum wage and alternative tariff schedules. With trade policy held at its 2015 level, raising the minimum wage from zero to its current level raises informality by 13 percentage points. Aggregate worker welfare is maximized at a minimum wage of about 54 percent of the current Colombian minimum wage. At its current level, the minimum wage lowers welfare by 1.3 percent in consumption-equivalent terms relative to an economy without a minimum wage, and moving to the optimum raises welfare by 1.5 percent. The welfare-maximizing minimum wage is positive because employers have wage-setting power, and redistribution toward noncollege workers sets its level. Relative to no minimum wage, the optimum benefits noncollege workers at the expense of college workers, so the aggregate welfare comparison depends on how gains and losses across the two groups are weighted, highlighting the role of redistribution (Dávila and Schaab, 2025). By contrast, reducing the minimum wage from its current level to the optimum benefits both groups, with larger gains for college workers.

Finally, I solve the model under tariff schedules from free trade to a higher-protection schedule, at every level of the minimum wage. Informality responds far less to tariffs than to the minimum wage. Across these schedules it moves by at most one percentage point. A tariff reaches only the tradable sector, which employs a third of workers, and within it the loss of import-competing jobs is partly offset by the gain in export jobs, while the minimum wage applies to formal jobs in both sectors. A higher minimum wage also weakens the formalization that trade liberalization brings, from 1.0 percentage point without a minimum wage to 0.5 at the current level, because the wage increase that comes with the export expansion pushes nontradable firms at the formality margin into informality. Neither comparison appears in the literature on trade and informality, which has taken the minimum wage as given, and evaluating the labor-market effects of trade liberalization therefore requires accounting for domestic labor-market policies. The minimum wage barely changes the gains from trade, about 1.1 percent of consumption for a 10 percent cut in trade costs at every level, and informality as a whole lowers them slightly, because much of it is tradable self-employment that competes with imports. The welfare-maximizing minimum wage, measured relative to average earnings, stays at 0.54 times the current level in every regime, because in general equilibrium tariffs barely change the trade-off between what a higher minimum wage gains and what it costs. Only the nominal minimum wage that implements it changes, moving with nominal average earnings.

Related literature. This paper contributes to three strands of literature. First, it contributes to the literature on trade, informality, and labor-market adjustment in developing countries by showing that the same tariff reduction generates different labor-market adjustment depending on how tightly the national minimum wage binds. Existing studies show that trade reforms can reshape the allocation between formal and informal work, with the direction and margin of adjustment depending on the nature of the trade shock and the institutional setting.[6] They also document persistent and heterogeneous adjustment across regions and workers.[7] A related literature studies how international trade changes employers' wage-setting power and other labor-market distortions.[8] Felix (2026) finds that workers' substitution into self-employment limits how far trade-induced concentration raises markdowns, and Kusaka (2023) finds that Colombian tariff cuts raised markdowns only modestly and without raising concentration, but neither study considers the minimum wage or treats informality as an outcome. Whether the minimum wage, which directly limits formal wage adjustment, changes the informality response to a trade shock has to my knowledge not been estimated. I identify the minimum-wage bite as an important determinant of this adjustment. Tariff reductions raise informality where the minimum wage binds more tightly but have no detectable effect where it binds less tightly. I find that this adjustment is mainly in self-employment, which in the estimated model also lowers workers' gains from trade.

Second, the paper contributes to research on minimum wages in imperfectly competitive labor markets and in economies with substantial informality. This literature shows that a minimum wage pulls in two directions. In a competitive labor market a binding minimum wage rations jobs, whereas when employers set wages a moderate minimum wage raises wages and employment together. The efficiency effect of a minimum wage therefore depends on employer wage-setting power and on how far above the market wage it is set.[9] A minimum wage also redistributes income. Even where it rations jobs, a minimum wage can be desirable as a redistributive tool (Lee and Saez, 2012), and empirical studies find that it raises earnings at the bottom of the distribution and compresses inequality, with employment effects that are often small.[10] In developing countries the rationing margin is often informality rather than unemployment, because informal work absorbs workers displaced from formal jobs (Dix-Carneiro et al., 2026), and a complementary literature studies informal employment,

[6] See Goldberg and Pavcnik (2003), Paz (2014), McCaig and Pavcnik (2018), Dix-Carneiro and Kovak (2019), Ponczek and Ulyssea (2022), and Dix-Carneiro et al. (2026).

[7] See Attanasio et al. (2004), Dix-Carneiro (2014), and Dix-Carneiro and Kovak (2017).

[8] See Jha and Rodríguez-López (2021), Pham (2023), Kusaka (2023), and Felix (2026).

[9] See Bhaskar and To (1999), Manning (2003), Flinn (2006), Cahuc and Laroque (2014), Berger et al. (2022), Berger et al. (2025), Ahlfeldt et al. (2023), and Haanwinckel (2025).

[10] See Cengiz et al. (2019), Harasztosi and Lindner (2019), Derenoncourt and Montialoux (2021), Dustmann et al. (2022), and Engbom and Moser (2022).

workforce composition, and firms' formality choices, and how these margins shape wages and responses to labor regulation.[11] In Colombia the minimum wage also spills over to informal wages (Maloney and Núñez Mendez, 2004; Pérez Pérez, 2020). Related work documents labor-market power and the role of self-employment.[12] I estimate how these forces balance, and therefore what level the minimum wage should take, in an open developing economy where employer wage-setting power is large, the rationing margin is informality, and trade changes which firms the minimum wage binds. I show that changes in product-market competition alter the range of firms for which the minimum wage limits wage-setting power without reducing employment, although in the estimated model this effect is small.

Finally, the paper contributes to the literature on trade policy in economies with domestic distortions by quantifying how the minimum wage and trade policy interact in welfare terms. The classical second-best literature established that the welfare effects of trade policy depend on distortions elsewhere in the economy and that the best remedy for a domestic distortion acts on the distortion itself (Bhagwati and Ramaswami, 1963; Johnson, 1965). Brecher (1974a,b) showed that with an economy-wide wage floor that creates unemployment, free trade is no longer generally optimal and the first-best policy pairs a tariff with a labor subsidy that removes the distortion. In that analysis the minimum wage only rations employment, so the question of its optimal level does not arise. Recent quantitative work replaces the rigidity with explicit labor-market frictions, under which trade raises wage inequality, adjustment is slow and unequal across workers, and domestic distortions in developing countries change the gains from trade.[13] Dix-Carneiro et al. (2026) incorporate an observed minimum wage into a nonspatial quantitative model of trade and informality, in which informality amplifies the gains from trade, but do not study its optimal level. Ruggieri (2019) studies how minimum wages and other labor-market institutions shape firm selection, job reallocation, unemployment, and the distribution of gains from trade. Both papers model labor markets through search frictions and wage bargaining, under which the minimum wage constrains downward wage adjustment, and neither incorporates heterogeneous worker types. What is not known is how the two policies should be set together when the minimum wage both offsets employer wage-setting power and redistributes across workers and regions, and whether trade policy changes the welfare-maximizing minimum wage. I introduce employer wage-setting power in a spatial economy with heterogeneous worker types and vary both policies independently. In the estimated model, informality lowers workers' gains from trade, because much of it is tradable self-employment that competes with imports, and the welfare-maximizing minimum

[11] See Meghir et al. (2015), Ulyssea (2018), Mondragón-Vélez et al. (2010), Haanwinckel and Soares (2021), Arango and Flórez (2021), Parente et al. (2026), and Derenoncourt et al. (2025).

[12] See Amodio and de Roux (2024), Amodio et al. (2025), and Felix (2026).

[13] See Helpman et al. (2010), Dix-Carneiro (2014), and Atkin and Donaldson (2022).

wage relative to average earnings does not move with the tariff regime. A higher minimum wage weakens the formalization that a tariff cut brings, and tariffs change the level of worker welfare nationally and the purchasing power of the minimum wage unevenly across regions.

The remainder of the paper is organized as follows. Section 2 describes the Colombian setting and data and presents the reduced-form evidence. Section 3 develops the quantitative spatial general-equilibrium model. Section 4 estimates the model and presents the quantitative analysis and counterfactuals. Section 5 concludes.

2 Setting, Data, and Reduced-Form Evidence

In this section I test whether the informality response to Colombia's 2010–2011 tariff reform depended on how tightly the minimum wage binds. The reform reduced tariffs by different amounts across industries, largely by compressing the inherited tariff schedule. Colombia sets a uniform national minimum wage, but wages differ widely across regions and education groups, so the same minimum wage binds more tightly in some local labor markets than in others. Combining these two sources of variation, I compare the informality response to a given tariff reduction across local labor markets that differ in the pre-reform minimum-wage bite. I then ask whether formal employment losses are concentrated near the minimum wage and whether employment moves below it.

2.1 The 2010–2011 Tariff Reform

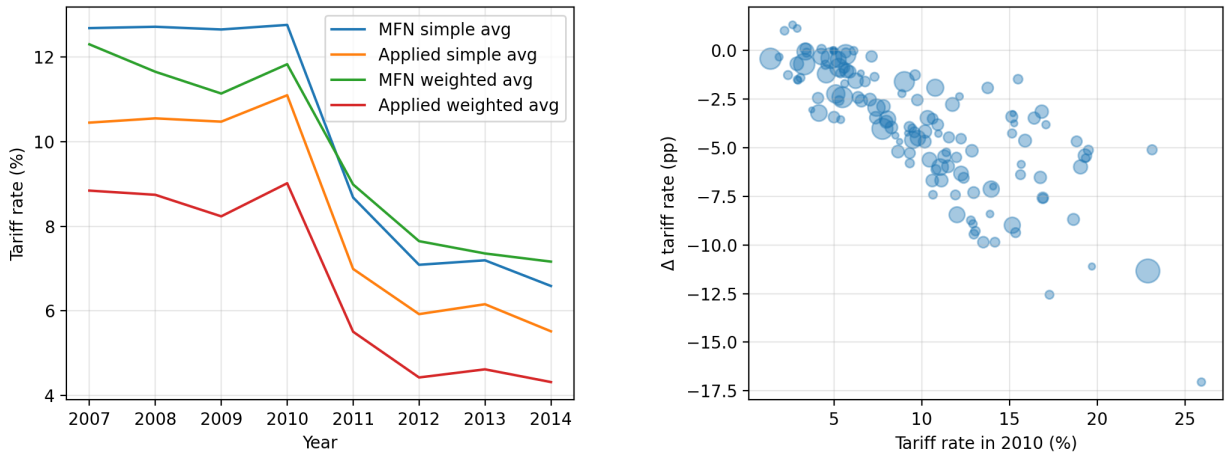
Colombia implemented a major unilateral tariff reform beginning in November 2010 through Decrees 4114 and 4115. The reform sought to reduce tariffs and simplify customs administration. It concentrated previously dispersed rates around 5, 10, and 15 percent and was implemented over a relatively narrow period from late 2010 through 2011.[14] Across the 29 tradable industries in the estimation sample, the average effectively applied tariff fell from 8.5 percent in 2009 to 5.6 percent in 2011, a reduction of 2.9 percentage points.

Tariff data come from UNCTAD-TRAINS at the HS6 product level and are mapped to four-digit ISIC Rev. 3 industries using standard concordances. Panel (a) of Figure 2 plots average tariff rates over time, and Panel (b) shows that industries with higher tariffs before the reform generally received larger reductions. Initial protection may be related to persistent industry characteristics. Reassuringly, the reductions show little systematic

[14] Colombia's free trade agreements with the EFTA states and Canada entered into force in July and August 2011, and those with the United States and the European Union in May 2012 and August 2013. The effectively applied tariff includes the preferential rates in force in each year. The statutory MFN reduction used as an instrument in Appendix A.6 is unaffected by these agreements.

relationship with a range of pre-reform industry characteristics, including informality levels and trends.[15]

Figure 2: The 2010–2011 Colombian tariff reform



(a) Tradable-industry tariff rates, 2007–2014

(b) Tariff change vs. pre-reform level

Notes: Panel (a) plots simple and import-weighted MFN and AHS (effectively applied) tariff rates across four-digit ISIC tradable industries, 2007–2014. Panel (b) plots the AHS tariff change between 2010 and 2011 against the 2010 tariff level for 136 four-digit tradable industries. Dots are sized by 2010 imports. The baseline reduced-form treatment uses the 2009–2011 change, aggregated to the two-digit industry level. *Source:* WITS/UNCTAD TRAINS.

2.2 The Labor Market and the Minimum Wage

The worker-level data come from the Gran Encuesta Integrada de Hogares (GEIH), Colombia's monthly household labor-force survey, for 2007–2019. The survey reports employment status, earnings, hours, industry, education, location, and demographic characteristics. I harmonize geographic identifiers into 24 first-level administrative regions, which I refer to as regions throughout. I classify workers into three mutually exclusive employment categories. Formal wage workers are employees whose employers contribute to pension and health insurance on their behalf. Informal wage workers are employees without these employer contributions, and self-employed workers have no employer. The main outcome equals one for informal wage workers and the self-employed and zero for formal wage workers, following the convention in the Colombian literature (Goldberg and Pavcnik, 2003; Arango and Flórez, 2021). The estimation sample consists of employed workers aged 18–65 in 29 two-digit tradable industries spanning agriculture, mining, and manufacturing (ISIC Rev. 3

[15]The corresponding balance tests are in Appendix A.2.

01–36).[16]

Colombia sets a single national minimum wage, with no variation across regions, industries, occupations, or firm sizes. It is negotiated annually among the government, employers, and unions, and a 1999 Constitutional Court ruling requires each annual adjustment to compensate at least for the previous year's inflation.[17] The minimum wage is high relative to much of the Colombian wage distribution (Bell, 1997; Maloney and Núñez Mendez, 2004; Arango and Flórez, 2021). In the pre-reform tradable-sector sample, it equals 86 percent of the median formal wage, and 44 percent of formal salaried workers earn no more than 1.10 times the minimum wage. Panel (a) of Figure 3 shows the contrast between formal and informal earnings distributions. Formal earnings bunch around the minimum wage. Informal earnings extend well below it.

I measure how tightly the minimum wage binds in a local labor market using the *minimum-wage bite*, the share of formal salaried workers in each region × education cell, across all sectors, earning no more than 1.10 times the contemporaneous hourly minimum wage, averaged over 2007–2009.[18] Workers can move across industries within a region, and wage distributions and the minimum-wage bite differ sharply across education groups. I therefore define local labor markets by region and education. Keeping industry out of the bite measure also separates it from the tariff treatment, which varies across industries. I restrict the measure to formal salaried workers because it is meant to capture how many compliant jobs sit near the statutory minimum wage. The 24 regions and four education groups produce 96 cells. In the baseline analysis I divide these cells at the median bite.[19]

Labor-market outcomes vary substantially across both education groups and regions (Table 1). In the pre-reform tradable-sector sample, 72 percent of workers are informal and 43 percent are self-employed. Informality declines from 88 percent among workers with primary education or less to 29 percent among workers with tertiary education. Informality also varies considerably across regions within education groups. Among workers who completed secondary education, for example, regional informality rates range from approximately 41 percent at the 10th percentile to 93 percent at the 90th percentile. Formal workers also earn more than informal workers at every education level.[20]

The minimum-wage bite varies sharply across education groups and, within education groups, across regions. It averages 0.60 among cells for workers with primary education

[16] Appendix A.1 details the sample construction.

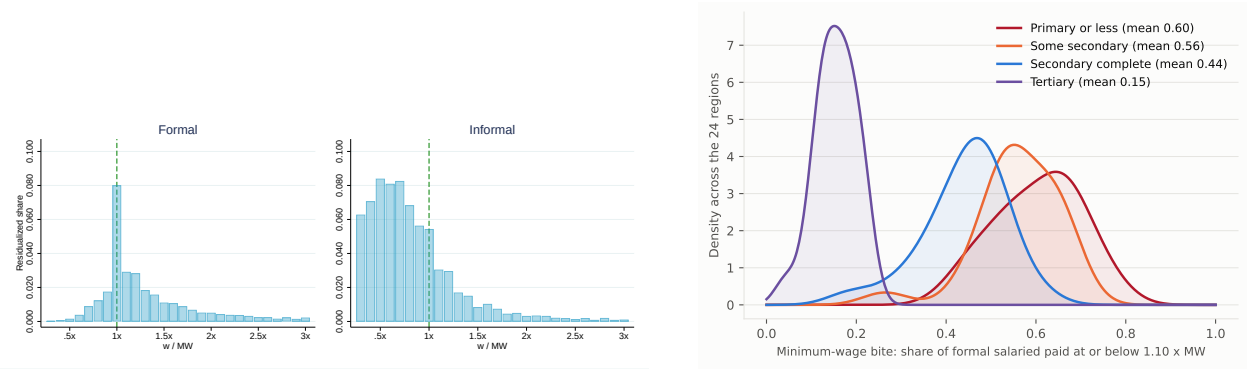
[17] Appendix Figure A.1 plots the real minimum wage over 2007–2019.

[18] See Appendix A.5.

[19] In Appendix A.10 I also use the continuous bite, alternative thresholds, and the bite measured at the industry × region and industry × region × education levels.

[20] Appendix Table A.3 reports corresponding labor-market statistics for workers across all Colombian sectors.

Figure 3: The minimum wage and its local bite before the tariff reform



(a) Earnings relative to the minimum wage

(b) Bite across region × education cells

Notes: Panel (a) plots the residualized share of workers in bins of earnings relative to the contemporaneous minimum wage, separately for formal and informal workers. The dashed line marks the minimum wage. Panel (b) plots the distribution across the 24 regions, separately by education, of the pre-reform minimum-wage bite measure. *Source:* GEIH.

Table 1: Labor-market statistics in tradable industries, pre-reform period

	All	Primary	Some sec.	Sec. complete	Tertiary
Panel A: Worker-level statistics					
Informality rate	0.718	0.876	0.722	0.524	0.286
Self-employment rate	0.426	0.521	0.414	0.306	0.190
Formal-employment share	0.282	0.124	0.278	0.476	0.714
Formal/informal wage ratio	2.19	1.90	1.69	1.68	1.82
Minimum-wage bite	0.516	0.598	0.551	0.458	0.155
Panel B: 10th–90th percentile range across regions					
Informality rate	[0.37, 0.97]	[0.79, 0.99]	[0.61, 0.97]	[0.41, 0.93]	[0.25, 0.70]
Self-employment rate	[0.19, 0.72]	[0.31, 0.79]	[0.29, 0.68]	[0.19, 0.69]	[0.14, 0.50]
Minimum-wage bite	[0.14, 0.66]	[0.47, 0.71]	[0.47, 0.65]	[0.33, 0.52]	[0.10, 0.21]

Notes: Both panels use workers aged 18–65 in the 29 two-digit tradable industries of the reduced-form analysis, 2007–2009, excluding January interviews. Panel A reports survey-weighted worker-level statistics. Panel B reports the unweighted 10th–90th percentile range across the 24 regions of survey-weighted region × education cell means, separately within each education group. The "All" column pools the 96 cells. The minimum-wage bite is the measure used in the regressions, the share of formal salaried workers in the region × education cell, across all sectors, paid at or below 1.10 times the contemporaneous hourly minimum wage, averaged over 2007–2009. Panel A reports its average over workers. *Source:* GEIH.

or less, compared with 0.15 among tertiary-education cells. Across regions, the 10th–90th percentile range is 0.47–0.71 for primary-education cells, 0.33–0.52 for completed-secondary cells, and 0.10–0.21 for tertiary-education cells. Panel (b) of Figure 3 displays these distributions. Although education accounts for most of the overall variation, meaningful regional variation remains within each education group. The baseline analysis uses both dimensions.[21]

[21] Appendix A.7 examines the regional variation within education groups separately.

2.3 Empirical Strategy

I use two complementary exercises for the reduced-form analysis. The first estimates how the informality response to industry-level tariff reductions varies with the pre-reform minimum-wage bite across local labor markets, to ask whether the response depends on how tightly the minimum wage binds. The second examines changes across the wage distribution, to ask whether formal employment losses are concentrated near the minimum wage and whether employment moves below it.

For the reduced-form analysis, I aggregate the tariff measures to the two-digit industry level to limit sampling noise within industry × region × education cells. I define the tariff reduction in industry j as $\Delta\tau_j \equiv \tau_{j,2009} - \tau_{j,2011}$, so that a positive value denotes liberalization. Across the 29 industries, the reductions have a standard deviation of 2.7 percentage points and range from -0.9 to 11.3 percentage points.

I begin with the static interaction specification

$$\begin{aligned}\text{Informality}_{ijdgt} = \; & \beta_L\big(\Delta\tau_j \times \text{Post}_t\big) + \beta_H\big(\Delta\tau_j \times \text{Post}_t \times \text{High}_{dg}\big) \\ & + \mathbf{X}_i'\boldsymbol{\Gamma}_t + \alpha_{jdg} + \delta_{dgt} + \varepsilon_{ijdgt},\end{aligned} \tag{1}$$

where Post_t equals one beginning in 2011. β_L is the response to a one-percentage-point tariff reduction in low-bite cells and β_H is how much larger the response is in high-bite cells, so $\beta_L + \beta_H$ is the high-bite response.

I include industry × region × education fixed effects, α_{jdg}, which absorb permanent differences across cells, and region × education × year fixed effects, δ_{dgt}, which absorb anything common to a local labor market in a given year, including local business cycles. I therefore compare industries within the same region × education × year cell. I interact the demographic controls with year, add calendar-month fixed effects, and weight by the survey weights.

I also estimate a dynamic version of equation (1), replacing Post_t with year indicators and omitting the base year 2010, so that both the low-bite response and the high-minus-low differential can vary by year. For β_H to be causal, no other shock after 2010 may have hit high-bite labor markets harder in the industries with larger tariff cuts. The pre-reform coefficients of the dynamic specification check for such shocks before the reform. I cluster standard errors two-way by industry and region, and because there are only 29 industries and 24 regions I also report wild-cluster-bootstrap and permutation-based inference.[22]

[22] The dynamic specification, the fixed-effect ladder, the instrumented estimates, and the inference details are in Appendix A.6.

2.4 Main Informality Result

Table 2 reports the estimates from equation (1). In labor markets where the minimum wage is more binding, a one-percentage-point larger tariff reduction is associated with a 0.79-percentage-point increase in informality, while the corresponding estimate where it is less binding, 0.09 percentage points, is statistically indistinguishable from zero. The high-minus-low difference is 0.71 percentage points, with a conventional two-way-clustered standard error of 0.27. At the average tariff reduction of 2.89 percentage points, the gap between high- and low-bite labor markets is about 2.0 percentage points of informality.

Table 2: Informality response to tariff reductions by minimum-wage bite

	Informality
Tariff cut × Post (β_L)	0.088
	(0.145)
Tariff cut × Post × High bite (β_H)	0.706**
	(0.273)
High-bite response ($\beta_L + \beta_H$)	0.795***
	(0.250)
Demographic controls × year	Yes
Observations	689,898
Industry × region × education FE	Yes
Region × education × year FE	Yes

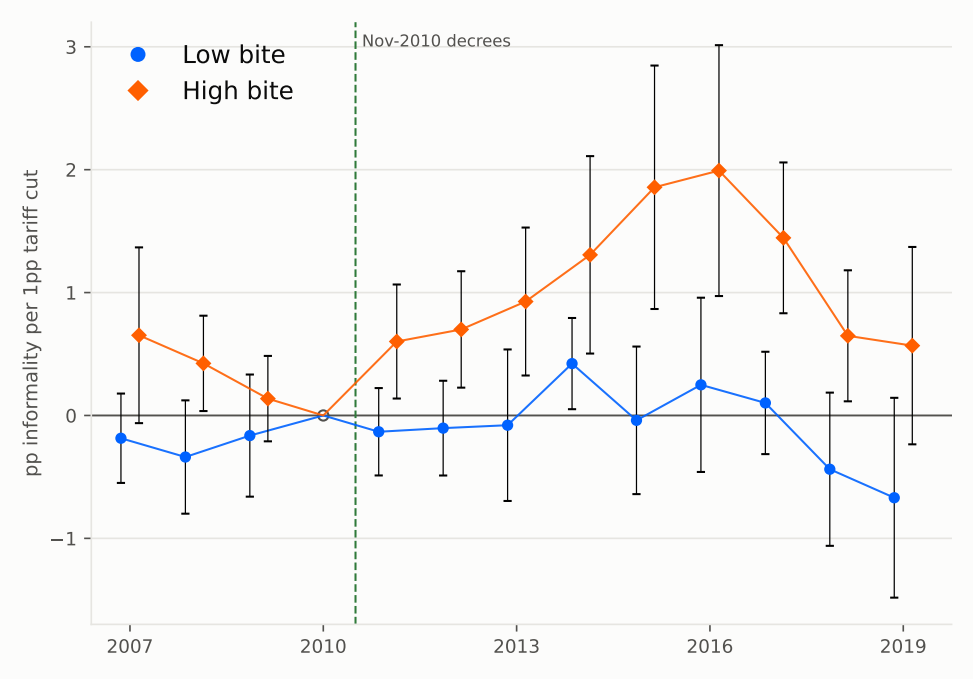
Notes: Worker-level regressions of the informality indicator on the applied 2009–2011 tariff cut of the worker's industry, interacted with Post and with High bite. Post equals one in 2011–2019. High bite identifies region × education cells above the median of the pre-reform minimum-wage-bite distribution. Coefficients are percentage-point changes in informality associated with a one-percentage-point tariff reduction. The sample contains 29 tradable industries. All specifications include calendar-month fixed effects and use survey weights. Standard errors two-way clustered by 29 industries and 24 regions are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.10$. Full static and event-study estimates, and alternative inference procedures, are in Appendix A.6.

Figure 4 plots the event-study estimates. The low-bite path stays close to zero in every year. The high-bite path rises after 2010 and stays positive through 2019.[23]

The additional informality response is concentrated in self-employment rather than informal wage employment. The self-employment differential is 0.89 percentage points, while the informal-wage-employment differential is −0.19 and statistically indistinguishable from zero. This pattern is relevant for the spatial model of Section 3 because self-employment

[23]Both paths fall by about 0.6 percentage points in 2018–2019 relative to 2011–2017, so the high-minus-low differential does not decline late in the sample. Its 2018–2019 average differs from its 2011–2017 average by −0.04 percentage points ($p = 0.857$), and the final two coefficients do not differ jointly from the earlier post-reform coefficients ($p = 0.921$).

Figure 4: Informality response by minimum-wage bite



Notes: The figure plots the low-bite response and the implied high-bite response to a one-percentage-point applied tariff reduction in each year, with 2010 omitted. Whiskers are 90 percent confidence intervals based on standard errors two-way clustered by industry and region.

does not require another employer to create an informal job.[24]

2.5 Adjustment Across the Wage Distribution

The informality result shows where the response is larger, but not which formal jobs disappear. If the minimum wage prevents formal wages from adjusting downward, formal employment losses should be concentrated at and just above the minimum wage, and informal employment, which is not bound by the minimum wage, should rise below it. To examine this, I follow Cengiz et al. (2019) and study how employment changes across the entire wage distribution. I divide workers into 28 bins of earnings, each 0.10 times the contemporaneous minimum wage wide, separately by formal and informal status. For each employment status s and earnings bin k, I estimate

$$Y_{ijdt}^{s,k} = \beta_k^s\big(\Delta\tau_j \times \text{Post}_t\big) + \mathbf{X}_i'\mathbf{\Gamma}_{t,k}^s + \alpha_{jd,k}^s + \delta_{dt,k}^s + \mu_{m,k}^s + \varepsilon_{ijdt}^{s,k}, \tag{2}$$

where $Y_{ijdt}^{s,k}$ equals one if worker i is employed in status s and earnings bin k, and zero otherwise. Industry $\times$ region fixed effects, $\alpha_{jd,k}^s$, absorb permanent differences across local

[24] See Appendix A.8 for the full decomposition.

industries, and region × year fixed effects, $\delta^s_{dt,k}$, absorb local labor-market shocks. The vector $\mathbf{X}_i$ contains the demographic controls of equation (1) and education, all interacted with year, and $\mu^s_{m,k}$ are calendar-month fixed effects. The specification uses survey weights and clusters standard errors by industry. The coefficient β^s_k is the post-reform change in the share of workers in bin k and status s associated with a one-percentage-point larger tariff reduction.

Figure 5 shows that the decline in formal employment is largest at the minimum wage. A one-percentage-point larger tariff reduction lowers the formal employment share by 0.25 percentage points in the bin containing the minimum wage, with smaller declines in the adjacent bins, while formal employment well above the minimum wage changes little. Informal employment below the minimum wage rises by 0.64 percentage points in total ($p < 0.001$), while informal employment above it is essentially unchanged. The response comes from workers with primary and lower-secondary education.[25] The concentration of formal employment losses around the minimum wage is consistent with limited formal-wage adjustment. Plant-level data from manufacturing point the same way. Plants paying close to the minimum wage cut production employment after larger tariff reductions while their pay is unchanged.[26]

2.6 Robustness and Limitations

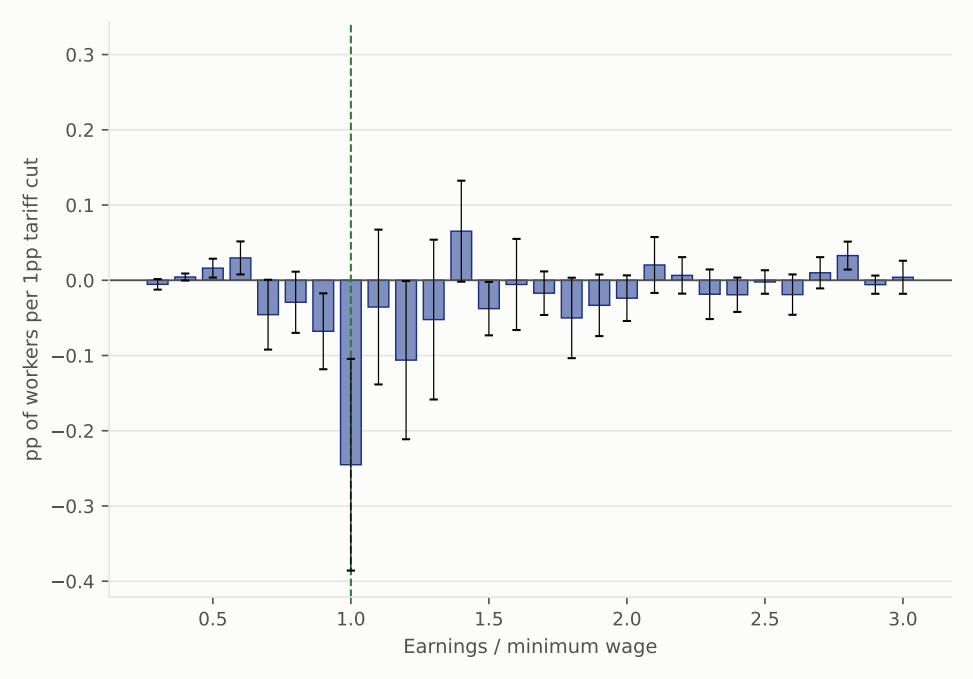
The high-minus-low differential remains positive when the bite is entered continuously or divided into terciles, when the threshold used to construct the bite is changed, when the bite is replaced by the minimum wage relative to median formal earnings, across specifications with industry × region × education fixed effects, and when the sample is restricted to manufacturing industries. Instrumenting the applied tariff reduction with the statutory reduction also produces a similar point estimate. Appendices A.6, A.10, and A.11 report these results.

The result is weaker under two alternative bite measures. Including all salaried workers, rather than only formal salaried workers, in the denominator lowers the differential from 0.71 to 0.26 and makes it imprecise. Measuring the bite at the industry × region level also produces an estimate close to zero. I keep the baseline measure. Informal employment is itself an outcome, and the industry-level cells are measured from much smaller pre-reform samples.

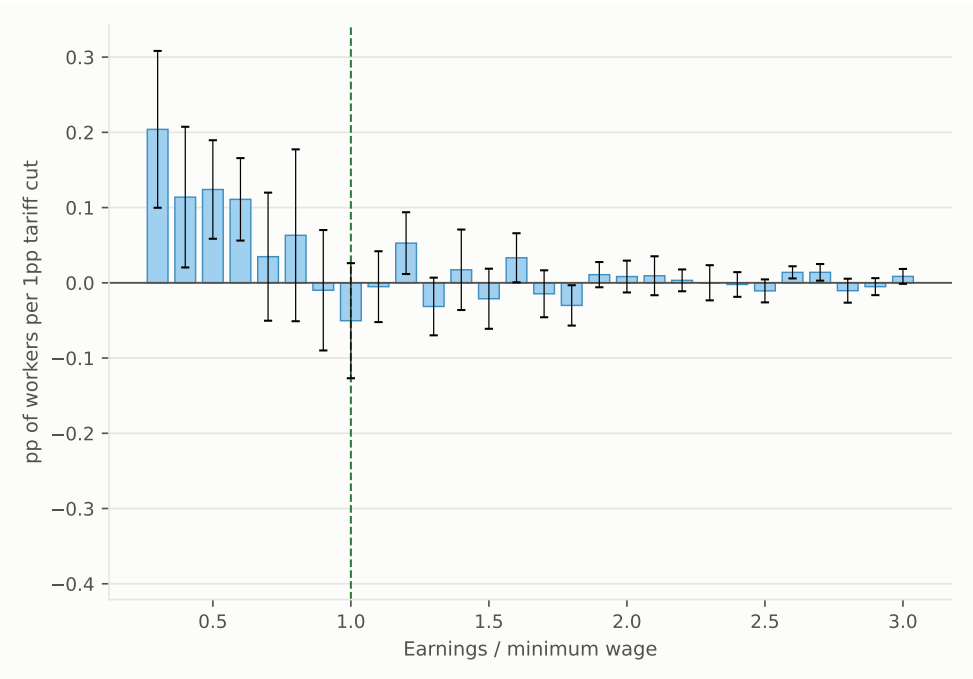
One limitation is that 82 percent of the variation in the region × education bite lies between education groups. The estimates are positive in separate college and noncollege samples, but I cannot fully separate regional variation in the minimum-wage bite from dif-

[25] See Appendix Table A.6.
[26] See Appendix A.12.

Figure 5: Differential employment changes across the wage distribution



(a) Formal employment



(b) Informal employment

Notes: Each bar reports $\widehat{\beta}_k^s$ from equation (2). The dashed vertical line marks the minimum wage. Whiskers are 90 percent confidence intervals based on standard errors clustered by industry.

ferences across education groups.[27] Another is that the GEIH is a repeated cross-section, so

[27]Specifications that use only the regional variation are in Appendix A.7.

the estimated changes in informality can come from workers changing formality status, from workers reallocating across industries and labor markets, or from changes in the composition of employment.

I find that the relationship between tariff reductions and informality differs sharply with the initial minimum-wage bite, and that in industries receiving larger tariff cuts formal employment near the minimum wage declines and informal employment below the minimum wage rises. These estimates are relative differences across labor markets. Therefore, they do not answer whether the tariff reform increased or decreased informality in aggregate, and they are silent on welfare and on the optimal minimum wage. Section 3 builds a model that explains these differences, and Section 4 uses it to answer these aggregate and policy questions.

3 Spatial General-Equilibrium Model

This section develops the quantitative model. I use it to explain the relative responses documented in Section 2 and to aggregate them into national informality, welfare, redistribution, and optimal policy. The model combines heterogeneous-firm export selection (Melitz, 2003), employer wage-setting power (Manning, 2003) and its role in international trade (Jha and Rodríguez-López, 2021), and an endogenous formal–informal production margin (Ulyssea, 2018). As in Berger et al. (2025), a moderate minimum wage can offset the underemployment that employer wage-setting power creates.

Three mechanisms in the model explain the evidence in Section 2. First, because employers have wage-setting power, a moderate minimum wage can raise employment and employer-worker surplus at some firms. Second, whether a firm is in this employment-improving region, or instead rations workers or operates informally, depends on its product-market access. Third, import competition lowers the domestic demand that all firms face. Only firms productive enough to export gain foreign demand.[28] Together, these mechanisms imply that the same trade shock changes informality differently depending on how tightly the minimum wage binds.

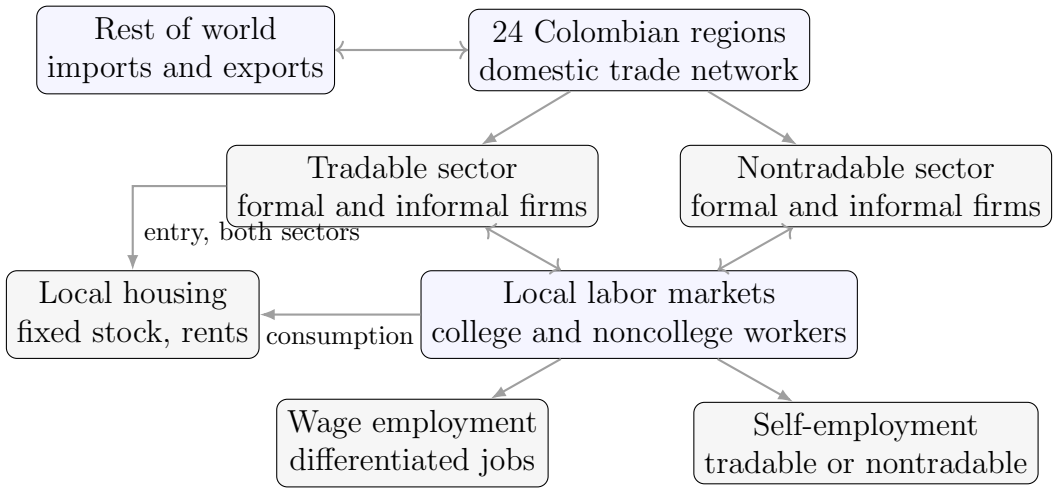
Tariff exposure and the bite of the minimum wage differ across regions, sectors, and workers, and local responses propagate through domestic trade, prices, and common labor markets. The model therefore connects 24 regions through domestic trade, and tradable and nontradable sectors share local labor markets. College and noncollege workers face the

[28] A closed-economy model with an exogenous demand contraction reproduces part of the import-competition mechanism. It has no gain in foreign market access and no selection into exporting, so the same trade shock cannot move exporters and nonexporters across different minimum-wage regimes.

same statutory minimum wage but differ in productivity, earnings, and minimum-wage bite. Workers allocate hours between wage employment and sector-specific self-employment. The model also includes import tariffs, with tariff revenue rebated to workers. Housing, firm entry, government transfers, and external balance close the spatial equilibrium. Figure 6 summarizes the structure. The national minimum wage applies to formal wage jobs in every region. International trade shocks hit the tradable sector first and then spread to other regions and to the nontradable sector.

The model is organized by region rather than by industry. The bite of the national minimum wage, measured in the data in Section 2, depends on the local wage distribution. In the model, a worker who loses a formal job moves to another employer, to informal work, or to self-employment within the same region. It abstracts from reallocation across tradable industries within a region, from differences in the bite of the minimum wage across those industries, and from imported intermediate inputs.[29] Section 4 estimates the model and uses it to simulate the tariff reform, alternative minimum wages, and joint trade and minimum-wage policies.

Figure 6: Spatial, sectoral, and labor-market structure of the quantitative model



3.1 Geography, Sectors, and Regional Market Access

The economy contains Colombian regions $d, k \in \mathcal{D}$ and the rest of the world. The quantitative application uses 24 regions. Region d has fixed populations L_{hd} of college and noncollege workers, indexed by $h \in \{C, N\}$, and a fixed housing stock $\overline{H}_d$. I hold populations fixed because the reduced-form analysis measures adjustment within locations. Wages, employment,

[29] A multi-sector version of the model with input-output linkages is work in progress.

self-employment, prices, rents, firm entry, formality, and trade nevertheless adjust endogenously.[30] Every region produces a tradable composite, T, and a nontradable composite, N. Both composites contain differentiated varieties produced across Colombian regions. Thus "nontradable" means that the sector does not trade internationally. Its varieties can still be shipped between Colombian regions. Only tradable varieties are imported from and exported to the rest of the world. Tariffs directly affect tradable goods, and workers and expenditure can reallocate toward the nontradable sector.

Households combine the two sectoral composites using the region-specific tradable expenditure share $\alpha_{T,d}$ and combine the resulting goods aggregate with housing. The goods and consumption price indexes are

$$P_{G,d} = \left(\frac{P_{T,d}}{\alpha_{T,d}}\right)^{\alpha_{T,d}} \left(\frac{P_{N,d}}{1-\alpha_{T,d}}\right)^{1-\alpha_{T,d}}, \qquad P_{C,d} = P_{G,d}^{1-\alpha_H} R_d^{\alpha_H},$$

where R_d is the regional rent and α_H is the housing expenditure share.[31] A common national minimum wage can therefore have different purchasing power across regions even before accounting for regional differences in wages.

Within sector $s \in \{T, N\}$, destination k spends $X_{s,k}$ on differentiated varieties. Let τ_{dk}^s denote the iceberg cost of shipping from origin d to destination k, and let $\sigma > 1$ be the elasticity of substitution across varieties. Domestic market access for a producer in region d is

$$\Pi_{sd}^D = \sum_{k \in \mathcal{D}} X_{s,k} P_{s,k}^{\sigma-1} \left(\tau_{dk}^s\right)^{1-\sigma}. \tag{3}$$

Equation (3) is the central spatial object in the model. A firm sells in every Colombian region, so a tariff shock in one region changes market access and labor demand in the others, through expenditure and through competition. Tradable producers may also pay a fixed cost to access foreign market demand, $\Pi_d^X = X^*(\tau_d^M)^{1-\sigma} e_x^\sigma$, where X^* is foreign expenditure. Imports enter region d at tariff-inclusive cost

$$p_d^M = (1+t_d)\tau_d^M e_x, \tag{4}$$

where t_d is the effective import tariff, τ_d^M is the international iceberg cost, and e_x is the domestic-currency price of the foreign good, whose foreign price is the numeraire abroad. A tariff reduction directly lowers the import price. It also changes domestic sectoral price indexes, regional expenditure, export profitability, and the exchange rate. These changes reach

[30] In Appendix B.3 I extend the model to allow migration.

[31] The consumption aggregate is $(G/(1-\alpha_H))^{1-\alpha_H}(H/\alpha_H)^{\alpha_H}$, so $P_{C,d}$ carries no constant. Because α_H is common to all regions, this is a choice of units.

other regions and the nontradable sector through the domestic trade network in equation (3).

3.2 Worker Types, Wage Employment, and Self-Employment

For each education group h and region d, a representative household pools the income of its members and chooses consumption and hours. Pooling delivers one consumption level for each region–education cell while preserving welfare differences across cells. Let c_{hd} denote consumption per worker and n_{hd} the per-worker composite of hours. Preferences are

$$u_{hd}(c_{hd}, n_{hd}) = \frac{c_{hd}^{1-\sigma_c} - 1}{1-\sigma_c} - \bar{\phi}_{hd}^{-1/\psi} \frac{n_{hd}^{1+1/\psi}}{1+1/\psi}, \qquad \sigma_c > 0,\ \psi > 0, \tag{5}$$

with the usual logarithmic limit when $\sigma_c = 1$. The parameter ψ is the Frisch elasticity and $\bar{\phi}_{hd}$ shifts labor supply.

Workers allocate hours among wage employment, tradable self-employment, and nontradable self-employment. Write these activities as $a \in \{W, ST, SN\}$. Their CES aggregate is

$$n_{hd} = \left[\sum_{a \in \{W,ST,SN\}} \chi_{a,hd}^{-1/\theta} n_{a,hd}^{(1+\theta)/\theta} \right]^{\theta/(1+\theta)}, \tag{6}$$

where θ governs substitution across activities and $\chi_{a,hd}$ shifts their relative attractiveness or productivity.[32] If $W_{a,hd}$ is the return to activity a, the corresponding inclusive return is

$$\mathcal{W}_{hd} = \left[\sum_{a \in \{W,ST,SN\}} \chi_{a,hd} W_{a,hd}^{1+\theta} \right]^{1/(1+\theta)}. \tag{7}$$

The household first-order conditions give

$$n_{hd} = \bar{\phi}_{hd} \left(\frac{\mathcal{W}_{hd}}{P_{C,d}} \right)^{\psi} c_{hd}^{-\sigma_c \psi}, \tag{8}$$

$$n_{a,hd} = \chi_{a,hd} \left(\frac{W_{a,hd}}{\mathcal{W}_{hd}} \right)^{\theta} n_{hd}, \qquad a \in \{W, ST, SN\}. \tag{9}$$

Thus a policy shock changes both total hours and their allocation across activities. Self-employment is not combined with informal wage employment. It is a separate competitive activity in each sector, with its return determined by sectoral prices and self-employment productivity. Workers displaced from formal jobs can therefore become own-account workers,

[32] In the estimation, θ differs by education group, θ_h, with the values in Table 3.

the margin on which the additional informality response in Section 2 is concentrated, and the welfare calculation values changes in their earnings separately (Amodio et al., 2025).

The household budget is

$$P_{C,d}c_{hd} = y^W_{hd} + W_{ST,hd}n_{ST,hd} + W_{SN,hd}n_{SN,hd} + T, \tag{10}$$

where y^W_{hd} is realized wage income and T is the national per-worker government transfer. Rents accrue to housing owners who are outside the worker households. They do not enter the budget and are spent on local goods.[33] Realized rather than potential wage income enters because applicants can be rationed at minimum-wage jobs.

Conditional on wage employment, workers choose among differentiated employers in their region–education labor market. Labor offered to employer j at wage w_{jhd} is

$$n^S_{jhd} = D_{hd}\left([1 + \xi(j)]w_{jhd}\right)^{\eta}, \qquad \eta > 0, \tag{11}$$

where $D_{hd} \equiv L_{hd}\, n_{W,hd}\, W^{-\eta}_{W,hd}$ combines the cell's supply of wage work with its wage index $W_{W,hd}$. The elasticity η measures how easily workers substitute across jobs. Because η is finite, each firm faces an upward-sloping labor-supply curve. This is the source of employer wage-setting power. Both worker types have the same elasticity η. Their supply curves differ only through D_{hd}, which reflects the size of each type's pool and the wages that other employers pay that type. Formal jobs have amenity ξ_F and informal jobs have amenity zero. In standard heterogeneous-firm trade models such as Melitz (2003), every firm pays the same wage. Here each employer faces an upward-sloping supply curve, so more productive employers pay higher wages, and identical workers earn different wages at different firms in the same labor market. Firms bound by the minimum wage pay exactly the minimum wage. As Section 3.4 explains, a formal firm that rations at the minimum wage hires fewer workers than apply. Unhired workers reallocate toward other wage jobs or either self-employment activity through equations (6)–(9).[34]

Worker types differ in productivity. An hour of type-h labor supplies s_h efficiency units in production, with $s_N = 1$ and $s_C > 1$. Labor supply in equation (11), the wage w_{jhd}, and the minimum wage are all per hour of work, not per efficiency unit, and a firm sets a separate wage for each type. An unconstrained formal firm pays every efficiency unit the same, so it pays a college worker s_C times the hourly wage of a noncollege worker. The statutory minimum wage is the same per hour for both types and therefore costs more per efficiency unit for noncollege workers. It can bind for noncollege workers but not for college

[33] See Appendix B.2.

[34] Appendix B.1 constructs the wage-work index when firms ration.

workers within the same firm. The two groups also differ in where they live and in what self-employment pays them, so even within a region they face different outside options and wage indexes, and the same national minimum wage can affect their employment and welfare differently.

3.3 Firms, Formality, and Exporting

Each region and sector has a pool of potential entrants. An entrant in sector s pays $R_d f_E^s$ for an entry cost of f_E^s units of local housing and draws permanent productivity φ. Based on expected profits, it exits or commits to formal or informal operation. It then draws transitory productivity ε, giving realized productivity $z = \varphi\varepsilon$, and chooses wages, employment, output, and prices.[35] A formal tradable firm also chooses whether to export after observing its realized productivity. The firm therefore chooses formality knowing only its permanent productivity, and sets wages, employment, and prices once it knows the transitory draw as well. Trade still enters the formality choice, through the market access a firm expects and, for a formal tradable firm, through the chance to export after a good draw. This two-stage structure allows formal and informal firms to overlap in realized size and productivity. Only entry uses local housing. Formal and informal operating costs and export costs are paid in units of the firm's own sector composite in its region, at price $P_{s,d}$.

Production uses effective labor. A formal firm j employs

$$n_j^{\text{eff}} = \sum_h s_h n_{jh}.$$

After the firm sets its CES price, let $\mathcal{R}_{sd}(z, n^{\text{eff}}; \Pi)$ denote revenue for a firm in sector s and region d with market access Π. Revenue is increasing and concave in effective labor, and it includes a region- and sector-specific productivity shifter, A_d^s.

Conditional on realized productivity and export status $x \in \{0, 1\}$, a formal firm solves

$$\pi_{sd}^F(z,x) = \max_{\{w_h, n_h\}_h} \mathcal{R}_{sd}\left(z, \sum_h s_h n_h; \Pi_{sd}^D + x\Pi_d^X\right) - \Xi_F \sum_h w_h n_h - P_{s,d}\left(f_s^F + x f_s^X\right) \quad (12)$$
$$\text{s.t.} \quad 0 \le n_h \le D_{hd}\left[(1+\xi_F) w_h\right]^{\eta}, \qquad w_h \ge w^{mw} \quad \text{if } n_h > 0.$$

The factor $\Xi_F \equiv 1 + \tau_p + \xi_F$ collects the payroll tax rate τ_p and the cost of the formal benefits that workers value as the amenity ξ_F.

[35] Permanent productivity is Pareto with shape k, bounded above (Appendix D.2). The transitory draw is log-normal, $\log \varepsilon \sim \mathcal{N}(-\sigma_\varepsilon^2/2, \sigma_\varepsilon^2)$, so that ε has mean one.

An informal firm is not subject to the payroll tax or minimum wage and cannot export.[36] It instead produces with region-specific productivity penalty δ_d^I and solves

$$\pi_{sd}^I(z) = \max_{\{w_h, n_h\}_h} \mathcal{R}_{sd}\left((1-\delta_d^I)z, \sum_h s_h^{\lambda_I} n_h; \Pi_{sd}^D\right) - \sum_h w_h n_h - P_{s,d} f_s^I \quad (13)$$
$$\text{s.t.} \quad n_h = D_{hd} w_h^{\eta}.$$

Informal firms use skill less intensively. An hour of type-h labor supplies $s_h^{\lambda_I}$ efficiency units there, with $\lambda_I \in (0,1]$. The productivity penalty summarizes the costs of operating outside the formal sector, including restricted access to customers, finance, public inputs, and contract enforcement, and the risk of detection. Formality follows from the comparison of expected values before ε is realized, as in Ulyssea (2018).[37] Because the penalty costs more revenue at more productive firms, while the minimum wage binds less tightly there, informality is chosen by the least productive firms.

3.4 Wage Setting and Minimum-Wage Regimes

Consider a formal firm. Hiring one more worker of type h raises the wage paid to all of its workers of that type, so the marginal cost of type-h labor is $\mu \Xi_F w_h$, where $\mu \equiv 1 + 1/\eta$ is the wage markdown.[38] The marginal revenue product of type-h labor is $\text{MRPL}_h \equiv \partial \mathcal{R}_{sd} / \partial n_h$. Without a minimum wage, the firm chooses employment to equate the two for each type. Because $\mu > 1$, the firm pays a wage equal to the marginal revenue product of labor divided by $\mu \Xi_F$ and employs fewer workers than it would if it took the wage as given.

[36] The minimum wage still reaches informal wages in equilibrium through the wage index in each firm's labor supply, but it is not a reference point in informal wage setting as in the lighthouse effect of Maloney and Núñez Mendez (2004) and Pérez Pérez (2020). Maloney and Núñez Mendez (2004) find no significant response of self-employment earnings to the minimum wage, consistent with the model's treatment of self-employment.

[37] These expected values and the free-entry condition are in Appendix B.4.

[38] Because each job is small relative to the labor market and job-level labor supply is isoelastic, μ is a constant and does not vary with how many workers are employed formally or informally. Informal employment affects a firm's labor supply only through the wage index and aggregate labor supply. In models with granular employers, such as Berger et al. (2022), the markdown rises with a firm's share of local employment and equals μ for a firm with a negligible share. Colombian plant data do not show that dependence. Amodio and de Roux (2024) estimate an elasticity of 2.5 on average and 2.6 to 3.4 for plants with above-median local employment shares, within one standard error of each other, and wages at their small-share plants do not respond to demand shocks while employment does, the response of a plant at the minimum wage. Kusaka (2023) finds that markdowns in Colombian manufacturing rose from 1977 to 2020 while local labor-market concentration fell, and that tariff cuts raised markdowns without raising concentration. Those estimates imply a markdown change of under half a percent for the 2010–2011 cuts. A markdown rising with size would weaken the efficiency case for the minimum wage, as in Berger et al. (2025).

A formal job that pays the minimum wage attracts

$$\bar{n}_{hd} = D_{hd}\left[(1+\xi_F)w^{mw}\right]^{\eta}$$

applicants of type h. Depending on its productivity and market access, a formal firm lies in one of three regimes for each worker type, listed from most to least productive:

- **R1: unconstrained monopsony.** The firm's unconstrained wage is at least w^{mw}, so the policy does not affect its wage or employment.
- **R2: binding without rationing.** The unconstrained wage is below w^{mw}, but labor demand at the minimum wage is at least $\bar{n}_{hd}$. The firm hires every applicant and employment equals $\bar{n}_{hd}$.
- **R3: binding with rationing.** Labor demand at the minimum wage is below $\bar{n}_{hd}$. The firm hires fewer workers than apply and sets marginal revenue product equal to $\Xi_F w^{mw}$.

For each worker type and a given market access, the three regimes are intervals of productivity, separated by two boundaries. The three regimes and the employment result below follow Ahlfeldt et al. (2023) and Berger et al. (2025). Here a firm's regime also depends on its export status, through market access. Because the minimum wage costs more per efficiency unit of noncollege labor, a firm's noncollege workers are always in a regime at least as constrained as its college workers. As productivity falls, a formal firm first pays its noncollege workers the minimum wage, then rations them, and eventually stops hiring them and employs only college workers. In what follows, a firm's regime refers to the regime of its noncollege workers.

At the minimum wage the firm can hire up to $\bar{n}_{hd}$ workers of type h without raising their wage, so its marginal cost of that labor falls from $\mu\Xi_F w_h$ to $\Xi_F w^{mw}$ and it no longer gains from restricting employment. Relative to the firm's unconstrained choice, the minimum wage therefore raises employment and worker earnings in R2. Firms in R3 ration applicants. Their employment is set by labor demand at the minimum wage. It exceeds the unconstrained level only at firms close to R2 and falls below it at less productive firms.[39] These results describe employment at a firm that stays formal, not aggregate welfare. Whenever the constraint binds, profit falls, and entry, formality, prices, and redistribution may change. Section 4 evaluates those margins.

[39]Proposition 1 in Appendix C states these results in a version of the model with one worker type and shows that R2 employment does not exceed the level that maximizes employer-worker surplus.

A higher minimum wage, a larger applicant pool, or lower market access moves the regime boundaries right, so more firms are constrained. An exporter has market access $\Pi^D_{sd} + \Pi^X_d$ rather than Π^D_{sd}, so a firm can be unconstrained if it exports and constrained if it does not. Trade moves the regime boundaries through two channels. The first is the relative-minimum-wage channel, the level of the minimum wage relative to market wages. It depends on how the minimum wage is adjusted when market wages change, and it is the same for every firm in a labor market. The second is the market-access channel. It measures a firm's market access relative to labor costs, which differs between exporters and nonexporters.[40]

3.5 Spatial Equilibrium

Housing links worker purchasing power and firm entry. Households spend the fixed share α_H on housing, while entrants use f^s_E units of local housing in sector s. Market clearing is

$$\alpha_H \frac{P_{C,d}}{R_d} \sum_h c_{hd} L_{hd} + M^E_{T,d} f^T_E + M^E_{N,d} f^N_E = \overline{H}_d,$$

where $M^E_{s,d}$ is entrant mass. Rents, which move with household income and entry, affect real consumption and the cost of entry but not the operating fixed costs in equations (12) and (13). Labor markets clear separately by region and education. Wage-work supply equals employment at formal and informal firms across both sectors, and the remaining activity supply is allocated to tradable or nontradable self-employment. A contraction in tradable employment changes the outside options and labor costs of nontradable firms, which hire in the same labor markets, so aggregate adjustment differs from the sum of the reduced-form coefficients for tradable workers.

Goods-market clearing equates output from firms and self-employment with household demand, the spending of housing owners, operating expenditures, domestic shipments, and, for tradables, imports and exports. Free entry equates the expected value of a productivity draw with the sector-specific housing-denominated entry cost $R_d f^s_E$ in each region and sector.

The government rebates payroll-tax and tariff revenue uniformly per worker. Its national budget is

$$\sum_d \sum_h L_{hd} T = \mathcal{T}^{\text{payroll}} + \mathcal{T}^{\text{tariff}}.$$

External balance determines the exchange rate e_x. Trade and minimum-wage policies therefore affect households through wages and employment, self-employment returns, consumer prices, rents, fiscal transfers, and the terms of trade. A spatial equilibrium consists of house-

[40] Appendix C derives the two channels and shows how trade changes the set of firms at which the minimum wage raises employment, in a version of the model with one region, one sector, and one worker type.

hold choices, firm policies and status choices, entry, sectoral prices, wage indexes, rents, transfers, and an exchange rate. In equilibrium, households and firms optimize, the labor, goods, and housing markets clear, free entry holds, and the government and external accounts balance. The equilibrium determines the regional allocation of formal wage employment, informal wage employment, tradable and nontradable self-employment, firm entry, exporting, consumption, and trade.[41]

3.6 Normalization, Welfare, and Policy Experiments

Following Ahlfeldt et al. (2023), I choose employment-weighted average earnings as the numeraire and set $\overline{w} = 1$ in every equilibrium. Nominal wages and prices are otherwise identified only up to a common multiplicative constant, so the normalization fixes their units without changing the real wages or consumption allocations relevant for welfare. The minimum-wage policy is therefore entered in units of average earnings. For computation, write

$$\kappa \equiv \frac{w^{mw}}{\overline{w}}, \tag{14}$$

so that setting κ sets the minimum wage directly in the normalized units. Holding κ fixed across equilibria is a wage-indexed rule, with average earnings in place of the wage index. Each counterfactual stores both κ and the regional purchasing power of the minimum wage, $w^{mw}/P_{C,d}$.[42] Section 4 states the reference equilibrium for every welfare comparison.

Welfare is evaluated for every region–education cell using utility in equation (5). Following Berger et al. (2025), let CEV_{hd} be the proportional increase in the consumption of cell (h, d) in a stated reference equilibrium that delivers its utility in the counterfactual, $u_{hd}\big((1 + CEV_{hd})c^0_{hd}, n^0_{hd}\big) = u_{hd}\big(c^1_{hd}, n^1_{hd}\big)$, where superscripts 0 and 1 denote the reference and counterfactual equilibria. Aggregate worker welfare is the common proportional increase in every cell's reference consumption that delivers the counterfactual level of utilitarian social welfare:

$$\sum_d \sum_h \omega_{hd}\, u_{hd}\big((1 + \overline{CEV})\, c^0_{hd}, n^0_{hd}\big) = \sum_d \sum_h \omega_{hd}\, u_{hd}\big(c^1_{hd}, n^1_{hd}\big), \tag{15}$$

where ω_{hd} is the population share of cell (h, d). The change for one education group applies the same definition to that group's cells. Because utility is separable and of the power form in consumption, $1 + \overline{CEV} = \big[\sum_d \sum_h \tilde{\omega}_{hd}(1 + CEV_{hd})^{1-\sigma_c}\big]^{1/(1-\sigma_c)}$ with weights $\tilde{\omega}_{hd} \propto \omega_{hd}\,(c^0_{hd})^{1-\sigma_c}$. Because $\sigma_c = 2$ in the calibration, cells with lower consumption receive more weight than their population share. The welfare-maximizing minimum wage in

[41] Appendix B.5 lists the outer unknowns and equilibrium conditions.

[42] See Appendix B.6 for the reporting details.

Section 4 maximizes $\overline{CEV}$. It is therefore a utilitarian optimum for workers, which values redistribution toward low-consumption cells, and it does not count the rent income of housing owners. Reporting the cell-level changes alongside $\overline{CEV}$ makes redistribution across education groups and regions explicit.

3.7 Connection to Informality and the Reduced-Form Analysis

Informality in the model is an outcome of labor demand and labor supply in each local labor market, in the sense of Allen and Arkolakis (2023). On the supply side, equations (8) and (9) give labor supply to wage work in the region–education labor market (h, d),

$$N^S_{W,hd} = L_{hd}\,\chi_{W,hd}\Big(\frac{W_{W,hd}}{\mathcal{W}_{hd}}\Big)^{\theta} n_{hd}, \tag{16}$$

which rises with the wage index $W_{W,hd}$ relative to the returns to self-employment, $W_{ST,hd}$ and $W_{SN,hd}$, and to consumer prices; equation (11) then allocates this supply across employers. On the demand side, after the firm sets its CES price, revenue is

$$\mathcal{R}_{sd}(z, n^{\text{eff}}; \Pi) = \Pi^{1/\sigma}\big(A^s_d\, z\, n^{\text{eff}}\big)^{(\sigma-1)/\sigma}. \tag{17}$$

Market access, Π^D_{sd} for a nonexporter and $\Pi^D_{sd} + \Pi^X_d$ for an exporter, and the productivity shifter A^s_d are therefore the two shifters of labor demand, and they enter identically up to the factor $\sigma - 1$. Each employer's labor demand follows from equation (17) and problems (12) and (13): an unconstrained formal firm (R1) demands labor in proportion to $\Pi^{\eta/(\sigma+\eta)}$, a rationing firm (R3) in proportion to Π, one for one with market access, and an R2 firm hires every applicant, $\bar{n}_{hd}$. The minimum wage thus does not shift demand; it kinks formal demand into the three regimes of Section 3.4.[43] Informality in a labor market is the informal employers' share of labor demand plus the self-employment share of labor supply. It rises when formal demand falls relative to informal demand, or when labor supply moves from wage work to self-employment.

The reduced-form analysis compares industries with larger and smaller tariff cuts within the same local labor market. Firms in a labor market face the same wage index, the same labor supply, and the same minimum wage, so the relative-minimum-wage channel is common to them and drops out of the comparison, whatever the indexation rule. What differs across industries is the market-access channel, that is, the shift in labor demand. A tariff cut shifts tradable labor demand through two terms. Import competition lowers domestic market

[43] Figure C.1 in Appendix C draws the kink and the employment response of each regime to a fall in market access.

access Π^D, by more in the industries and regions with larger cuts. Export access Π^X rises with the exchange rate that balances national trade, by the same proportion everywhere. A comparison across industries within a labor market, or across regions with time effects, therefore identifies the response of informality to the first term, a movement along the local supply curve (16) caused by a differential shift of labor demand through equation (17) (Adão et al., 2026); the second term is common to all units and drops out. A larger tariff cut lowers the market access of an industry's nonexporters relative to labor costs and raises their regime cutoffs, so firms move from R1 toward R2 and from R2 into R3, and the least productive formal firms may become informal.[44] Because every worker in R2 or R3 is paid the minimum wage, the empirical bite measure, the share of formal salaried workers paid at or near the minimum wage, approximates the share of a labor market's formal employment at firms the minimum wage constrains. The model yields three implications for how the response to such a demand shift varies with the local bite of the minimum wage.

1. The minimum-wage bite can amplify the informality response to import competition. Where the minimum wage does not bind, formal firms are in R1 and respond to lower market access by cutting wages and employment. Informal firms and formal nonexporters contract in the same proportion, so the informal share is unchanged. Where the minimum wage binds, two further margins operate. R3 firms cannot lower their wage and cut employment by more, and firms near the formality cutoff switch to informal production. The model therefore predicts a larger rise in informality after a tariff cut in labor markets with a high minimum-wage bite when rationing firms account for enough of the employment bound by the minimum wage. Formal employment does not rise in any regime. Whether it falls by proportionally more than informal employment, so that the informal share rises, depends on the mix of constrained firms. Rationing firms cut employment by more than informal firms do, and R2 firms by less.[45] Section 2 documented this pattern.

2. Formal employment losses are concentrated at the minimum wage. The three regimes respond differently to lower market access. R1 firms cut both wages and employment. R2 firms keep employment fixed. R3 firms keep the wage at the minimum and cut employment one for one with market access, which is more than an R1 firm does. Where R3 firms account for most minimum-wage employment, formal job losses after a tariff cut are therefore concentrated among workers paid the minimum wage. Section 2 documented this

[44] See Proposition 2 in Appendix C.

[45] In a version of the model with one region, one sector, and one worker type, the informal share rises when rationing firms account for more than a share $\eta/(\sigma+\eta)$ of employment at nonexporters bound by the minimum wage. See Appendix C.9.

in the distribution of formal employment around the minimum wage.

3. Employment appears below the minimum wage. Jobs lost at the minimum wage reappear below it in two ways. A firm that switches to informal operation pays its unconstrained wage, which is below the minimum. Workers released by rationing firms lower the wage index, which raises employment at firms that were already informal, and by equation (16) they move into self-employment, whose return has not fallen.[46]

A higher measured minimum-wage bite shows that more workers are employed near the minimum wage, but not how those workers are divided between R2 and R3. The three implications are therefore about relative responses across labor markets with different initial minimum-wage bites, not about the sign of the national change in informality after trade liberalization, because the national change also contains the common export-access term, which raises formal labor demand in every region. I turn to aggregate welfare and the optimal minimum wage with the estimated model in Section 4.

4 Estimation and Quantitative Analysis

I now take the spatial model to Colombian household, customs, and regional expenditure data and use it to ask how the minimum wage and trade policy jointly determine informality and welfare. After estimating the model, I run four counterfactual exercises. First, I simulate the 2010–2011 tariff cuts and compare their national effect on informality and worker welfare with the regional labor-demand shock that the reduced-form design measures. Second, I vary the national minimum wage under current tariffs, from no minimum wage to levels above the current one, and find the level that maximizes worker welfare. Third, I cut international trade costs by 10 percent at each level of the minimum wage, in the estimated economy, in an economy without informal firms, and in one without informal firms or self-employment, to see how much of the gain from trade runs through each. Fourth, I solve the model under four tariff regimes at every level of the minimum wage, to see how informality responds to each policy and whether the trade regime changes the welfare-maximizing minimum wage.

4.1 Taking the Model to the Data

I estimate the model on 2015 data. The household survey measures the number of college and noncollege workers in each region and how each region–education group divides its work

[46] In the data, the rise below the minimum wage is in self-employment rather than informal wage employment (Section 2). In the model, workers released by rationing firms can also move into self-employment, which does not require another employer to create the job.

among formal wage work, informal wage work, and self-employment. It also measures earnings, the minimum-wage bite, employer size, and regional rents. Customs records measure trade and exporter participation, and the 2015 interregional input–output table measures expenditure and trade flows among the 24 regions.[47]

Regional endowments, expenditure shares, tariffs, and spatial trade costs are constructed from data before the simulated method of moments (SMM) estimation. Bilateral iceberg costs are recovered from domestic expenditure shares and interregional trade flows using the Head–Ries procedure (Head and Ries, 2001). International trade costs come from input–output and world output data, and tariffs from customs data. Table 3 classifies the remaining parameters as externally set, estimated in separate empirical exercises,[48] mechanically recovered from observed quantities, or estimated internally by SMM, the only group searched over in the objective.

Let m_ℓ^{data} and $m_\ell^{model}(\Theta)$ denote moment ℓ in the data and model and let se_ℓ put the discrepancy on a common sampling-error scale. The estimator minimizes

$$\widehat{\Theta} = \arg\min_{\Theta} \sum_{\ell=1}^{L} \left[\frac{m_\ell^{model}(\Theta) - m_\ell^{data}}{se_\ell} \right]^2 .$$

Scaling by se_ℓ prevents moments measured in pesos or large employment counts from mechanically dominating moments measured as shares.

Several parameters affect the same outcomes, so they are identified jointly, but each has a main source of variation. The moments vary by region, education group, sector, activity, and exporter status. Region-by-sector wage levels inform sectoral productivity, and housing stocks are recovered so that the model matches regional rents exactly. Formality and the minimum-wage bite by region, sector, and education, and formal–informal wage gaps by region and sector, inform the local formality wedge, the dispersion of realized productivity, and the incidence of the wage constraint. Regional tradable employment shares identify comparative advantage across the two sectors. The national formal-firm count informs entry costs, while exporter participation and the export-sales ratio inform the fixed cost and value of foreign market access. Wage dispersion and the college–noncollege wage gap help determine productivity dispersion and the skill parameters.[49]

Table 4 reports selected moments.[50] The model reproduces the geography of formality and sectoral specialization, the minimum-wage bite by education group, the number of formal

[47] The source, unit, and construction of every model object are in Appendix D.1.
[48] See Appendix D.3.
[49] Appendix D.4 lists the 318 moments by block.
[50] I report every block of the objective and plot the regional fit in Appendix D.5.

Table 3: Parameters

Parameter	Value	Source or main identifying moments
Set externally		
σ_c, ψ	2.0, 0.40	Maintained calibration values
α_H, τ_p, ξ_F	0.252, 0.25, 0.264	Household budget survey 2016–17; statutory rate; benefits data
f_s^I	0	Restriction
w^{mw}, L_{hd}, $\alpha_{T,d}$, t_d	Data	Household survey, input–output table, customs
τ_{dk}^T, τ_{dk}^N, τ_d^M	Data	Head–Ries inversion of 2015 regional and world flows
Estimated outside the SMM objective		
η	2.50	Amodio and de Roux (2024)
θ_h	5.0 (noncollege), 1.5 (college)	Tariff-IV estimates of substitution between wage work and self-employment, by education
σ	4.00	Gravity estimate on 2015 customs data
Recovered by inversion		
A_d^S, $\chi_{a,hd}$, $\bar{\phi}_{hd}$	Data-implied	Self-employment earnings, activity shares, and hours
$\overline{H}_d$	Data-implied	Rents relative to Bogotá
Estimated by simulated method of moments (estimates in Appendix D.2)		
A_d^T, A_d^N		Region-by-sector wage levels and sectoral employment shares
δ_d^I		Formality and formal–informal wage gaps
f_E^T, f_E^N, f_T^F, f_N^F		Firm counts, sectoral formality, and regional employment
f_T^X, X^*		Exporter share and export-sales ratio
σ_ε, k, s_C, λ_I		Wage dispersion, wage gaps, bite by type, and type premia

firms, and the share of tradable firms that export. Formal–informal wage gaps, formality, and region-by-sector wage levels account for most of the remaining distance between model and data.

4.2 The Tariff Reform in the Estimated Model

I next simulate the tariff reductions implemented in 2010–2011 in two ways. The first simulates the actual tariff reductions. The second simulates the labor-demand shift that the reduced form identifies. This is an untargeted test of how trade changes informality in the model.

The reduced-form analysis measures each worker's tariff change at the industry level, whereas the quantitative model has one tradable sector in each region. Following Kovak

Table 4: Selected moments in the data and the estimated model

	Data	Model	Correlation
Targeted			
Formal share of wage employment, noncollege			0.87
Formal share of wage employment, college			0.76
Tradable share of wage employment, by region			0.90
Minimum-wage bite, noncollege (median)	0.469	0.476	0.43
Minimum-wage bite, college (median)	0.163	0.149	0.45
Formal–informal log wage gap (mean over region–sector cells)	0.529	0.659	
Share of tradable firms that export	0.102	0.112	
Formal firm count (model units)	0.218	0.216	
Export sales ratio, value-added basis	0.300	0.261	
Untargeted			
Tradable share of wage employment, national	0.277	0.343	
Informal share of wage jobs, nontradables minus tradables	−0.130	−0.091	
Exports / GDP	0.143	0.0984	

(2013), I map the reform into regional tariff changes with pre-reform employment weights,

$$\Delta t_d = \sum_i \omega_{di,0} \Delta t_i, \tag{18}$$

where $\omega_{di,0}$ is region d's pre-reform employment share in tradable industry i and Δt_i is the industry's 2009–2011 tariff reduction. The regional reductions average 2.66 percentage points. I treat the estimated 2015 equilibrium as the post-reform economy and compare it with a counterfactual in which each region's tariff is higher by Δt_d, holding the minimum wage fixed relative to average earnings. The reduced form compares industries within a labor market and the model has one tradable sector per region, so the comparison here is across regions, each region's demand shift being the employment-weighted average of its industries' cuts. Both identify the response to the differential demand shift, at two levels of aggregation.

The reduced-form estimates of Section 2 compare industries and regions with different tariff cuts. Dix-Carneiro et al. (2026) point out that such comparisons identify the differential effect of a trade-induced labor-demand shock, not the aggregate effect of trade. Adão et al. (2026) show this formally for spatial models. In the terms of Section 3.7, a regional regression with time effects measures the movement along the local supply curve caused by the region's own shift in labor demand, while shifts common to all regions are in the time effects. The differential term of the reform is each region's import price, which falls with its own tariff cut and lowers the market access of its tradable firms. The common terms are the depreciation, which raises export access in every region, the rebate, and the price

changes that the domestic trade network transmits. The time effects absorb them, so the estimates compare regions that lost more demand with regions that lost less. In the model of Dix-Carneiro et al. (2026) this comparison is akin to comparing the economy with one that experiences a negative labor-demand shock, and they validate the model against the regional evidence of Dix-Carneiro and Kovak (2019) and Ponczek and Ulyssea (2022) with a 1 percent fall in productivity. I apply the same logic to the Colombian reform. Market access is an equilibrium object that depends on every region's prices and expenditure, so it cannot be set directly. Productivity is a primitive that enters labor demand identically up to the factor $\sigma - 1$ (Section 3.7). The shift can equally be read as a rise in foreign productivity. A region's tradable labor demand in equation (17) depends on its productivity relative to that of the producers it competes with, so a fall in domestic productivity and a rise in foreign productivity of the kind studied in the China-shock literature (Autor et al., 2013; Adão et al., 2026) are the same labor-demand shift in the exposure the regression identifies. I therefore lower each region's tradable productivity by the amount that lowers its firms' revenue as much as the import-competition term does, the fall in the domestic demand of its tradable firms that the cut implies through the model's import shares, holding the exchange rate and foreign demand at their 2015 values.[51] Table 5 reports the aggregate results in two columns.

In the first simulation, the tariff reductions lower national informality by 0.13 percentage points. Two demand shifts work against each other. Import competition lowers tradable labor demand in every region, and the depreciation raises formal labor demand through exporting, the larger shift because only formal firms export. The tariff reductions formalize the sector exposed to import competition and spill a little informality into nontradables, and the national effect is a fifth of the tradable effect because a third of wage work is tradable and because the nontradable spillover offsets part of it. Three margins produce this pattern, and Table 5 separates them. First, the tariff cuts lower import prices, and under balanced trade the real exchange rate depreciates and exports expand, by 6.6 percent. Exporting requires formality, so the exporter cutoff falls, formal tradable employment rises by 2.3 percent, and tradable-sector informality falls by 0.75 percentage points.[52] Second, self-employed producers

[51] A 1 percentage point cut of a region's tariff lowers the demand shifter of its tradable firms by $(\sigma - 1)$ times the region's import share times the log change in one plus the tariff. Dividing by $\sigma - 1$ gives the productivity change with the same effect on revenue, 0.27 percent per percentage point at the estimate. The shock is applied to tradable productivity in every region at once, with the worker-side shifters held at their estimated values. A uniform 1 percent fall in tradable productivity, the import-competition analogue of the economy-wide productivity shift in Dix-Carneiro et al. (2026), raises national informality by 0.07 percentage points and tradable-sector informality by 0.35, lowers formal tradable employment by 0.6 percent, and lowers worker welfare by 0.13 percent.

[52] The tradable price index falls by 0.6 percent and the real exchange rate depreciates by 1.0 percent. Tradable entry rises by 1.0 percent. Two thirds of the fall in tradable-sector informality is the informal share of wage work, and the remaining third is self-employment.

Table 5: The 2010–2011 tariff reform in the estimated model: tariff cuts and the regional labor-demand shock

	Tariff cuts	Regional labor-demand loss
Exports (percent change)	+6.6	+0.1
Formal tradable employment (percent change)	+2.3	−0.4
Inclusive informality (percentage points)		
All workers	−0.13	+0.05
Noncollege	−0.15	+0.05
College	−0.08	+0.01
Tradable sector	−0.75	+0.26
informal wage part	−0.50	−0.01
self-employed part	−0.25	+0.27
Nontradable sector	+0.17	−0.07
Worker welfare (consumption-equivalent, percent)		
All workers	−0.38	−0.11
Noncollege	−0.41	−0.11
College	−0.01	−0.13
Regional slope of tradable-sector informality on the tariff cut (percentage points per point)	−0.85	+0.52

Notes: Column 1 is the 2015 equilibrium minus the pre-reform counterfactual, with the pre-reform economy as the reference. Column 2 is the economy with the productivity loss minus the 2015 equilibrium, with 2015 as the reference. Both are at the current minimum wage held fixed relative to average earnings. Column 1 raises each region's 2015 tariff by its pre-reform-employment-weighted industry reduction (equation (18), mean 2.66 percentage points). Column 2 keeps 2015 tariffs and lowers each region's tradable productivity by the productivity equivalent of its cut (mean 0.7 percent). Informality includes informal wage workers and the self-employed, pooled over education groups with employment weights. The tradable and nontradable rows pool both education groups. Welfare is the consumption-equivalent change of equation (15) against the same reference. The slope is a worker-weighted regression across the 24 regions of the change in tradable-sector informality on the region's tariff cut.

of tradables compete directly with imports. Their earnings fall relative to wages, and workers leave tradable self-employment for wage work. Third, formal tradable firms expand and the minimum wage, indexed to average earnings, rises with them, so nontradable firms at the formality margin lose workers and some switch to informal status. Nontradable informality rises by 0.17 percentage points.[53]

Worker welfare falls by 0.38 percent even though informality falls. The tariff reductions remove tariff revenue, which the model rebates equally to every worker, and they worsen the

[53]Informality falls slightly more among noncollege workers (−0.15 percentage points) than among college workers (−0.08). The national decline is equivalent to reducing the current minimum wage by about 0.5 percent.

terms of trade through the depreciation that balanced trade requires. These losses outweigh the fall in consumer prices, 0.1 percent, and the gain in formal employment. The loss falls on noncollege workers, whose welfare falls by 0.41 percent and whose consumption falls by 0.2 percent, because the equal rebate is a larger share of their income and because they hold the tradable self-employment jobs whose earnings fall. College welfare is unchanged. Section 4.5 shows that this is a general property of tariffs in the model. Tariff revenue and the terms of trade make a tariff above the 2015 level raise worker welfare, so a tariff cut from that level lowers it.

The second column of Table 5 reports the results from the regional labor-demand version, the loss of local labor demand that reduced-form designs measure. Only the downward demand shift is present. Formal and informal employers lose demand together, so the informal share of wage work barely moves, and the labor released by rationing and exiting formal firms goes to self-employment, whose return did not shift. Informality now rises, by 0.26 percentage points in the tradable sector, through self-employment, and formal tradable employment falls by 0.4 percent.[54] Across regions, tradable-sector informality rises by 0.52 percentage points per percentage point of tariff cut, the order of magnitude of Section 2's estimate, 0.79 in high-bite labor markets and 0.09 in low-bite ones, whereas under the tariff cuts themselves it falls by 0.85. The tariff cuts also depreciate the real exchange rate and expand exports, and this common demand shift, which the time fixed effects absorb in the reduced form, formalizes the tradable sector.

4.3 Minimum-Wage Policy

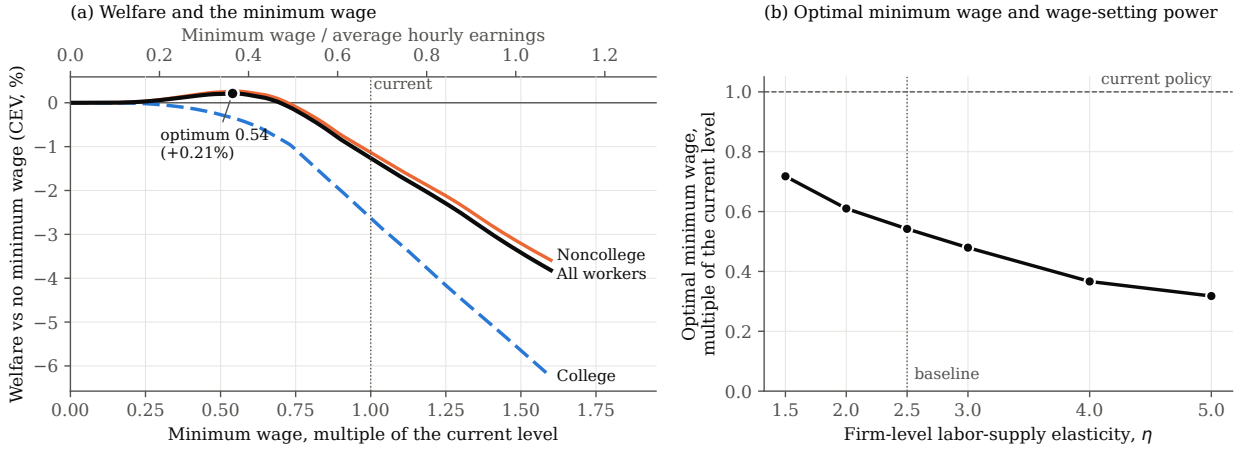
I now look for the national minimum wage that maximizes worker welfare under current tariffs, and compare the current policy with it. I hold the 2015 tariff schedule fixed and solve the model for minimum wages from none to 1.6 times the current level, in steps of 0.01. I compare each policy with the equilibrium without a minimum wage under the same tariffs, following Berger et al. (2025), with welfare measured as in equation (15), and I also report the change from the current policy to the optimum.[55] Figure 7 plots welfare against the minimum wage and reports welfare and informality at four levels, no minimum wage, the optimum, the current policy, and 1.25 times the current policy.

A minimum wage raises welfare only at low levels, and the current policy lies well beyond the point where it turns negative. Panel (a) of Figure 7 plots aggregate and education-specific

[54] Nationally, informality rises by 0.05 percentage points. It rises more among noncollege workers, 0.05 percentage points against 0.01 for college workers, the group on which the minimum wage binds. In this version worker welfare falls by 0.11 percent.

[55] Table D.9 reports welfare and informality at selected points of the grid.

Figure 7: Welfare and the minimum wage



(c) Welfare and informality at four levels of the minimum wage

	No minimum wage	Optimum	Current	1.25 times current
Minimum wage, multiple of current	0.00	0.54	1.00	1.25
Relative to average earnings (κ)	0.00	0.36	0.67	0.84
Worker welfare vs no minimum wage (consumption-equivalent, percent)				
All workers	0	+0.21	−1.26	−2.29
Noncollege	0	+0.26	−1.13	−2.12
College	0	−0.34	−2.64	−4.16
Inclusive informality (percent of workers)				
All workers	53.3	55.1	66.3	72.3
Noncollege	60.2	62.6	76.2	82.6
College	34.0	34.7	40.1	44.6

Notes: Panel (a): consumption-equivalent welfare of workers relative to the no-minimum-wage equilibrium under the 2015 tariff schedule, for all workers (utilitarian aggregate), noncollege workers, and college workers. The bottom axis expresses the minimum wage as a multiple of its current level; the top axis reports the same policy relative to average hourly earnings, which are normalized to one in every equilibrium. The minimum wage varies from 0 to 1.6 times its current level in steps of 0.01. The dot marks the optimum (0.54) and the dotted line the current policy. Panel (b): the welfare-maximizing minimum wage, as a multiple of its current level, when the model is solved with the firm-level labor-supply elasticity η changed and all other parameters at their estimates. The dotted line marks the baseline, $\eta = 2.5$. Panel (c): the same welfare measure and inclusive informality, the share of informal wage workers and the self-employed among workers, at four levels of the minimum wage; selected points of the grid are in Appendix Table D.9.

welfare against the minimum wage. The welfare-maximizing minimum wage is about 0.54 times the current Colombian minimum wage.[56] In wage-relative terms, the optimum sets κ

[56] I report outcomes at 0.54, the minimum wage that maximizes worker welfare among the solved grid points. Worker welfare is flat near the top. The policies 0.54 and 0.55 are within 0.001 percentage points of each other. Welfare falls faster above this range than below it. It is 0.086 percentage points below the maximum at 0.64 and 0.037 below at 0.44. Table D.12 reports how the optimum changes under alternative assumptions. Allowing workers to migrate across regions moves the best policy to about 0.55 to 0.56, but

at 0.36, against 0.67 for the current policy.[57] At the current policy, aggregate worker welfare is 1.26 percent lower than without a minimum wage. At the optimum, it is 0.21 percent higher. Moving directly from the current policy to the optimum raises aggregate worker welfare by 1.50 percent.

The current minimum wage raises informality by 13.0 percentage points, and most of that increase comes from wage work. At the current minimum wage, 66.3 percent of workers are informal. Moving from the current policy to the optimum lowers informality by 11.2 percentage points, and removing the minimum wage altogether lowers it by 13.0. Among noncollege workers the informal share of wage work rises from 7.5 percent without a minimum wage to 40.7 percent at the current one, while their self-employment share rises by 3 points. Employment falls as well, by about 4 percentage points between no minimum wage and the current policy, so the minimum wage acts on both the composition of employment between formal wage work, informal wage work, and self-employment and on its level.[58]

The optimum redistributes toward noncollege workers, whereas the current policy hurts both groups. Relative to no minimum wage, the optimum raises the welfare of noncollege workers by 0.26 percent and lowers that of college workers by 0.34 percent. Noncollege workers receive the direct wage gain because the same statutory policy binds more often for them. At the current policy, both groups lose relative to no minimum wage, noncollege workers by 1.13 percent and college workers by 2.64 percent. Reducing the minimum wage from its current level to the optimum therefore raises the welfare of noncollege workers by 1.42 percent and of college workers by 2.37 percent. Both groups gain from the reduction, even though college workers would lose from introducing the optimum starting from no minimum wage. Figure 8 reports both comparisons by region and education, and the pattern holds in almost every region.[59]

The positive optimum can reflect both employer wage-setting power and redistribution. To gauge the role of wage-setting power, I solve the model again at other values of the firm-level labor-supply elasticity η, holding all other parameters at their estimates. A lower η means more wage-setting power, a larger markdown $\mu = 1 + 1/\eta$. At the baseline $\eta = 2.5$, $\mu = 1.4$, so, before payroll taxes and nonwage benefits, an unconstrained firm pays workers

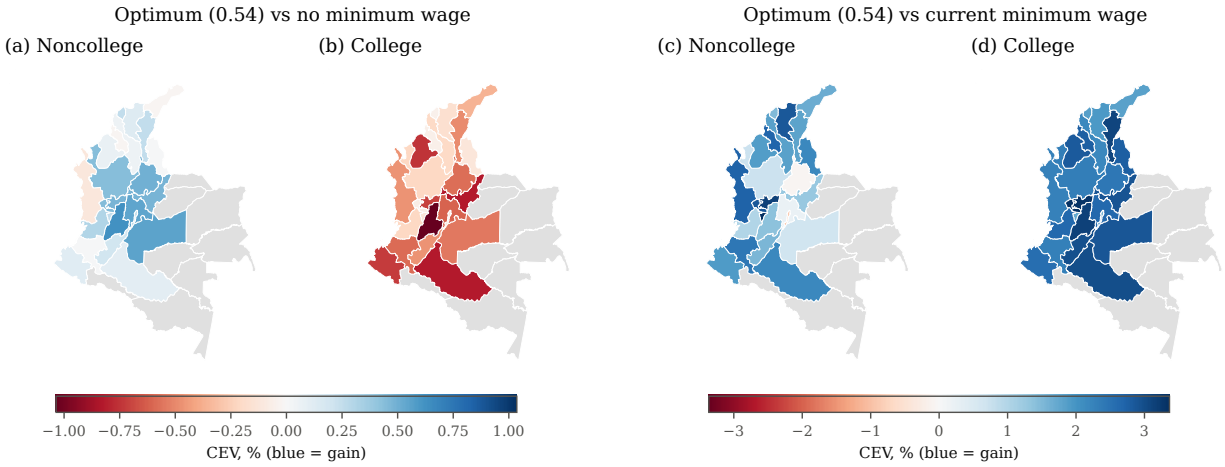
welfare at 0.54 stays within about 0.001 percentage points of the best.

[57] "The current policy" here is the 2015 level. Relative to average earnings, the minimum wage has stayed close to that level since. In the GEIH, the hourly minimum wage was 0.67 of average hourly earnings in 2015, 0.69 in 2025, and 0.72 in the first half of 2026, after the 23 percent nominal increase for 2026.

[58] The employment rate is 58.3 percent at the current policy, 61.2 percent at the optimum, and 62.1 percent without a minimum wage. The policy binds on 46 percent of noncollege formal wage workers at the current level and on 23 percent at the optimum.

[59] Relative to no minimum wage, college workers lose from the optimum in every region, while noncollege workers gain in 21 of the 24. Relative to the current policy, college workers gain in every region, and noncollege workers gain in 22 of the 24.

Figure 8: Regional and worker-type incidence of minimum-wage policy



Notes: Each panel reports the consumption-equivalent welfare change of the indicated education group in each region when the minimum wage is set at the national optimum (0.54 times its current level), under the 2015 tariff schedule. Panels (a) and (b) use the no-minimum-wage equilibrium as the reference; panels (c) and (d) use the current minimum wage. Each pair of panels shares one color scale. Gray regions are not in the model.

about 71 centavos in wages for each peso of marginal revenue product. Panel (b) of Figure 7 shows the result (Table D.10). The optimal minimum wage falls steadily as wage-setting power weakens, from 0.72 times the current level at $\eta = 1.5$ to 0.32 at $\eta = 5$, and the welfare gain it delivers falls much faster. At the highest elasticities the optimum is still positive but worth almost nothing. The current policy improves on no minimum wage only at the lowest elasticity. A positive minimum wage is therefore valuable in the model because employers have wage-setting power. Given that power, redistribution toward noncollege workers sets its level. The efficiency terms of the welfare change alone would put the optimum at about 0.22 times the current minimum wage, for a gain of only about 0.001 percent (Table D.11).

4.4 Trade and the Minimum Wage

I next ask whether the minimum wage changes what trade does to workers. As in Dix-Carneiro et al. (2026), I lower international iceberg trade costs, here by 10 percent. I do so at seven levels of the minimum wage, from none to 1.25 times the current one, each held fixed relative to average earnings, and Table 6 reports four of them, no minimum wage, the optimum of Section 4.3, the current policy, and 1.25 times the current policy. At each level, I compare the economy after the trade-cost cut with the same economy before it and measure worker welfare by the consumption-equivalent change in equation (15), and I report the change in informality alongside it.

The minimum wage barely changes the gains from trade (Table 6). The trade-cost cut

Table 6: Worker gains from a 10 percent cut in international trade costs and the informality response, by minimum wage

Panel A. All workers	No minimum wage		Optimal minimum wage		Current minimum wage		1.25 times current		Range
	Welfare (%)	Inform. (pp)	Welfare (%)	Inform. (pp)	Welfare (%)	Inform. (pp)	Welfare (%)	Inform. (pp)	Welfare (%)
Baseline	1.13	−1.16	1.15	−1.18	1.13	−0.90	1.10	−0.69	0.10
No informal firms	1.02	−0.36	1.01	−0.34	1.05	−0.42	1.10	−0.41	0.12
No informal firms or self-employment	1.14	0.00	1.12	0.00	1.18	0.00	1.12	0.00	0.11

Panel B. Welfare by worker type (%)	No minimum wage		Optimal minimum wage		Current minimum wage		1.25 times current	
	Non-college	College	Non-college	College	Non-college	College	Non-college	College
Baseline	1.12	1.28	1.13	1.32	1.12	1.28	1.08	1.29
No informal firms	1.02	0.98	1.02	0.99	1.06	0.97	1.11	0.99
No informal firms or self-employment	1.15	1.02	1.13	1.03	1.20	0.98	1.13	0.87

Notes: Welfare is the consumption-equivalent change in worker welfare, in percent, from cutting international iceberg trade costs by 10 percent, relative to the same economy at 2015 trade costs and the same minimum wage, held fixed relative to average earnings. Informality is the change in the share of workers who are informal wage workers or self-employed, in percentage points, for the same comparison. The optimal minimum wage is the level that maximizes the welfare of all workers at the 2015 tariffs, 0.54 times the current level. Range is the largest minus the smallest gain for all workers over minimum wages of 0, 0.25, 0.50, 0.54, 0.75, 1.00, and 1.25 times the current level. In the economy without informal firms or self-employment, the self-employment shifters are set to zero. Every economy keeps the estimated parameters; the wage-work versus self-employment elasticity is 5 for noncollege and 1.5 for college workers.

raises worker welfare by 1.13 percent without a minimum wage, by 1.15 percent at the optimum, and by 1.13 percent at the current one, and across the seven levels the gain of all workers varies by at most 0.10 percentage points. The minimum wage is defined relative to average earnings, so the trade-cost cut leaves the set of firms it constrains almost unchanged. The share of noncollege formal wage workers at the minimum wage moves from 46.5 to 47.1 percent.

College workers gain more from the trade-cost cut than noncollege workers. The trade-cost cut lowers the price of imported goods, which raises workers' real income, but it also lowers earnings in tradable self-employment, which competes with imports.[60] Tradable self-employment accounts for 22 percent of noncollege work and 4 percent of college work, so

[60]Tradable self-employment earnings fall by about 1 percent relative to wage earnings for noncollege workers and by 2 percent for college workers.

college workers gain more, 1.28 against 1.12 percent at the current minimum wage.

The trade-cost cut also lowers informality, and by less the higher the minimum wage. It formalizes the tradable sector by about 4 percentage points at every minimum wage, through the export expansion of Section 4.2.[61] The national response nonetheless falls from 1.16 percentage points without a minimum wage to 0.69 at 1.25 times the current level. The tradable sector formalizes by about the same amount at every level, and the difference comes from the nontradable sector, where informality rises by 0.14 percentage points without a minimum wage and by 0.66 at 1.25 times the current level, because the export expansion raises wages, which pushes nontradable firms at the formality margin into informality, and a higher minimum wage leaves more firms at that margin.

To isolate the role of informal employment, I repeat the exercise in two economies that keep the estimated parameters. In the first, informal firms cannot operate. In the second, self-employment is also shut down, which corresponds to the no-informality scenario of Dix-Carneiro et al. (2026), who count the self-employed as informal firms with one worker. Removing informal firms lowers the gain slightly, to 1.02 percent without a minimum wage, 1.01 percent at the optimum, and 1.05 percent at the current one, against 1.13, 1.15, and 1.13 in the baseline, and the minimum wage still matters little. In that economy the trade-cost cut lowers informality by less than half a percentage point, because the formalization margin of wage work is gone and only self-employment remains. Removing self-employment as well raises the gain to 1.18 percent at the current minimum wage. The increase goes to noncollege workers, whose gain rises to 1.20 percent because they no longer hold the tradable self-employment jobs whose earnings fall. In Dix-Carneiro et al. (2026), informality more than doubles the real income gains from trade, because trade reallocates resources from informal firms, which escape taxes and regulations, to formal firms. In this model, informality includes tradable self-employment, whose earnings fall relative to wage earnings when imports become cheaper, so informality lowers workers' gains instead, but the difference is small at the estimate, 0.05 percentage points at the current minimum wage, because noncollege workers leave tradable self-employment readily when its earnings fall.

4.5 Trade Policy and the Optimal Minimum Wage

I finally solve the model under four tariff regimes at every level of the minimum wage, to ask how informality responds to each policy and whether the trade regime changes the welfare-maximizing minimum wage. The regimes are free trade, the 2015 schedule, the 2009

[61] Formal tradable employment rises by 5 to 9 percent, tradable informal wage work falls, and tradable self-employment shrinks by 4.5 percent. At the current minimum wage the trade-cost cut lowers informality by 0.90 percentage points.

schedule, and a higher-protection schedule, with mean tariffs of 0, 3.5, 7.9, and 12.3 percent. In each, the minimum wage is defined relative to average earnings, the wage-indexed rule of Section 3.6. Table 7 reports informality under each regime, nationally and by sector, at the four levels of the minimum wage of Figure 7.

Informality responds far more to the minimum wage than to tariffs. A tariff reaches only the tradable third of workers, where import competition and the export expansion pull in opposite directions and the export expansion wins, and the nontradable sector offsets part of the effect through the indexed minimum wage. Between no minimum wage and the current one, it rises by 13 percentage points in every regime, while between free trade and 12 points of protection it rises by at most one percentage point. Protection raises informality through two channels. Under balanced trade, a tariff that lowers imports also lowers exports, through the real appreciation that restores the trade balance, so exporting pays less and fewer tradable firms formalize to export. And the tariff raises the price of import-competing goods, so tradable self-employment earns more and more noncollege workers choose it. The effect is concentrated in the tradable sector. The minimum wage, by contrast, moves both sectors equally.[62]

A higher minimum wage weakens the formalization that a tariff cut brings. Section 2 compared local labor markets under one national minimum wage, whereas here the national level varies. In both comparisons, the formalization that a tariff cut brings is smaller when the minimum wage binds more tightly. Moving from high protection to free trade lowers national informality by 0.97 percentage points without a minimum wage and by 0.54 at the current one (Table 7). The tradable sector formalizes by about the same amount at every level of the minimum wage. The difference is in the nontradable sector. The tariff cut expands formal tradable firms and raises average earnings, so the minimum wage, which is set relative to average earnings, rises with them and pushes nontradable firms at the formality margin into informality. The minimum wage's own effect on informality, by contrast, is almost the same under every tariff.[63]

The welfare-maximizing minimum wage is the same in all four regimes,[64] 0.54 times the

[62] At the current minimum wage, tradable self-employment is 3 percent larger under high protection than under free trade and exports are 23 percent smaller. High protection raises tradable-sector informality by 3.0 percentage points at the current minimum wage. Two thirds of the increase is informal wage work and the rest self-employment. Nontradable informality falls by 0.7 percentage points, all of it informal wage work, the mirror image of the spillover in Section 4.2. From no minimum wage to the current one, tradable informality rises by 12.6 percentage points and nontradable informality by 13.2.

[63] Among noncollege workers, the group on which the minimum wage binds, the fall is 1.16 against 0.62. The tradable sector formalizes by 3.4 percentage points without a minimum wage and by 2.8 at 1.25 times the current level. The nontradable spillover is 0.3 percentage points without a minimum wage and 0.7 at the current one, because a higher minimum wage leaves more nontradable firms at the margin. The minimum wage's own effect is 13.2 percentage points under free trade and 12.7 under high protection.

[64] The four regimes are shown side by side in Appendix D.8, together with the elasticity ladder under each

Table 7: The response of informality to the minimum wage and to protection

	Minimum wage (multiple of current)			
	0.00	0.54	1.00	1.25
Informality, all workers (percent), by regime				
Free trade	53.0	54.9	66.2	72.2
2015 tariffs	53.3	55.1	66.3	72.3
2009 tariffs	53.7	55.5	66.5	72.5
High protection	54.0	55.8	66.7	72.7
Informality by sector, 2015 tariffs (percent of the sector's workers)				
Tradable sector	55.3	58.4	67.9	72.2
Nontradable sector	52.3	53.5	65.5	72.4
Protection effect: high protection minus free trade (pp)				
All workers	+0.97	+0.89	+0.54	+0.50
Noncollege	+1.16	+1.04	+0.62	+0.56
College	+0.47	+0.47	+0.33	+0.35
Tradable sector	+3.42	+3.28	+3.04	+2.84
Nontradable sector	−0.26	−0.31	−0.70	−0.65
Minimum-wage effect: this level minus none (pp), by regime				
Free trade	0	+1.86	+13.16	+19.16
2015 tariffs	0	+1.84	+13.03	+19.01
2009 tariffs	0	+1.81	+12.88	+18.84
High protection	0	+1.78	+12.74	+18.69

Notes: Inclusive informality, the share of informal wage workers and the self-employed among workers, pooled over the 24 regions and both education groups with employment weights. A sector's informality counts the informal wage workers and the self-employed producing that sector's good over all workers of the sector; the tradable sector has 33 percent of workers in every regime. Mean tariffs are 0 (free trade), 3.5 percent (2015), 7.9 percent (2009), and 12.3 percent (high protection). The minimum wage is held fixed relative to average earnings.

current level, or κ of 0.36. It stays there because, in general equilibrium, tariffs barely change what a higher minimum wage gains and what it costs.[65] The gain is the higher pay of the noncollege workers it covers and the narrower labor wedge at the firms it constrains. The cost is the firms that exit or turn informal and the workers who move into informal wage work and self-employment. The efficiency gains of the minimum wage are small here, as

regime (Table D.14), which differs by at most 0.01 across regimes at every η.

[65] What tariffs change is the level of worker welfare at every minimum wage. Measured against the 2015 equilibrium with the current minimum wage, worker welfare at the optimal minimum wage is 1.00 percent higher under free trade, 1.50 percent higher under 2015 tariffs, 2.03 percent higher under 2009 tariffs, and 2.46 percent higher under high protection. This ranking comes from the lump-sum rebate of tariff revenue to workers and from the terms of trade, the same forces behind the welfare loss from the 2010–2011 cuts in Section 4.2. International trade costs also move the optimum little. Changing every region's international trade cost by up to 10 percent in either direction moves the best policy between 0.53 and 0.55 (Appendix Figure D.5).

in the closed-economy analysis of Berger et al. (2025), so redistribution sets its level, and redistribution works through the bite. In the spirit of the targeting principle of Bhagwati and Ramaswami (1963), the minimum wage acts on a domestic distortion, employer wage-setting power. Trade policy can then change the best minimum wage in two ways, by changing the markdown or by changing how many workers the minimum wage binds on. The markdown is the same at every unconstrained firm by assumption, so a tariff shifts labor demand without changing the distortion. This aligns with the finding of Felix (2026) that most of the wage decline after Brazil's trade liberalization came from lower marginal revenue products rather than from greater labor-market power, even though concentration rose. Because the optimal minimum wage is expressed relative to average earnings, the bite also changes little across regimes. This does not mean that the optimal minimum wage is constant in other units. Relative to the 2015 regime, the optimal minimum wage measured in consumption is 0.1 percent higher under free trade and 0.3 percent lower under high protection, and measured in foreign currency it is 1.2 percent lower under free trade and 3.0 percent higher under high protection, because protection appreciates the real exchange rate.[66] The nominal minimum wage that implements the optimum must therefore move with nominal average earnings.

5 Conclusion

This paper studies how the minimum wage shapes informality responses to trade liberalization and how the two policies jointly determine welfare. Combining Colombia's 2010–2011 tariff reform with differences in the minimum-wage bite across local labor markets, I find that a one-percentage-point larger tariff reduction raises informality by 0.8 percentage points where the minimum wage binds more tightly, and has no detectable effect where it binds less tightly. Formal employment near the statutory minimum declines, and informal employment below it rises.

I then build and estimate a spatial general-equilibrium model with heterogeneous firms and export selection, employer wage-setting power, and endogenous formality and self-employment. In the model, a moderate minimum wage can raise employment by limiting employers' wage-setting power, but when import competition lowers market access, informality rises where enough minimum-wage employment is at firms that ration formal jobs. The tariff cuts reduce informality in the aggregate, while the regional loss of labor demand that reduced-form designs measure raises it. Yet informality responds far more to the minimum

[66] The regional range under high protection runs from 2.0 percent higher in La Guajira to 1.4 percent lower in Chocó. The minimum wage in units of consumption is κ divided by the regional consumption price index, averaged over regions with worker weights.

wage than to tariffs, and a higher minimum wage weakens the formalization that tariff cuts bring. Evaluating the labor-market effects of trade liberalization therefore requires accounting for domestic labor-market policies. The welfare-maximizing minimum wage is about 54 percent of the current one, and moving to it raises worker welfare by 1.5 percent. It is the same across tariff regimes, and the minimum wage barely changes the gains from cutting international trade costs by 10 percent, 1.1 percent with or without a minimum wage. Removing informal firms and self-employment raises that gain to 1.2 percent, because tradable self-employment competes with imports.

I see two natural directions for future work. First, the quantitative model pools the tradable industries of each region into one sector, so the quantitative comparison with the reduced-form evidence is conducted across regions rather than across industries within a region. The model reproduces the reduced-form heterogeneity only weakly. Richer sectoral heterogeneity and input-output linkages would allow the comparison across industries within a region to be taken to the model directly.[67] Second, the model has no unemployment. Workers who are not hired at the minimum wage reallocate to other wage jobs or to self-employment. In practice, some displaced workers remain unemployed while others take up self-employment as a form of disguised unemployment. The reduced-form response is concentrated in self-employment, which may partly reflect this margin. Modeling unemployment and labor-market dynamics would distinguish the two and capture the costs workers bear during the transition after a trade reform.

[67] A multi-sector version of the model with input-output linkages is work in progress.

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A Appendix to Section 2

A.1 Data and Sample Construction

The GEIH is a monthly repeated cross-section, not a worker panel. Pooling 2007–2019 gives about 3.8 million employed person-month observations before restrictions. I exclude January interviews, whose earnings question refers to December and would otherwise be compared with the newly adjusted January minimum wage, restrict the sample to workers aged 18–65 in the 29 two-digit agriculture, mining, and manufacturing industries that carry tariff lines, and drop observations with missing employment status, region, education, industry, or survey weight. Electricity, gas, and water supply (ISIC 40) also carries a tariff line but lies outside the quantitative model's tradable sector (ISIC 01–37), so I exclude it. After removing singleton cells, 689,898 worker-month observations remain. All descriptive statistics and regressions use the GEIH survey weights, and all regressions include calendar-month fixed effects.

Because the sample covers agriculture, mining, and manufacturing, it is less urban and more male than the Colombian workforce as a whole or a manufacturing-only sample. The same industries, plus recycling (ISIC 37), make up the tradable sector of the quantitative model. Appendix A.11 reports manufacturing-only estimates, and Section 4 describes the customs records and interregional input-output accounts used to estimate the spatial model.

A.2 Tariff Construction and Industry-Level Changes

UNCTAD-TRAINS reports effectively applied and statutory Most Favored Nation tariff rates at the HS6 product level. Products are mapped to four- and two-digit ISIC Rev. 3 industries, and industry rates are constructed as simple averages over the mapped tariff lines. Figure 2 uses the four-digit measures and the reduced-form regressions the two-digit measures. The baseline treatment is the change in the effectively applied industry rate between 2009 and 2011. Appendix A.6 uses the statutory tariff reduction as an instrument. Table A.1 reports all three two-digit measures for each industry.

Three industries had small tariff increases between 2009 and 2011. I keep them because they are part of the same schedule adjustment, and dropping them would select industries on the realized treatment. Electricity, gas, and water supply, whose applied rate rose by 4.9 percentage points, is excluded because it lies outside the tradable sector of the quantitative model. The average applied reduction is 2.89 percentage points, with a standard deviation of 2.68 and an employment-weighted average of 2.80. The statutory and applied reductions share the same compression pattern and differ because applied rates incorporate preferential

Table A.1: Tariff rates and reductions by industry

ISIC rev.3	Industry	Applied rate (%)		Reduction (pp)			Worker share (%)
		2009	2011	2009–11	2010–11	MFN	
1	Agriculture, hunting, related services	9.28	6.51	2.77	1.66	1.18	49.54
2	Forestry and logging	7.60	5.95	1.65	1.36	1.77	0.71
5	Fishing	5.40	5.35	0.05	1.18	4.33	2.17
10	Mining of coal and lignite	4.94	4.90	0.04	0.07	0.00	0.81
11	Crude petroleum and natural gas	9.99	4.92	5.07	4.26	5.00	0.91
13	Mining of metal ores†	2.41	3.34	-0.93	-0.93	0.00	1.49
14	Other mining and quarrying†	3.62	3.65	-0.03	0.36	0.02	0.60
15	Food products and beverages†	7.84	7.91	-0.07	3.19	1.53	11.06
16	Tobacco products	3.65	1.68	1.97	1.41	5.00	0.12
17	Textiles	14.27	7.20	7.07	8.41	9.14	2.27
18	Wearing apparel and fur	17.83	13.89	3.94	5.41	5.00	7.56
19	Leather, luggage and footwear	16.65	13.04	3.61	5.64	5.04	2.91
20	Wood and wood products	5.87	2.45	3.42	4.05	9.07	0.78
21	Paper and paper products	8.24	4.83	3.41	3.64	4.34	0.70
22	Publishing and printing	6.27	4.75	1.52	4.68	3.05	1.43
23	Coke and refined petroleum	7.46	3.73	3.73	4.02	4.16	0.08
24	Chemicals and chemical products	5.52	4.00	1.52	1.48	2.07	2.45
25	Rubber and plastics	11.73	5.50	6.23	7.51	7.87	1.56
26	Other non-metallic minerals	8.99	4.56	4.43	6.30	7.35	1.73
27	Basic metals	4.94	2.59	2.35	2.54	4.24	0.38
28	Fabricated metal products	11.48	5.36	6.12	6.20	7.05	3.36
29	Machinery and equipment	8.15	5.03	3.12	3.41	3.54	0.85
30	Office and computing machinery	5.01	4.46	0.55	0.39	0.47	0.04
31	Electrical machinery	10.23	5.23	5.00	5.30	5.58	0.36
32	Radio, TV and communication equipment	3.83	3.34	0.49	0.67	2.40	0.04
33	Medical and optical instruments	6.12	4.88	1.24	1.39	1.30	0.33
34	Motor vehicles and trailers	22.01	10.74	11.27	10.43	2.07	0.63
35	Other transport equipment	1.79	1.68	0.11	1.03	0.12	0.26
36	Furniture and manufacturing n.e.c.	15.56	11.33	4.23	4.78	4.17	4.88
Mean		8.51	5.61	2.89	3.44	3.68	3.45
Std. dev.		4.90	3.09	2.68	2.75	2.70	
Worker-weighted mean		10.09	7.29	2.80	2.97	2.62	

Notes: The 29 two-digit ISIC rev.3 tradable industries of the estimation sample. Electricity, gas and water supply (ISIC 40) also carries a tariff line but is excluded, because the quantitative model's tradable sector covers ISIC 01–37. Applied (AHS) and statutory (MFN) rates from UNCTAD TRAINS, simple averages over the HS6 lines mapped to each industry. Reduction is the 2009 rate minus the 2011 rate, so a positive entry is liberalization. The 2010–11 column is the alternative window and the MFN column the instrument. Worker share is the share of the estimation sample's survey-weighted person-months. † marks the three industries whose applied rate rose. The correlation between the 2009–11 reduction and the 2009 level is 0.82.

agreements and exemptions.

Table A.2 correlates the applied tariff reduction with pre-reform industry characteristics. The reduction is strongly related to the 2009 tariff level, as the compression of the schedule implies, and not significantly related to pre-reform informality, its 2007–2009 change, average wages, or the female and tertiary-educated worker shares. The correlation with the urban

worker share is positive and marginally significant. I read this as little selection on observed pre-reform characteristics.

Table A.2: Tariff reductions and pre-reform industry characteristics

Pre-reform industry characteristic	Correlation	Permutation p-value
Applied tariff rate, 2009	0.823	< 0.001
Average informality, 2007–2009	−0.246	0.205
Change in informality, 2007–2009	0.031	0.866
Log average hourly wage, 2007–2009	0.187	0.332
Female worker share, 2007–2009	0.100	0.604
Tertiary-educated worker share, 2007–2009	0.046	0.811
Urban worker share, 2007–2009	0.354	0.053

Notes: Each row reports the industry-level correlation between the stated characteristic and the 2009–2011 reduction in the effectively applied tariff, measured in percentage points. Pre-reform worker characteristics are survey-weighted within the 29 two-digit tradable industries of the estimation sample; January interviews are excluded. The change in informality is the 2009 value minus the 2007 value. Permutation p-values are based on 5,000 reassignments of the tariff reduction across industries.

A.3 Labor-Market Statistics for All Sectors

The main-text statistics describe workers in tariff-exposed tradable industries because that is the estimation sample. In the all-sector 2015 data used to construct the quantitative moments, the survey-weighted national informality rate is 69.9 percent and self-employment accounts for 51.3 percent of employment. Table A.3 instead summarizes the cross-sectional distribution of region × education cells in 2009 using workers from all Colombian sectors, including nontradables. Its mean is unweighted across the 96 cells, not the national aggregate. The tariff regressions stay within tradable industries, since nontradable industries have no tariff of their own, so the table is descriptive only.

A.4 The Minimum Wage, 2007–2019

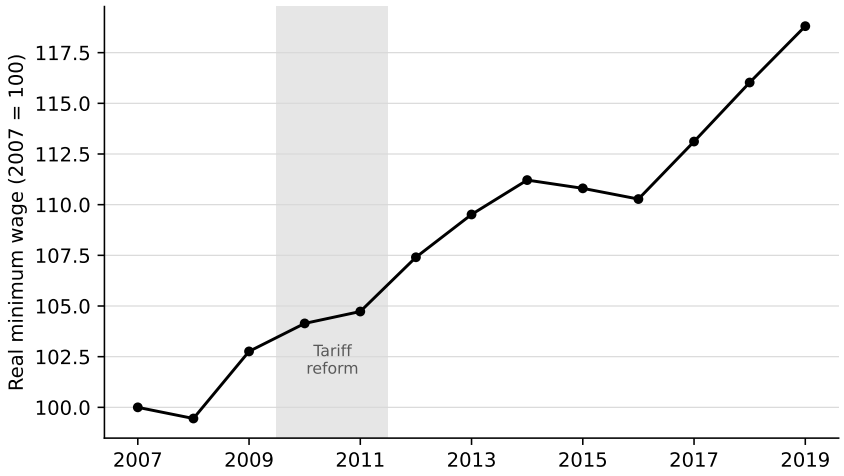
Figure A.1 deflates the statutory monthly minimum wage by the annual average of the monthly consumer price index. The real minimum wage rose by 18.8 percent between 2007 and 2019. It fell slightly in 2008, 2015, and 2016, when inflation exceeded the nominal adjustment, and rose by about 2.5 percent per year in 2017–2019. Around the tariff reform, it rose by 1.3 percent in 2010 and 0.6 percent in 2011.

Table A.3: Labor-market statistics across all Colombian sectors, 2009

	Mean	Std. dev.	P10	Median	P90	Cells
Informality rate	0.734	0.190	0.440	0.778	0.951	96
Self-employment rate	0.514	0.159	0.319	0.494	0.726	96
Informal wage employment rate	0.220	0.094	0.105	0.209	0.340	96
Share of formal salaried workers within 1.10 MW	0.447	0.206	0.146	0.502	0.680	96
Kaitz index (MW / median formal salaried wage)	0.820	0.208	0.488	0.911	1.000	96
Mean formal salaried hourly wage / MW	1.733	0.905	1.067	1.293	3.053	96
Mean informal wage-worker hourly wage / MW	1.048	0.392	0.700	0.871	1.682	96

Notes: The unit of observation is a region × education cell. The table reports the unweighted distribution across 96 cells in the 2009 GEIH, February–December, with survey-weighted cell means. Wages are hourly and expressed relative to the hourly minimum wage. The Kaitz index is the hourly minimum wage over the cell's survey-weighted median hourly wage of formal salaried workers. Informality is the sum of self-employment and informal wage employment. The table includes workers in tradable and nontradable sectors.

Figure A.1: Real minimum wage, 2007–2019



Notes: The statutory monthly minimum wage deflated by the annual average of the monthly DANE consumer price index, indexed to 2007 = 100. The shaded area marks the 2010–2011 tariff reform.

A.5 Construction and Variation of the Minimum-Wage Bite

For each region d and education group g, the baseline bite is

$$\text{Bite}_{dg} = \frac{\sum_{i\in(d,g)} \omega_i \mathbf{1}\{i \text{ is a formal salaried worker and } w_i \leq 1.10\, MW_t\}}{\sum_{i\in(d,g)} \omega_i \mathbf{1}\{i \text{ is a formal salaried worker}\}},$$

where ω_i is the survey weight and the sums pool 2007–2009. Hourly earnings and the hourly equivalent of the contemporaneous minimum wage are used. Averaging over three years reduces sampling noise, and all three years precede the tariff reform.

The baseline cell groups workers by region and education but not by industry. Workers

can move across industries within a region, while education captures differences in skills and wage distributions that determine how tightly the national minimum wage binds. Leaving industry out of the baseline cell also keeps the bite apart from the industry-level tariff treatment. Appendix A.10 alternatively measures the bite at the industry × region and industry × region × education levels. These finer cells let the bite vary by industry, but they come from much smaller samples.

The formal-salaried denominator is chosen to measure the concentration of compliant jobs near the statutory minimum wage. A denominator containing informal workers would also vary with the prevalence of informal employment. Appendix A.10 reports the results with that denominator, with thresholds at 1.00 and 1.05 times the minimum wage, with the continuous bite, terciles, and Kaitz-index measures, and with the alternative cell definitions.

The baseline bite measure is estimated precisely at the region × education level. A split-sample calculation produces a correlation of 0.96 between the bite computed on two random halves of the pre-reform observations, and the sampling-variance reliability is approximately 0.99. The within-education component is also precisely measured, with an estimated reliability of approximately 0.97. I therefore report both the pooled comparison and specifications that use only the variation within education groups.

A.6 Interaction Specification, Instruments, and Inference

The dynamic version of equation (1) is

$$\begin{aligned}\text{Informality}_{ijdgt} = &\sum_{h\neq 2010} \beta_{L,h}\mathbf{1}[t=h]\Delta\tau_j + \sum_{h\neq 2010} \beta_{H,h}\mathbf{1}[t=h]\Delta\tau_j \text{High}_{dg} \\ &+ \mathbf{X}_i'\mathbf{\Gamma}_t + \alpha_{jdg} + \delta_{dgt} + \varepsilon_{ijdgt}. \end{aligned} \tag{A.1}$$

The two paths plotted in Figure 4 are $\beta_{L,h}$ and $\beta_{L,h} + \beta_{H,h}$. The differential is $\beta_{H,h}$. The outcome and tariff reduction are expressed in percentage points, so each coefficient is the percentage-point change in informality associated with a one-percentage-point tariff reduction.

Table A.4 reports the static differential under four sets of fixed effects. With only bite-group × year effects and the tariff-reduction levels, the differential is −0.15. Adding industry × region × education effects absorbs persistent differences across these cells and raises the differential to 0.64. It remains between 0.64 and 0.71 as region × year and education × year effects, followed by region × education × year effects, are added.

The statutory MFN reduction is an alternative source of tariff variation. Both the applied and statutory reductions arise from the compression of the tariff schedule, but the applied

Table A.4: Fixed-effect ladder

	Low path		High path		Gap		Static	
	2007–09	2011–19	2007–09	2011–19	2007–09	2011–19	differential	N
A. Region × education bite (headline split)								
L0	−0.494	0.508	0.615	1.203	1.109	0.695	−0.152	690,030
	(0.286)	(0.309)	(0.516)	(0.363)	(0.552)	(0.483)	(0.560)	
L1	−0.315	−0.048	0.338	1.086	0.652	1.134	0.636	689,898
	(0.202)	(0.254)	(0.334)	(0.352)	(0.336)	(0.450)	(0.298)	
L2	−0.289	−0.082	0.376	1.087	0.665	1.169	0.661	689,898
	(0.186)	(0.230)	(0.280)	(0.348)	(0.298)	(0.431)	(0.275)	
L3 (headline)	−0.229	−0.076	0.405	1.116	0.634	1.193	0.706	689,898
	(0.230)	(0.261)	(0.261)	(0.326)	(0.280)	(0.420)	(0.273)	
B. Education split: primary or lower secondary								
L0	−0.309	0.207	0.456	1.302	0.765	1.095	0.492	690,030
	(0.257)	(0.200)	(0.487)	(0.339)	(0.400)	(0.310)	(0.294)	
L1	−0.224	−0.045	0.259	1.093	0.484	1.138	0.763	689,898
	(0.231)	(0.221)	(0.273)	(0.376)	(0.205)	(0.436)	(0.325)	
L2	−0.218	−0.087	0.318	1.137	0.536	1.224	0.809	689,898
	(0.203)	(0.199)	(0.226)	(0.377)	(0.185)	(0.428)	(0.308)	
L3 (headline)	−0.152	−0.080	0.340	1.173	0.492	1.253	0.869	689,898
	(0.249)	(0.228)	(0.232)	(0.355)	(0.174)	(0.400)	(0.293)	

Notes: Two-path OLS event studies and the matching static regression under four fixed-effect sets, from loose to tight. L0: High × year cells, with the dose level and the dose × High level entered as regressors. L1: L0 plus industry × region × education cells. L2: L1 plus region × year and education × year cells (for the education split High × year is then spanned). L3: industry × region × education and region × education × year cells, the headline specification of Table 2. Every rung includes the demographic controls × year and calendar-month fixed effects, survey weights and two-way clustering by industry and region; base year 2010. Entries are percentage points of informality per percentage point of applied cut, with standard errors in parentheses. The static differential is the coefficient on dose × post × High.

tariff also incorporates preferential agreements and exemptions. At the industry level, the first-stage regression of the applied reduction on the statutory reduction has a slope of 0.60, a standard error of 0.15, and an F-statistic of 15.1. In the worker-level static regression, however, the Kleibergen–Paap F-statistic is 4.79, so the instrument is weak by conventional standards. The two instruments are individually strong, with Sanderson–Windmeijer F-statistics of 30 and 41, but nearly collinear, because the second is the first interacted with High. Appendix Table A.5 reports the static coefficients for the headline OLS specification alongside the corresponding instrumented estimates. The static instrumented differential is 0.69, close to the OLS estimate of 0.71.

With treatment varying across only 29 industries and 24 regions, inference is the main difficulty. The conventional standard errors in Table A.5 are two-way clustered by industry and region, but cluster asymptotics may be optimistic with so few clusters. As additional checks, I estimate a covariate-free analogue on an industry × region × education × year panel of cell means, using the same fixed effects and cell-size weights. Its static differential is 0.75, compared with 0.71 in the worker-level regression. For this collapsed-cell estimate,

Table A.5: OLS and instrumented static interaction estimates

	OLS (1)	Statutory IV (2SLS) (2)
Static interaction specification, post = 2011–2019		
Low bite: dose × post (β_L, slack)	0.088	0.154
	(0.145)	(0.198)
Differential: dose × post × High (β_H)	0.706	0.691
	(0.273)	(0.311)
High bite: $\beta_L + \beta_H$ (binds)	0.795	0.844
	(0.250)	(0.341)
Observations	689,898	689,898
Kleibergen–Paap rk Wald F, static		4.79
Industry × region × education FE	Yes	Yes
Region × education × year FE	Yes	Yes
Demographic controls × year; calendar-month FE	Yes	Yes
Sample years	2007–2019	2007–2019

Notes: Worker-level regressions of the informality indicator on the applied 2009–2011 tariff cut of the worker's industry (dose, percentage points) interacted with post (2011–2019) and with High, the indicator for high minimum-wage-bite region × education cells (share of formal salaried workers paid at or below 1.10 times the hourly minimum wage, 2007–2009). The sample contains 29 tradable industries. Entries: percentage points of informality per percentage point of cut; high bite = $\beta_L + \beta_H$. Column (2) instruments the applied cut with the statutory MFN cut. Controls: year-specific age, age squared, male, age × male, literacy, household head, married and urban, plus calendar-month fixed effects; survey weights. Parentheses contain standard errors two-way clustered by 29 industries and 24 regions. Small-cluster inference based on a collapsed-cell analogue is reported separately in the text.

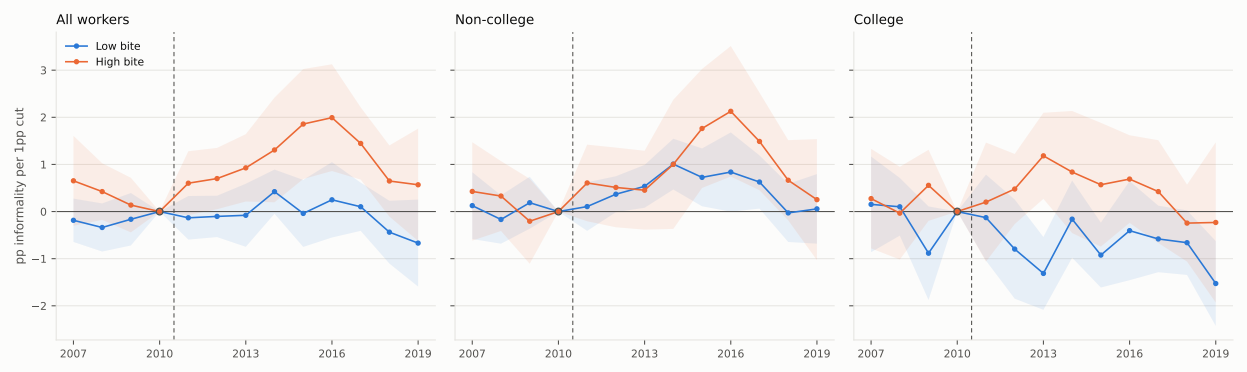
the wild-cluster-bootstrap p-value is 0.083. Permutation p-values are 0.017 unconditionally and 0.006 conditional on the 2009 applied tariff. I report these values separately because they are for the collapsed-cell estimate, not the worker-level coefficient in Table A.5.

A.7 Dynamics and Pre-Reform Diagnostics

Figures A.2–A.4 report the interaction event study for the full sample and the noncollege and college subsamples under three functional forms, with the bite measured at the region × education level. In every sample and functional form, informality rises after the reform in the highest-bite group. The high-minus-low differential is positive in every case except college workers under terciles, where the lowest-bite tercile also rises and its path is imprecisely estimated.

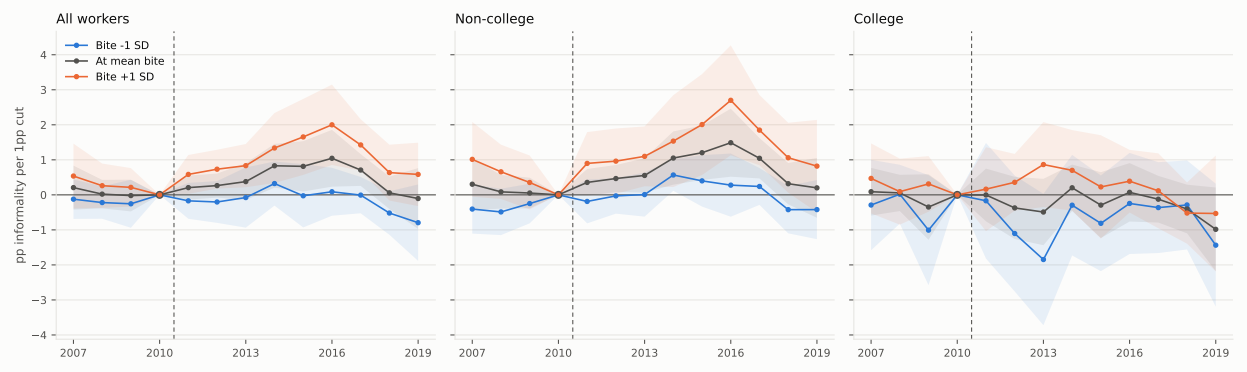
The baseline high-minus-low differential averages 0.634 over 2007–2009 and 1.193 over 2011–2019. The pre-reform average is 53 percent of the post-reform average. With conventional clustered standard errors, the 2007 coefficient (0.84) and the pre-reform average are significant at the 5 percent level. The 2008 and 2009 coefficients are not. The wild-bootstrap p-value of the collapsed-cell pre-reform average is 0.274. Subtracting the pre-reform average from the post-reform average gives 0.559. The baseline specification does not adjust

Figure A.2: Event studies using a binary bite split



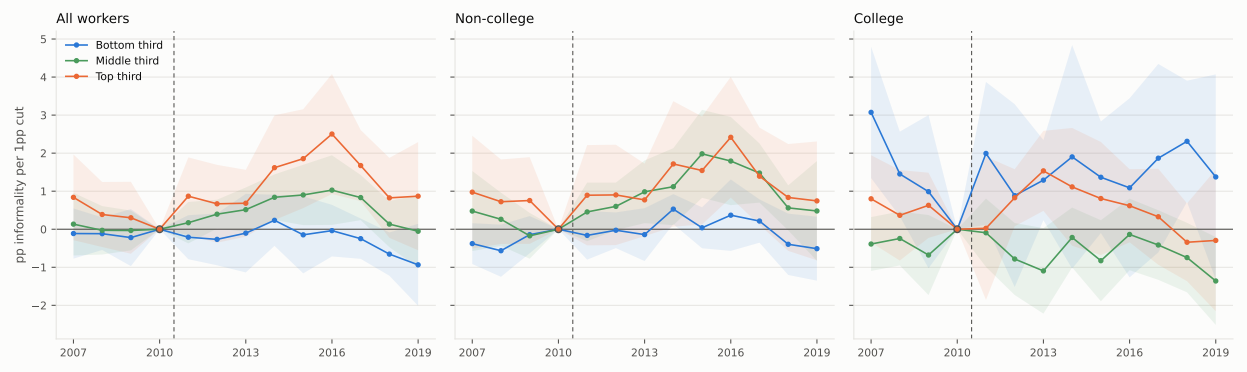
Notes: Panels show the full sample, noncollege workers, and college workers, with the bite measured at the region × education level. Each panel plots the informality response to a one-percentage-point applied tariff reduction in each year, with 2010 omitted. Shaded bands are 90 percent confidence intervals based on standard errors two-way clustered by industry and region.

Figure A.3: Event studies using the continuous bite, standardized to one standard deviation



Notes: Conventions follow Figure A.2.

Figure A.4: Event studies comparing bite terciles



Notes: Conventions follow Figure A.2.

for differential linear trends. The pre-reform differences warrant caution in interpreting the post-reform differential causally.

Of the bite's variance, 82.2 percent lies between education groups. Splitting the sample by education gives positive post-reform differentials for both college and noncollege workers. Standardizing the bite within education, which leaves only regional differences, gives a positive estimate for college workers but not for noncollege workers, and pooling the two gives -0.16 with a p-value of 0.325 because the signs differ. The data therefore support heterogeneity across region $\times$ education labor markets and leave open whether regional variation matters on its own, apart from education.

A.8 Self-Employment and Informal Wage Employment

Informality is the sum of self-employment and informal wage employment, so re-estimating equation (1) for the two components decomposes the headline estimate exactly. Under OLS, the self-employment differential is 0.89 with a conventional p-value of 0.001, while the informal-wage-employment differential is -0.19 with a p-value of 0.301. The self-employment event study has a pre-reform average of 0.15 and a post-reform average of 1.04. The additional informal employment in high-bite labor markets is therefore concentrated in own-account work.

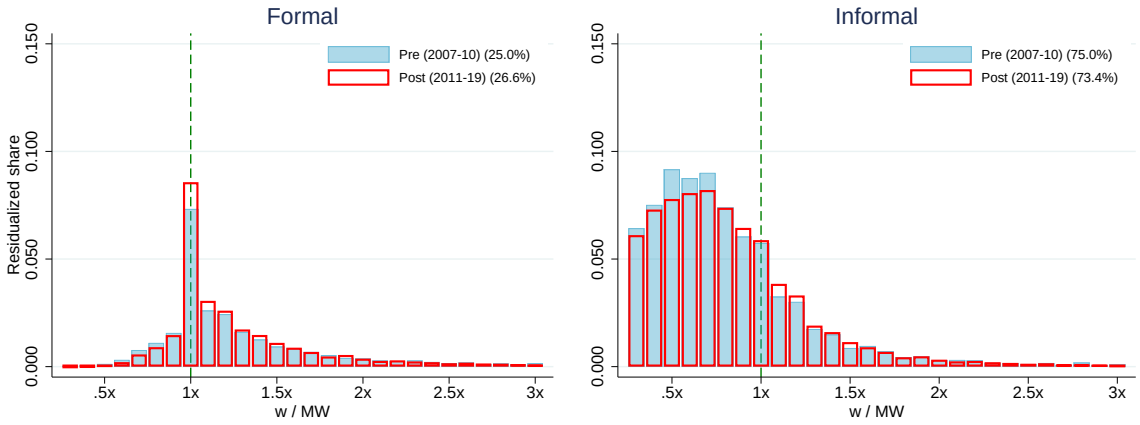
A.9 Wage-Distribution Evidence

The main text estimates equation (2) separately for 28 earnings bins of width 0.10 covering $0.25 \leq w/\text{MW} < 3.05$. Table A.6 reports the same specification for broader wage intervals, pooled and separately by education group. Table A.7 compares alternative fixed effects and a fixed-denominator outcome, and Figure A.6 and Table A.8 report dynamic versions of the broader-band regressions.

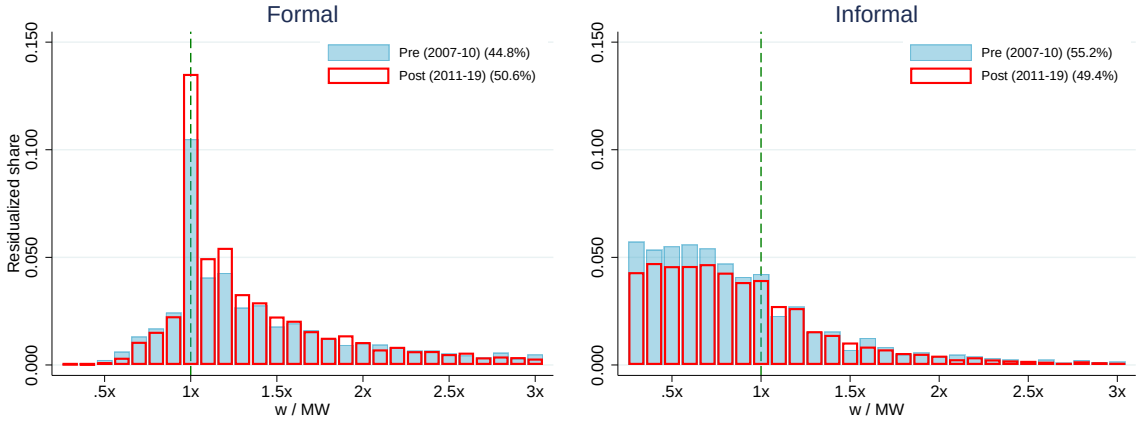
Figure A.5 plots the levels behind the coefficient estimates. Both groups become more formal over time. The identifying variation is therefore not the change within the group receiving larger reductions alone, but its change relative to the group receiving smaller reductions.

Table A.6 reports the wage-band estimates. Formal employment falls by 0.28 percentage points per percentage point of tariff reduction in the band containing the minimum wage and by 0.14 in the band immediately above it. The first is significant at the 5 percent level ($p = 0.04$), and the second is not ($p = 0.48$). Total formal employment falls by 0.63 ($p = 0.009$), and informal employment below the minimum wage rises by 0.64 ($p < 0.001$). The responses come from workers with primary and lower-secondary education. In these

Figure A.5: Residualized wage distributions before and after the reform, by size of the tariff reduction



(a) Industries receiving larger tariff reductions



(b) Industries receiving smaller tariff reductions

Notes: Each panel plots the share of all workers in the relevant industries located in each earnings bin, separately for formal and informal status. The dashed line marks the minimum wage.

groups, formal employment in the minimum-wage band falls by 0.33 and 0.70, and informal employment below the minimum wage rises by 0.94 and 0.74. Both responses are small for workers with upper-secondary or tertiary education.

Table A.7 shows that the signs of these estimates do not depend on the fixed effects. With industry, year, region and calendar-month fixed effects and level controls, total formal employment falls by 0.87 and informal employment below the minimum wage rises by 0.98, both more precisely estimated. Adding region × year, region × education × year or industry × region fixed effects moves the estimates toward the main specification. Columns (6) and (7) follow Cengiz et al. (2019) and measure jobs relative to the industry's pre-reform employment,

Table A.6: Differential employment changes by wage band

	Pooled	Primary	Lower secondary	Upper secondary	Tertiary
A. Applied tariff cut × post (percentage points per percentage point of cut)					
Formal, $w/\text{MW} < 0.95$	−0.10	−0.23***	−0.03	−0.13	0.10
	(0.06)	(0.08)	(0.08)	(0.14)	(0.08)
Formal, $0.95 \leq w/\text{MW} < 1.15$ (minimum wage)	−0.28**	−0.33	−0.70***	−0.22	0.05
	(0.13)	(0.20)	(0.19)	(0.14)	(0.14)
Formal, $1.15 \leq w/\text{MW} < 1.65$	−0.14	−0.21	−0.25	0.26	−0.28
	(0.19)	(0.14)	(0.19)	(0.28)	(0.20)
Formal, $1.65 \leq w/\text{MW} < 2.15$	−0.10***	−0.10*	0.01	−0.09	0.09
	(0.04)	(0.05)	(0.14)	(0.11)	(0.07)
Formal, $w/\text{MW} \geq 2.15$	−0.01	0.00	−0.06	0.07	0.02
	(0.04)	(0.06)	(0.08)	(0.06)	(0.15)
Formal, all wages	−0.63***	−0.87**	−1.04***	−0.10	−0.02
	(0.22)	(0.33)	(0.29)	(0.15)	(0.13)
Self-employed, $w/\text{MW} < 0.95$	0.72*	1.42**	0.54	0.21	0.30*
	(0.39)	(0.52)	(0.52)	(0.27)	(0.15)
Informal wage worker, $w/\text{MW} < 0.95$	−0.07	−0.48	0.20	0.08	−0.08
	(0.27)	(0.43)	(0.40)	(0.20)	(0.10)
Informal (wage or self-employed), $w/\text{MW} < 0.95$	0.64***	0.94***	0.74***	0.30**	0.22
	(0.16)	(0.25)	(0.24)	(0.11)	(0.15)
B. Pre-reform level, 2007–2010 (percent of the group's workers)					
Formal, $w/\text{MW} < 0.95$	4.5	3.4	5.3	6.5	5.0
Formal, $0.95 \leq w/\text{MW} < 1.15$ (minimum wage)	10.9	5.8	12.9	20.5	14.9
Formal, $1.15 \leq w/\text{MW} < 1.65$	8.4	3.8	7.9	15.3	20.4
Formal, $1.65 \leq w/\text{MW} < 2.15$	3.0	0.9	2.4	4.6	12.9
Formal, $w/\text{MW} \geq 2.15$	2.3	0.4	1.2	2.9	14.7
Formal, all wages	29.1	14.3	29.7	49.9	67.9
Self-employed, $w/\text{MW} < 0.95$	29.9	39.4	26.8	17.5	8.3
Informal wage worker, $w/\text{MW} < 0.95$	20.6	26.7	19.6	13.0	4.5
Informal (wage or self-employed), $w/\text{MW} < 0.95$	50.5	66.1	46.4	30.5	12.8
Observations	572,274	229,522	93,045	165,082	84,625
Industry clusters	29	29	29	29	29

Notes: Worker-level linear probability models for membership of a status × wage band, pooled and by education group, with the specification of equation (2): the applied 2009–2011 tariff cut of the worker's industry interacted with post (2011–2019); industry × region and region × year fixed effects; age, age squared, sex, age × sex, literacy, household head, marital status, urban status and education, each interacted with year; calendar-month fixed effects. Survey weights. Standard errors clustered by industry are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.10$. The minimum-wage band $[0.95, 1.15)$ and the three formal bands above it, $[1.15, 1.65)$, $[1.65, 2.15)$ and $[2.15, 3.05)$, are fixed by rule as unions of 0.10-wide bins rather than chosen from the estimates, and the five formal bands partition formal employment. Panel B: weighted means over 2007–2010. Sample: GEIH 2007–2019, tradable industries, January excluded, $0.25 \leq w/\text{MW} < 3.05$.

so that changes in industry size are not absorbed by the denominator. The estimates keep their signs and total employment changes little, but they are less precise. Under the main set of fixed effects with this denominator, in column (6), the decline in total formal employment is significant at the 5 percent level ($p = 0.048$), and the rise in informal employment below the minimum wage is not ($p = 0.13$).

Figure A.6 and Table A.8 report the dynamic estimates. Total formal employment and informal employment below the minimum wage have small pre-reform averages, −0.02 and −0.12. After 2010 they move to −0.66 and 0.56 ($p = 0.009$ and $p < 0.001$). The formal

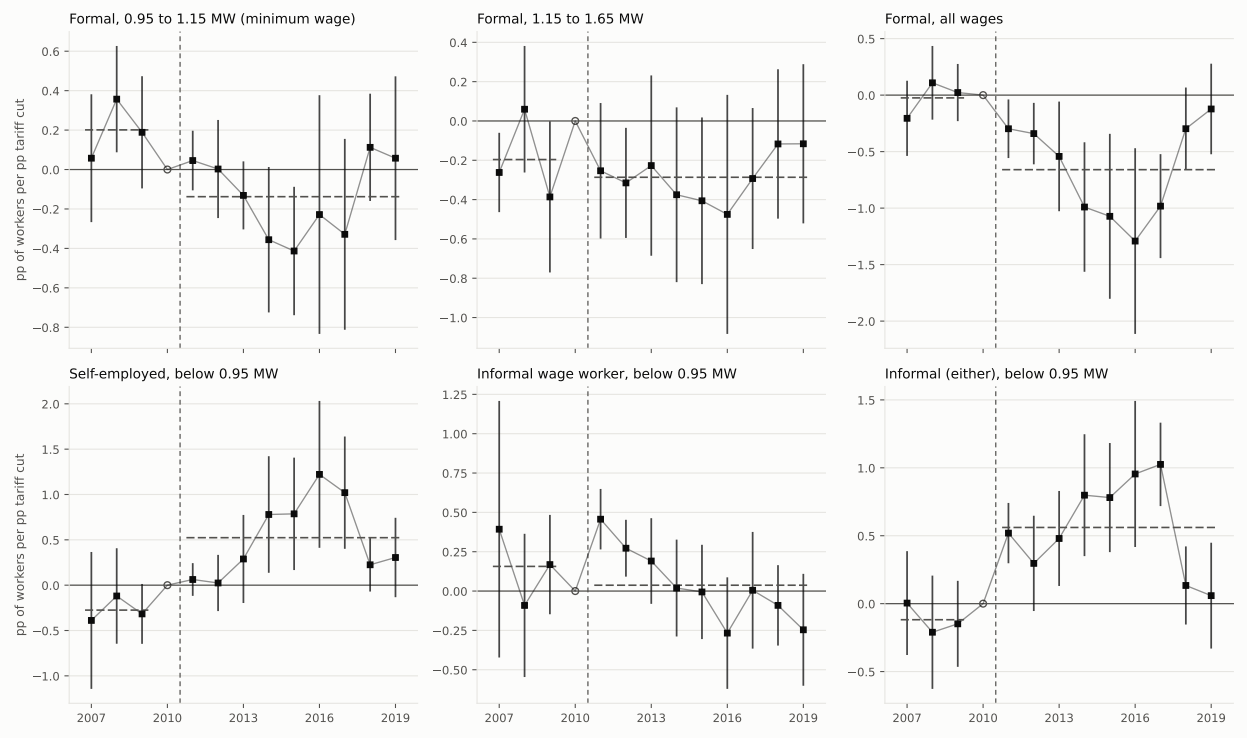
Table A.7: Wage-distribution estimates under alternative specifications

	Share of the industry's workers (pp)					Percent of 2007–2009 employment	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Formal, all wages	−0.63***	−0.60***	−0.77***	−0.82***	−0.87***	−0.99**	−0.94
	(0.22)	(0.21)	(0.25)	(0.23)	(0.26)	(0.48)	(0.59)
Formal, $0.95 \leq w/\text{MW} < 1.05$ (minimum-wage bin)	−0.25***	−0.23*	−0.29***	−0.28**	−0.23	−0.34*	−0.23
	(0.09)	(0.12)	(0.10)	(0.11)	(0.15)	(0.18)	(0.26)
Formal, $0.95 \leq w/\text{MW} < 1.65$	−0.42	−0.37	−0.54*	−0.53*	−0.52		
	(0.27)	(0.31)	(0.29)	(0.31)	(0.34)		
Informal, $w/\text{MW} < 0.95$	0.64***	0.67***	0.78***	0.84***	0.98***	0.47	0.69**
	(0.16)	(0.15)	(0.17)	(0.19)	(0.24)	(0.30)	(0.30)
Total employment						−0.49	−0.28
						(0.76)	(0.85)
Industry × region FE	Yes	Yes				Yes	
Industry FE			Yes	Yes	Yes		Yes
Region × year FE	Yes	Yes		Yes		Yes	
Region × education × year FE			Yes				
Region and year FE					Yes		Yes
Demographics and education × year	Yes					Yes	

Notes: Worker-level regressions on the applied 2009–2011 tariff cut interacted with post. Column (1) is the specification of equation (2) (industry × region and region × year fixed effects; age, age squared, sex, age × sex, literacy, household head, marital status, urban status and education, each interacted with year; calendar-month fixed effects). Columns (2)–(5) and (7) use age, age squared, sex, urban status and education as level controls and calendar-month fixed effects. Columns (1)–(5): the outcome is an indicator for the status and wage range, so coefficients are percentage points of the industry's workers per percentage point of cut. Columns (6)–(7): following Cengiz et al. (2019), the outcome counts jobs relative to the industry's average 2007–2009 employment, so coefficients are percent of pre-reform employment and the rows need not sum to zero; the effect on total employment is reported in the last row. Standard errors clustered by industry are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.10$. Sample as in Table A.6.

minimum-wage band has a positive pre-reform average of 0.20 ($p = 0.09$) and turns negative after the reform. Self-employment rises after the reform (0.52, $p = 0.045$) while informal wage work does not (0.04, $p = 0.80$). The wage-bin analysis therefore points to self-employment as the margin of informal adjustment.

Figure A.6: Event-study estimates by wage band



Notes: Each path reports the year-specific coefficient on the applied tariff reduction, with 2010 omitted. Whiskers are 90 percent confidence intervals clustered by industry. Dashed horizontal lines mark the 2007–2009 and 2011–2019 averages.

Table A.8: Pre- and post-reform averages by wage band

	2007–2009 average	2011–2019 average
Formal, $0.95 \leq w/\text{MW} < 1.15$ (minimum wage)	0.20^{*}	-0.14
	(0.11)	(0.16)
Formal, $1.15 \leq w/\text{MW} < 1.65$	-0.20	-0.29
	(0.14)	(0.23)
Formal, all wages	-0.02	-0.66^{***}
	(0.13)	(0.23)
Self-employed, $w/\text{MW} < 0.95$	-0.27	0.52^{**}
	(0.31)	(0.25)
Informal wage worker, $w/\text{MW} < 0.95$	0.16	0.04
	(0.28)	(0.14)
Informal (wage or self-employed), $w/\text{MW} < 0.95$	-0.12	0.56^{***}
	(0.19)	(0.15)
Observations	572,274	
Industry clusters	29	

Notes: Event-study versions of the pooled band regressions of Table A.6: the applied tariff cut interacted with year indicators for 2007–2019, 2010 omitted, with the same fixed effects, controls, survey weights and industry clustering. Entries are averages of the yearly coefficients relative to 2010, in percentage points per percentage point of cut. Standard errors clustered by industry are in parentheses. $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.10$. Sample as in Table A.6.

A.10 Alternative Measures of the Minimum-Wage Bite

Table A.9 reports the differential under alternative definitions of the bite. It stays positive with thresholds of 1.05 and 1.00 times the minimum wage, with the bite entered continuously or in terciles, with the minimum wage relative to the cell's median formal wage, and with industry × region × education cells, which give 0.71 as in the baseline. Two alternatives lower it. Industry × region cells, which pool education groups, give 0.06. These cells are small, with a median of 50 person-month observations and split-half correlations near 0.45, so measurement error attenuates their estimates. Computing the bite among all salaried workers gives 0.26 with a p-value of 0.414. That denominator moves with the share of workers outside covered formal employment, and because informality is the outcome, the choice of denominator is a substantive one.

Table A.9: Alternative definitions of the minimum-wage bite

Definition of bite	Differential	Std. err.	p
A. Threshold, formal salaried denominator			
1.10× MW (baseline)	0.706	(0.273)	0.017
1.05× MW	0.706	(0.273)	0.017
1.00× MW	0.551	(0.240)	0.031
B. Threshold, all salaried in the denominator			
1.10× MW	0.258	(0.310)	0.414
1.05× MW	0.258	(0.310)	0.414
1.00× MW	0.301	(0.353)	0.403
C. Alternative measure			
Kaitz: MW / cell median formal wage	0.829	(0.241)	0.002
D. Functional form (threshold 1.10*, formal denominator)*			
Continuous, per standard deviation	0.409	(0.159)	0.017
Terciles, top minus bottom	1.022	(0.415)	0.022
E. Cell at which the bite is measured			
Region × education (baseline)	0.706	(0.273)	0.017
Industry × region × education	0.712	(0.330)	0.042
Industry × region	0.059	(0.269)	0.827

Notes: Each row is the differential β_H from the static interaction specification, in percentage points of informality per percentage point of applied tariff reduction, re-estimated with the stated definition of the minimum-wage bite and with the demographic controls absorbed, so every row is comparable with Table 2. Standard errors two-way clustered by industry and region. Panels A to C use the median split. The 1.10 and 1.05 rows of panel A coincide because, although the two measures correlate 0.9975 rather than being equal, a median split assigns all 96 cells identically under both. Their continuous counterparts differ (0.409 and 0.388 per standard deviation).

A.11 Alternative Samples and Industry Scope

The baseline sample covers 29 tariff-exposed industries in agriculture, mining, and manufacturing. Restricting the sample to the 22 manufacturing industries raises the static differential to 0.93 and the post-reform average to 1.54, against 0.71 and 1.19 in the baseline, but the pre-reform average rises as well, to 0.80 with a wild-bootstrap p-value of 0.016, against 0.63 and 0.274 in the baseline. Net of the pre-reform gap, the differential is 0.74 in manufacturing and 0.56 in the baseline, and adding electricity, gas, and water supply (ISIC 40) lowers the static differential to 0.61 and the net one to 0.47, so the three scopes are of the same order of magnitude. The four-digit tariff data show the same compression of the tariff schedule as Section 2. I aggregate the treatment to two-digit industries to limit sampling noise within industry $\times$ region $\times$ education cells.

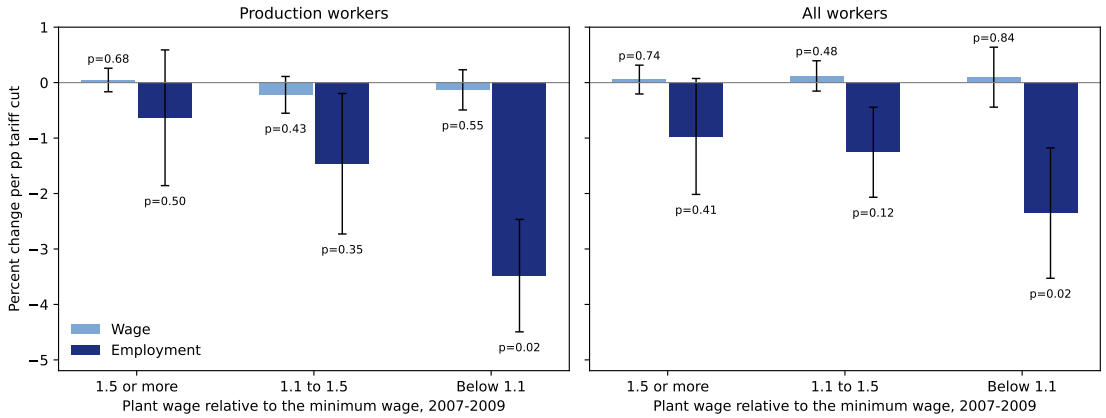
A.12 Plant-Level Evidence from Manufacturing

The Annual Manufacturing Survey (EAM) covers formal manufacturing plants with ten or more workers and reports employment and pay separately for production and administrative workers. Export tariffs facing Colombian manufacturing averaged about 1 percent in 2010 and changed little through 2016, so the reform mainly changed plants' domestic market access. I group plants by the average 2007–2009 monthly pay of their production workers relative to the minimum wage, below 1.1 times, between 1.1 and 1.5 times, and 1.5 times or more. For each group I regress log production pay per worker and log production employment on the plant's two-digit tariff reduction interacted with Post, with plant and region $\times$ year fixed effects, plants assigned to their 2009 industry, and standard errors clustered by the 22 manufacturing industries.[68]

The responses differ across groups in the way the rationing regime of Section 3.4 predicts (Figure A.7). At plants paying production workers close to the minimum wage, a one-percentage-point larger tariff reduction lowers production employment by 3.5 percent (wild-bootstrap $p = 0.02$), while production pay is unchanged (-0.1 percent, $p = 0.55$). At plants paying 1.5 times the minimum wage or more, neither employment nor pay changes significantly. For all workers, employment falls by 2.4 percent at plants close to the minimum wage ($p = 0.02$).

[68] The sample keeps plants observed in 2008 and 2009 with at least ten workers in 2009. Plant-years with production pay below half the minimum wage or above the 99.5th percentile are set to missing, as are one-year changes in log employment or pay larger than one in absolute value that reverse in the following year. Weighting plants by their 2007–2009 employment gives a similar employment decline at plants near the minimum wage for all workers (-3.7 percent, $p = 0.03$). In that specification, production pay also falls at plants paying 1.5 times the minimum wage or more (-0.3 percent, $p = 0.04$).

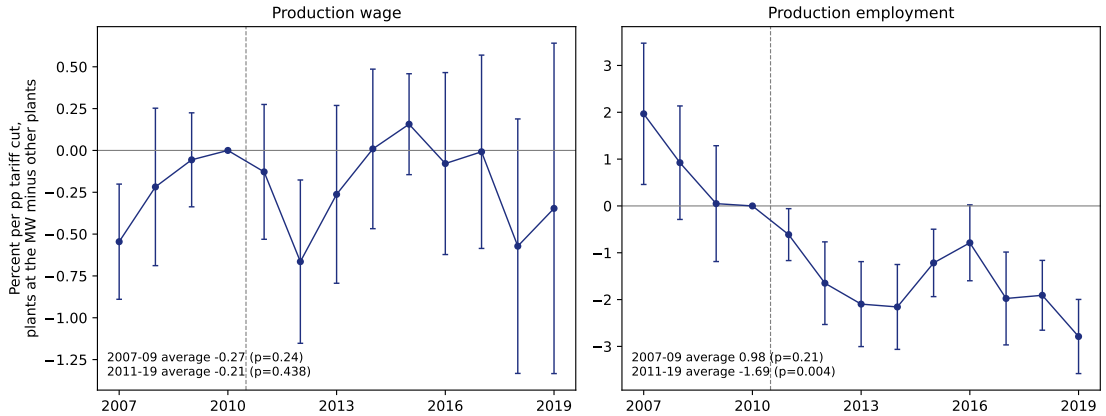
Figure A.7: Wage and employment responses by plant pay relative to the minimum wage



Notes: Each pair of bars reports the response of log pay per worker and log employment to a one-percentage-point larger two-digit tariff reduction after 2010, for plants grouped by their 2007–2009 average pay relative to the minimum wage. Whiskers are 90 percent confidence intervals clustered by industry, and p-values are from the wild cluster bootstrap.

Figure A.8 reports the event-study version. After 2010, production employment at plants close to the minimum wage falls by 1.7 percent per percentage point of tariff reduction relative to other plants ($p = 0.004$). Before the reform, the average difference is not statistically significant (0.98, $p = 0.21$). Production pay at these plants shows no differential change before or after 2010.

Figure A.8: Event-study estimates for plants close to the minimum wage



Notes: Each point is the year-specific difference in the response to the tariff reduction between plants paying production workers below 1.1 times the minimum wage and other plants, with 2010 omitted. Whiskers are 90 percent confidence intervals clustered by industry.

B Appendix to Section 3

B.1 Household Allocation and Wage-Work Subnest

Given $P_{C,d}$ and activity returns, the household first allocates total hours using equation (8) and then allocates those hours using equation (9). The wage-work return $W_{W,hd}$ is the inclusive value of differentiated formal and informal jobs. When firms ration, I build it from shadow wages, the wages at which realized employment would lie on the job-level labor-supply curve, rather than counting every applicant at the posted minimum wage as employed.

Let Ω_{hd} be the set of employers available to type h in region d. Abstracting from the formal amenity in the notation, the wage-work index takes the CES form

$$W_{W,hd} = \left[\int_{j \in \Omega_{hd}} \widetilde{w}_{jhd}^{1+\eta} \, dj \right]^{1/(1+\eta)},$$

where $\widetilde{w}_{jhd} = w_{jhd}$ when all applicants are hired and equals the shadow wage associated with realized employment when the firm rations. This construction makes household labor supply consistent with firm employment and realized wage income.

Tradable and nontradable self-employment are competitive activities whose returns equal the value of their marginal products and enter equations (7) and (10) separately. I let their productivities and activity shifters differ by region and education so that the model matches both the level and the composition of self-employment.

B.2 Ownership of Housing and Firms

Owners outside the worker households hold the fixed housing stock and the claims to firms, so rent and profit income do not enter equation (10). Housing owners spend their rent on local goods. With free entry, the expected net return to firm ownership is zero after the housing-denominated entry cost, and the operating surplus that covers that cost accrues to housing owners as rent. The main welfare criterion is therefore worker welfare.

B.3 Migration Extension

The baseline holds L_{hd} fixed. In the extension, workers of type h choose a region after observing region-specific location tastes. With V_{hd} the indirect utility of living in region d, ζ_{hd} a time-invariant amenity, and type-I extreme-value tastes, the population share in region

d is

$$\frac{L_{hd}}{L_h} = \frac{\exp(\nu V_{hd} + \zeta_{hd})}{\sum_{k \in \mathcal{D}} \exp(\nu V_{hk} + \zeta_{hk})}, \tag{B.1}$$

where ν sets how strongly location choice responds to utility. With L_{hd} endogenous, these population-share equations join the equilibrium system, and migration feeds back into labor supply, housing demand, local expenditure, and firm entry. The baseline results do not use this extension or estimate ν.

B.4 Two-Stage Firm Values

Permanent productivity φ is observed before the formality commitment, whereas transitory productivity ε is realized afterward. Let $V^F_{sd}(\varphi)$ and $V^I_{sd}(\varphi)$ denote the expected values of formal and informal operation before the transitory draw. They satisfy

$$V^F_{sd}(\varphi) = \mathbb{E}_\varepsilon \left[\max_{x \in \{0,1\}} \pi^F_{sd}(\varphi\varepsilon, x) \right],$$
$$V^I_{sd}(\varphi) = \mathbb{E}_\varepsilon \left[\pi^I_{sd}(\varphi\varepsilon) \right].$$

The entrant chooses the largest of zero, $V^F_{sd}(\varphi)$, and $V^I_{sd}(\varphi)$. Only tradable firms can export, so $x = 0$ for $s = N$. Given realized $z = \varphi\varepsilon$, equations (12) and (13) give the firm-level minimum-wage regimes of Section 3.4.

The expected entry value is

$$\mathcal{V}^E_{sd} = \int \max\left\{0, V^F_{sd}(\varphi), V^I_{sd}(\varphi)\right\} \, dG_s(\varphi).$$

Free entry requires $\mathcal{V}^E_{sd} = R_d f^s_E$.

B.5 Outer Equilibrium System

With J regions and two worker types, the outer equilibrium has nine unknowns per region, two type-specific wage indexes $W_{W,hd}$, two sectoral price indexes $P_{T,d}$ and $P_{N,d}$, the rent R_d, two sectoral entrant masses $M^E_{T,d}$ and $M^E_{N,d}$, and two type-specific consumption levels c_{hd}, plus one national unknown, the exchange rate e_x, which makes $9J + 1$ unknowns, or 217 when $J = 24$.

Table B.1: Spatial equilibrium system

Condition	Number	Economic content
Labor-market clearing	$2J$	Wage labor supplied equals formal and informal labor demanded by region and education.
Goods-market clearing	$2J-1$	Sectoral supply equals household and firm demand, self-employment output, domestic trade, and international trade. One condition is redundant.
Housing-market clearing	J	Household housing demand plus entry costs equals the fixed regional housing stock.
Free entry	$2J$	Expected firm value equals the housing-denominated entry cost in each region and sector.
Household budgets	$2J$	Consumption expenditure equals wage income, self-employment income, and transfers.
External balance	1	Tradable exports equal tariff-exclusive import expenditure, determining e_x.
Numeraire	1	Employment-weighted average earnings equal one.
Total	$9J+1$	217 conditions when $J=24$.

B.6 Normalization and Reported Minimum-Wage Units

The average-wage normalization is applied separately in each equilibrium. If a counterfactual specifies $\kappa' = w^{mw\prime}/\overline{w}'$, its consumption-real value in region d is

$$\frac{w^{mw\prime}}{P'_{C,d}} = \kappa' \frac{\overline{w}'}{P'_{C,d}}.$$

For every counterfactual I therefore store κ', $\overline{w}'/P'_{C,d}$, and $w^{mw\prime}/P'_{C,d}$. A peso value would need a nominal anchor in addition. Wage indexation and price indexation also differ. Holding $w^{mw}/\overline{w}$ fixed keeps the policy aligned with average earnings, holding $w^{mw}/P_{C,d}$ fixed keeps its regional purchasing power constant, and trade can move average earnings and consumption prices differently through the terms of trade and spatial prices. I report both so that a stable wage-relative minimum wage is not read as a stable nominal minimum wage or as a constant-purchasing-power policy.

C A Simple Theoretical Framework

This appendix develops a parsimonious framework for interpreting how a minimum wage changes firms' responses to trade liberalization. It describes a single economy without regions or sectors and derives how firms' regimes respond to a change in trade costs, holding aggregate conditions fixed unless stated otherwise. Relative to the model of Section 3, it has one worker type and a single productivity draw and abstracts from self-employment, housing, the payroll tax, and the formal-job amenity. Domestic absorption, E_D, and the foreign demand shifter, A_X, take the place of the market-access terms Π_{sd}^D and Π_d^X. These simplifications yield closed-form regime boundaries.

C.1 Environment

The economy is a one-sector small open economy. A representative household consumes a CES final good and supplies labor to differentiated jobs. Firms take as given the household's aggregate labor supply, N_w, and the wage index, $\widetilde{W}_w$, which summarizes the wages offered by all other jobs. Labor supplied to a job paying wage w is[69]

$$n^S(w) = N_w \left(\frac{w}{\widetilde{W}_w} \right)^{\eta}, \qquad \eta > 0. \tag{C.1}$$

The elasticity η measures how easily workers substitute across jobs. Because η is finite, each firm faces an upward-sloping labor-supply curve. Hiring another worker requires raising the wage paid to all of its workers. This is the source of employer wage-setting power.[70]

Final demand has elasticity of substitution $\sigma > 1$. Let E_D denote domestic real absorption and use the final-good price index as numeraire. A firm's market access, A, is the demand shifter it faces. With productivity z and employment n, the firm earns gross revenue

$$R(z, n; A) = A^{1/\sigma} (zn)^{(\sigma-1)/\sigma}.$$

A firm that serves only the domestic market has $A = E_D$. Exporting requires the fixed cost f^X and a bilateral iceberg cost $\tau > 1$, the same for imports and exports. The foreign demand shifter is

$$A_X = A^* e_x^{\sigma} \tau^{1-\sigma}, \tag{C.2}$$

[69] The household problem in Appendix C.4 allows a job-specific amenity. It is set to zero throughout this appendix. Section 3 introduces a formal-job amenity.

[70] The household problem that delivers equation (C.1), together with the aggregate labor-supply condition, is stated in Appendix C.4.

where A^* collects foreign expenditure and the foreign price index and e_x is the domestic-currency price of the foreign numeraire. An exporter allocates output across the two markets to equalize marginal revenue, so its market access is the sum of the two shifters:

$$E_X = E_D + A_X, \qquad \Gamma_X \equiv \frac{E_X}{E_D} > 1.$$

There are no tariffs in this analytical model, and all international trade barriers are bilateral iceberg costs.

After paying an entry cost, a firm draws productivity z from a Pareto distribution with cumulative distribution function $G(z) = 1 - (z_{\min}/z)^k$. Following Ulyssea (2018), formality is an endogenous production decision. An informal firm has effective productivity $(1-\delta^I)z$, where $\delta^I \in [0,1)$ is a productivity penalty,[71] pays operating cost f^I, is not subject to the minimum wage, and cannot export. Its value is

$$V_I(z) = \max_{w, n \leq n^S(w)} \left\{ R((1-\delta^I)z, n; E_D) - wn - f^I \right\}. \tag{C.3}$$

A formal firm pays operating cost f^F, faces the minimum wage, and may export. For sales status $a \in \{D, X\}$, its value is

$$V_F^a(z) = \max_{w \geq w^{mw},\, n \leq n^S(w)} \left\{ R(z, n; E_a) - wn - f^F - \mathbf{1}\{a = X\} f^X \right\}. \tag{C.4}$$

The firm chooses the largest of exit, with value zero, $V_I(z)$, $V_F^D(z)$, and $V_F^X(z)$. Informality therefore has two costs, the productivity penalty and the loss of export access, and one benefit, exemption from the minimum wage. Because the penalty costs more revenue at more productive firms, while the minimum wage binds less tightly there, informality is chosen by the least productive firms, and nonexporters above the formality cutoff remain formal even though they never export. Entry, operating, and export fixed costs are paid in units of the final good. Firms take aggregate labor supply, domestic absorption, the wage index, and the real exchange rate as given. These and the mass of entrants are determined in general equilibrium.[72]

[71] The penalty captures, in reduced form, costs of informal operation that rise with scale. In Ulyssea (2018), informal firms face an expected cost of detection that increases with their size, so informality is chosen by small, low-productivity firms. A proportional penalty delivers the same selection with closed-form regime boundaries.

[72] See Appendix C.4 for the equilibrium conditions.

C.2 Minimum-Wage Regimes and Efficiency

Consider a formal firm. Along its inverse labor-supply curve, the wage is $w(n) = bn^{1/\eta}$, where $b \equiv \widetilde{W}_w N_w^{-1/\eta}$. Hiring one more worker raises the wage paid to all workers, so the marginal cost of labor is $\mu w(n)$, where $\mu \equiv 1 + 1/\eta$ is the wage markdown.[73] The marginal revenue product of labor is

$$\text{MRPL}(n; z, A) \equiv \frac{\partial R(z, n; A)}{\partial n} = \rho_\sigma A^{1/\sigma} z^{\rho_\sigma} n^{-1/\sigma},$$

where $\rho_\sigma \equiv (\sigma - 1)/\sigma$. Without a minimum wage, the firm chooses employment n^0 to equate the two. Suppressing z and A,

$$\text{MRPL}(n^0) = \mu w(n^0).$$

Because $\mu > 1$, the firm pays a wage equal to the marginal revenue product of labor divided by μ and employs fewer workers than it would if it took the wage as given.

Let n^c solve $\text{MRPL}(n^c) = w(n^c)$. This employment level maximizes employer-worker surplus, defined as gross revenue minus the area under the firm's inverse labor-supply curve. It is constrained efficient. It removes the employer wage-setting wedge while leaving the product-market markup in place. Because the marginal revenue product is decreasing in employment and $\mu > 1$, $n^0 < n^c$.

A formal job that pays the minimum wage attracts

$$\bar{n} = N_w \left(\frac{w^{mw}}{\widetilde{W}_w} \right)^{\eta} \tag{C.5}$$

applicants. Depending on its productivity and market access, a formal firm lies in one of three regimes, listed from most to least productive:

- **R1: unconstrained monopsony.** The firm's unconstrained wage is at least w^{mw}, so the policy does not affect its wage or employment.
- **R2: binding without rationing.** The unconstrained wage is below w^{mw}, but labor demand at the minimum wage is at least $\bar{n}$. The firm hires every applicant and employment equals $\bar{n}$.

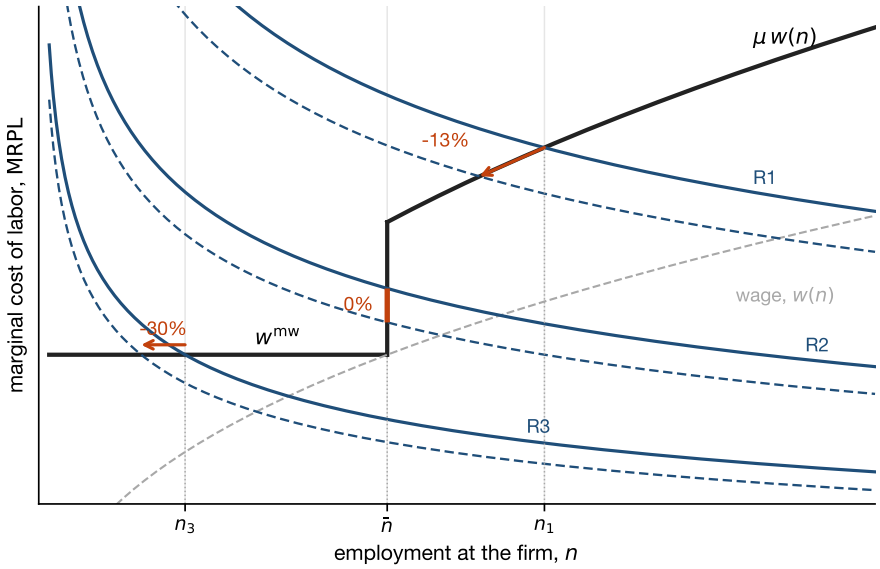
[73] Because each job is small relative to the labor market and job-level labor supply is isoelastic, μ is a constant and does not vary with how many workers are employed formally or informally. Informal employment affects a firm's labor supply only through the wage index and aggregate labor supply. In models with granular employers, such as Berger et al. (2022), the markdown varies with labor-market concentration.

- **R3: binding with rationing.** Labor demand at the minimum wage is below $\bar{n}$. The firm hires fewer workers than apply and sets marginal revenue product equal to w^{mw}.

Conditional on market access, employment in the three regimes is

$$\begin{aligned} n_1(z;A) &= \left[\frac{\rho_\sigma A^{1/\sigma} z^{\rho_\sigma}}{\mu b}\right]^{\sigma\eta/(\sigma+\eta)}, \\ n_2(z;A) &= \bar{n}, \\ n_3(z;A) &= \left[\frac{\rho_\sigma A^{1/\sigma} z^{\rho_\sigma}}{w^{mw}}\right]^{\sigma}. \end{aligned} \tag{C.6}$$

Figure C.1: The minimum wage kinks a formal firm's marginal cost of labor



Notes: One formal firm in the model of this appendix. The dashed grey curve is the wage the job must pay to attract n workers, $w(n) = bn^{1/\eta}$. Without a minimum wage the marginal cost of labor is $\mu w(n)$. With the floor w^{mw}, the marginal cost is w^{mw} for every hire up to the applicant pool $\bar{n}$ and $\mu w(n)$ beyond it (black). The solid blue curves are MRPL$(n; z, A)$ at three levels of market access A (denoted Π in Section 3), placing the firm in R1, R2, and R3; the dashed blue curves are the same firms after a 30 percent fall in A, which has the same effect as a fall in $z^{\sigma-1}$. The red marks show the employment response from equation (C.6): the R1 firm moves down $\mu w(n)$ and cuts employment by 13 percent, the elasticity $\eta/(\sigma+\eta)$; the R2 firm keeps every applicant, $\bar{n}$; the R3 firm moves along the floor and cuts employment by 30 percent, one for one with A. The least productive formal firms switch to informal operation. Drawn with the estimated $\eta = 2.5$, so $\mu = 1.4$, and $\sigma = 4$; the three market-access levels and the size of the fall are illustrative.

For sales status $a \in \{D, X\}$, let z_a^s denote the lower boundary of R2, which separates it

from R3, and z_a^u the upper boundary, which separates it from R1. The boundaries satisfy

$$(z_a^u)^{\sigma-1} = \left(\frac{\mu}{\rho_\sigma}\right)^{\sigma} \frac{\bar{n}\,(w^{mw})^{\sigma}}{E_a}, \tag{C.7}$$

$$z_a^s = \mu^{-\sigma/(\sigma-1)} z_a^u, \tag{C.8}$$

where E_D applies to nonexporters and E_X to exporters. A higher minimum wage, a larger applicant pool, or lower market access moves both boundaries right, so more firms are constrained. By equation (C.8), the ratio z_a^s/z_a^u depends only on η and σ. A change in market access therefore moves the two boundaries of R2 in the same proportion.[74]

The three regimes and the employment result below follow Ahlfeldt et al. (2023) and Berger et al. (2025). Here a firm's regime also depends on its export status, through market access.

Proposition 1 (The minimum wage raises employment in R2, conditional on export status)**.** *Hold the aggregates fixed and let $a \in \{D, X\}$ be a formal firm's sales status. The firm is in R2 if and only if $z \in [z_a^s, z_a^u)$, and at every such firm*

$$n^0 < \bar{n} \leq n^c. \tag{C.9}$$

Relative to the firm's unconstrained choice, the minimum wage therefore raises employment, worker earnings, and employer-worker surplus. Firms with $z \geq z_a^u$ are in R1 and are unaffected. Firms with $z < z_a^s$ are in R3 and ration applicants. Their employment is set by labor demand at the minimum wage. It exceeds n^0 only at firms close to z_a^s and falls below n^0 at less productive firms.

At the minimum wage the firm can hire up to $\bar{n}$ workers without raising its wage, so its marginal cost of labor falls from μw to w^{mw} and it no longer gains from restricting employment.[75] The proposition describes employment at a firm that stays formal, not aggregate welfare. Whenever the constraint binds, profit falls, and entry, formality, prices, and redistribution may change. The quantitative model evaluates those margins.

[74] Appendix C.5 derives the boundaries.
[75] The proof is in Appendix C.6.

C.3 Trade and the Scope of the Minimum-Wage Rationale

Let $m \equiv w^{mw}/\widetilde{W}_w$ denote the relative minimum wage, its level relative to the wage index. Equation (C.7) can be written

$$(z_a^u)^{\sigma-1} = \left(\frac{\mu}{\rho_\sigma}\right)^{\sigma} m^{\sigma+\eta} \frac{N_w \widetilde{W}_w^{\sigma}}{E_a}. \tag{C.10}$$

The term in m is the relative-minimum-wage channel. It depends on how the minimum wage is adjusted when market wages change, and it is the same for every firm. The last term is the market-access channel. It measures a firm's market access relative to labor costs, which differs between exporters and nonexporters.

The market-access channel separates exporters from nonexporters. An exporter has market access $E_X = \Gamma_X E_D$, so equation (C.10) implies, for both boundaries,

$$z_X^r = \Gamma_X^{-1/(\sigma-1)} z_D^r, \qquad r \in \{s, u\}. \tag{C.11}$$

Both exporter boundaries lie below the corresponding nonexporter boundaries, whatever the minimum-wage rule. A firm with productivity between the two upper boundaries is unconstrained if it exports and constrained if it does not. A firm between the two lower boundaries rations applicants only if it does not export. Which firms export is a separate question. A firm exports if and only if its productivity exceeds a cutoff, z_x^*, at which the gain from foreign sales equals the export fixed cost.[76]

Proposition 2 (Trade moves the regime boundaries through two channels)**.** *Let $\ell \equiv -\log \tau$, so that a higher ℓ means lower bilateral iceberg costs. For each sales status $a \in \{D, X\}$ and each boundary $r \in \{s, u\}$,*

$$\frac{d \log z_a^r}{d\ell} = \underbrace{\frac{\sigma+\eta}{\sigma-1}\frac{d \log m}{d\ell}}_{\text{relative minimum wage}} - \underbrace{\frac{1}{\sigma-1}\frac{d}{d\ell}\log\left(\frac{E_a}{N_w \widetilde{W}_w^{\sigma}}\right)}_{\text{market access}}. \tag{C.12}$$

The relative-minimum-wage channel is common to all firms. The market-access channels of exporters and nonexporters differ by $(\sigma-1)^{-1}\, d \log \Gamma_X / d\ell$, so the exporter boundaries fall relative to the nonexporter boundaries if and only if liberalization raises Γ_X.

How the relative minimum wage moves is a matter of policy. I consider two rules. Under *wage indexation* the minimum wage is a fixed fraction of the wage index, so m is constant,

[76] See Appendix C.8.

trade acts only through market access, and the economy is compared before and after liberalization at the same policy stance. Under *price indexation* the minimum wage is fixed in units of the final good, so m falls whenever liberalization raises the wage index. Colombia's minimum wage is reset annually rather than mechanically tied to either rule in the model. Section 4 therefore states the counterfactual rule explicitly and holds the minimum wage fixed relative to average earnings when comparing tariff regimes.

Consider first wage indexation. The relevant object is the set of formal firms at which the minimum wage raises employment. By Proposition 1, these are the constrained firms with productivity of at least $z_a^e \equiv \mu^{-\eta/(\sigma-1)} z_a^s$.[77] These are every R2 firm and the R3 firms closest to R2. A firm that would belong to this set but operates informally is beyond the reach of the minimum wage. The set is therefore truncated from below by the formality cutoff, z_F, the productivity above which a firm operates formally.

Assumption 1 (The marginal exporter is constrained)**.** $z_D^s \leq z_x^* < z_D^u$. *The firm that is indifferent about exporting is in R2 when it does not export.*

Under Assumption 1, the set of formal firms at which the minimum wage raises employment is the interval

$$\mathcal{C} = [\underline{z}, \bar{z}), \qquad \underline{z} \equiv \max\{z_F, z_D^e\}, \qquad \bar{z} \equiv \max\{z_x^*, z_X^u\}.^{78} \tag{C.13}$$

Its lower edge is set by nonexporters and by the formality margin, and its upper edge by exporters.

Proposition 3 (Export access shrinks $\mathcal{C}$ at a constant relative minimum wage)**.** *Suppose the minimum wage is indexed to the wage index, so that m is constant, and hold $N_w \widetilde{W}_w$ fixed. Suppose the marginal exporter does not ration as a nonexporter, $z_x^* \geq z_D^s$, and the least productive formal firm does not export. Then a rise in Γ_X weakly lowers the share of formal firms in $\mathcal{C}$.*

(a) Under Assumption 1 the share falls strictly, because the upper edge of $\mathcal{C}$ falls relative to its lower edge and to the formality cutoff.

(b) If exporters are already unconstrained, $z_x^* \geq z_D^u$, the share is unchanged.

(c) When $\underline{z} = z_D^e$ and $\bar{z} = z_X^u$,

$$\frac{\bar{z}}{\underline{z}} = \mu^{(\sigma+\eta)/(\sigma-1)} \, \Gamma_X^{-1/(\sigma-1)}, \tag{C.14}$$

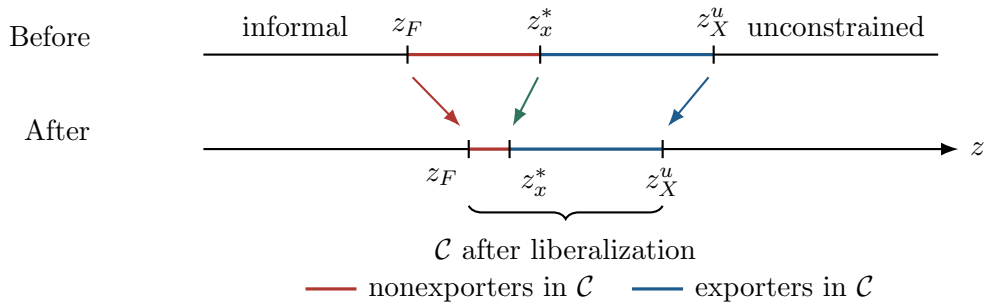
[77] See Appendix C.6.

[78] If exporters are already unconstrained, $z_x^* \geq z_D^u$, every firm in the set is a nonexporter and its upper edge is z_D^u.

under any minimum-wage rule.

Exporters gain market access, so the most productive firms in $\mathcal{C}$ become unconstrained and leave it at the upper edge.[79] The proposition holds $N_w\widetilde{W}_w$ fixed. A cut in trade costs also changes it, which moves the formality cutoff. If the formality cutoff moves right, the least productive firms in $\mathcal{C}$ become informal, where the minimum wage does not reach them, and $\mathcal{C}$ shrinks from both ends. Figure C.2 illustrates this case.

Figure C.2: Bilateral liberalization under a wage-indexed minimum wage



Notes: The colored interval is $\mathcal{C}$, the set of formal firms at which the minimum wage raises employment. Nonexporters are in red and exporters in blue. Firms to its left are informal and firms to its right are unconstrained. The figure illustrates the case under Assumption 1 in which the lower edge of $\mathcal{C}$ is the formality cutoff and that cutoff rises. The exporter upper boundary falls relative to it, and the export cutoff falls. The figure is schematic.

Price indexation changes the outcome, because trade then moves the relative minimum wage. When liberalization raises the wage index, m falls and the relative-minimum-wage channel moves every boundary left. For nonexporters it outweighs the market-access channel. The nonexporter and the exporter boundaries both move left. A minimum wage that is fixed in goods binds on fewer firms after liberalization, because market wages rise past it. When absorption moves with the wage bill, the nonexporter boundaries move right only if the minimum wage rises by more than a fraction $(1+\eta)/(\sigma+\eta)$ of the increase in the wage index.[80] The same liberalization therefore narrows the reach of the minimum wage under one rule and lowers the relative minimum wage under the other. How trade interacts with the minimum wage depends on how the minimum wage is set, which is why Section 4 evaluates the two policies jointly.

Three qualifications apply. First, Proposition 3 excludes the case in which the marginal exporter rations applicants when it does not export ($z_x^* < z_D^s$). There exporting eases its rationing and $\mathcal{C}$ can grow. Second, a firm that leaves $\mathcal{C}$ at its upper edge is not harmed. Market access has raised its wage above the minimum wage, and it no longer needs the

[79] The proof is in Appendix C.8.
[80] See Appendix C.7.

correction. The result concerns the scope of the minimum wage's efficiency role. It does not imply that national informality rises, aggregate welfare falls, or the optimal minimum wage declines, because employment in the rest of R3, entry, consumer prices, fiscal effects, and redistribution also adjust. Third, the analytical exercise changes bilateral iceberg costs, whereas the Colombian reform primarily changes import tariffs.[81] Their complete aggregate effects require the quantitative model.

C.4 Household Problem and General-Equilibrium Closure

The representative household consumes the final good and supplies labor to differentiated jobs. Utility is

$$U(C, N_w) = \frac{C^{1-\sigma_c}}{1-\sigma_c} - \bar{\phi}^{-1/\psi} \frac{N_w^{1+1/\psi}}{1+1/\psi}, \qquad \sigma_c > 0,\ \psi > 0.$$

The inner labor aggregator is

$$N_w = \left[\int_{j \in \Omega} (1+\xi_j)^{-1} n_j^{(\eta+1)/\eta}\, dj \right]^{\eta/(\eta+1)}.$$

Conditional on aggregate labor supply and the consumption marginal utility, cost minimization across jobs delivers equation (C.1) when $\xi_j = 0$ for every job. When a minimum-wage firm rations applicants, the wage index uses the shadow wage that rationalizes realized employment on the job-level labor-supply curve rather than the posted minimum wage.

For a given (τ, w^{mw}), the equilibrium solves for

$$\mathcal{Z}(\tau, w^{mw}) = \big(C, E_D, N_w, \widetilde{W}_w, M_E, e_x\big),$$

where M_E is the mass of entrants. The six outer conditions are top-level labor supply, wage-index consistency, the household budget, free entry, final-good absorption consistency, and trade balance. The final-good price index is the numeraire rather than an additional unknown. In compact form,

$$\mathcal{F}(\mathcal{Z}; \tau, w^{mw}) = 0.$$

Entry, formality, and export fixed costs enter final-good demand. Household income contains wages, rationing rents, and net firm profits. There is no tariff revenue. Trade balance equates integrated export revenue to the value of imports in a common currency. It does not equate the foreign demand shifter A_X to aggregate exports.

[81] Appendix C.10 connects the import-cost component of the two exercises.

If the Jacobian $\mathcal{F}_{\mathcal{Z}}$ is nonsingular, the local response to lower iceberg costs is

$$\frac{d\mathcal{Z}}{d\ell} = -\mathcal{F}_{\mathcal{Z}}^{-1}\mathcal{F}_{\ell}.$$

This expression emphasizes that the responses of E_D, E_X, N_w, and $\widetilde{W}_w$ in Proposition 2 are equilibrium outcomes. The proposition maps them into the regime boundaries but does not sign them.

C.5 Regime Cutoffs

The no-minimum-wage first-order condition is

$$\rho_\sigma A^{1/\sigma} z^{\rho_\sigma} n^{-1/\sigma} = \mu b n^{1/\eta}. \tag{C.15}$$

Solving equation (C.15) gives the first line of equation (C.6). The R2–R1 boundary sets the unconstrained wage equal to w^{mw}, equivalently $n_1 = \bar{n}$. This gives

$$(z_D^u)^{\sigma-1} = \left(\frac{\mu}{\rho_\sigma}\right)^{\sigma} \frac{\bar{n}\,(w^{mw})^{\sigma}}{E_D}.$$

At the R3–R2 boundary, labor demand at the minimum wage equals applicant supply. Using the third line of equation (C.6) and equation (C.5) yields

$$z_D^s = \mu^{-\sigma/(\sigma-1)} z_D^u.$$

Replacing E_D by E_X multiplies both boundaries by $\Gamma_X^{-1/(\sigma-1)}$, proving equation (C.11).

C.6 Proof of Proposition 1

Under unconstrained monopsony, marginal revenue product equals marginal factor cost:

$$\mathrm{MRPL}(n^0) = \mu w(n^0) > w(n^0).$$

Because marginal revenue product is decreasing and inverse labor supply is increasing, $n^0 < n^c$. The argument below does not use the value of market access, so it applies to exporters and nonexporters alike.

At an R2 firm, the unconstrained wage is below the minimum wage, implying $n^0 < \bar{n}$.

The absence of rationing requires

$$\text{MRPL}(\bar{n}) \geq w^{mw} = w(\bar{n}),$$

which implies $\bar{n} \leq n^c$. Employer-worker surplus is increasing between n^0 and $\bar{n}$, proving the R2 statement.

At an R3 firm, employment is demand determined at the minimum wage rather than pinned down by applicant supply. The cutoff at which R3 employment equals unconstrained monopsony employment is

$$z_a^e = \mu^{-\eta/(\sigma-1)} z_a^s, \qquad a \in \{D, X\}.$$

Thus $n_3 > n^0$ for $z_a^e < z < z_a^s$ and $n_3 < n^0$ for $z < z_a^e$. Throughout R3, $n_3 < n^c$.

C.7 The Relative Minimum Wage under Alternative Minimum-Wage Rules

Let

$$\varepsilon_{mw} \equiv \frac{d \log w^{mw}}{d\ell}, \qquad \varepsilon_N \equiv \frac{d \log N_w}{d\ell}, \qquad \varepsilon_W \equiv \frac{d \log \widetilde{W}_w}{d\ell}, \qquad \varepsilon_D \equiv \frac{d \log E_D}{d\ell}.$$

The relative minimum wage responds by $d \log m / d\ell = \varepsilon_{mw} - \varepsilon_W$. Under wage indexation $\varepsilon_{mw} = \varepsilon_W$. Because the final-good price index is the numeraire, w^{mw} is a real minimum wage, and price indexation is $\varepsilon_{mw} = 0$. For nonexporters, Proposition 2 gives

$$(\sigma - 1) \frac{d \log z_D^r}{d\ell} = (\sigma + \eta)(\varepsilon_{mw} - \varepsilon_W) + \varepsilon_N + \sigma \varepsilon_W - \varepsilon_D. \tag{C.16}$$

If no firm is constrained, every firm's wage bill is the share ρ_σ / μ of its revenue. With balanced trade, the revenue of domestic firms equals domestic absorption, so $E_D = (\mu/\rho_\sigma)\widetilde{W}_w N_w$ and $\varepsilon_D = \varepsilon_N + \varepsilon_W$. Equation (C.16) then becomes

$$(\sigma - 1) \frac{d \log z_D^r}{d\ell} = (\sigma + \eta)\varepsilon_{mw} - (1 + \eta)\varepsilon_W. \tag{C.17}$$

The nonexporter boundaries move right if and only if $\varepsilon_{mw} > [(1 + \eta)/(\sigma + \eta)]\varepsilon_W$. When liberalization raises the wage index, wage indexation satisfies this inequality and price indexation violates it. With constrained firms the proportionality between absorption and the wage bill is only approximate.

C.8 Proofs of Propositions 2 and 3

Taking logs of equation (C.10) and differentiating gives equation (C.12) for $r = u$, and equation (C.8) extends it to $r = s$. Because $E_X = \Gamma_X E_D$,

$$\frac{d}{d\ell} \log \left(\frac{z_X^r}{z_D^r} \right) = -\frac{1}{\sigma - 1} \frac{d \log \Gamma_X}{d\ell},$$

which does not depend on m. This proves Proposition 2.

Single crossing of the export decision follows from the envelope theorem. Let $\Pi(z, A)$ be optimized operating profit and define the gain from exporting as $\Delta\Pi(z) = \Pi(z, E_X) - \Pi(z, E_D) - f^X$. Then

$$\frac{d\Delta\Pi(z)}{d \log z} = \frac{\sigma - 1}{\sigma} \left[R(z; E_X) - R(z; E_D) \right] > 0. \tag{C.18}$$

Thus export status is selected by a productivity cutoff, z_x^*.

To obtain equation (C.13), note that formal nonexporters have $z_F \leq z < z_x^*$. By Appendix C.6, the minimum wage raises a nonexporter's employment if and only if $z_D^e \leq z < z_D^u$, and Assumption 1 gives $z_x^* < z_D^u$. The nonexporters in $\mathcal{C}$ are therefore those with $\max\{z_F, z_D^e\} \leq z < z_x^*$. Exporters have $z \geq z_x^* \geq z_D^s > z_X^e$, so the minimum wage raises an exporter's employment if and only if $z < z_X^u$. The union is $[\underline{z}, \bar{z})$ with $\bar{z} = \max\{z_x^*, z_X^u\}$. Equation (C.14) follows from $z_X^u = \Gamma_X^{-1/(\sigma-1)} z_D^u$, $z_D^u = \mu^{\sigma/(\sigma-1)} z_D^s$, and $z_D^s = \mu^{\eta/(\sigma-1)} z_D^e$. It uses only the boundary formulas and therefore holds under any minimum-wage rule, which is part (c) of Proposition 3.

For the remainder of Proposition 3, normalize productivity by $\zeta \equiv (N_w \widetilde{W}_w^\sigma / E_D)^{1/(\sigma-1)}$ and write $u \equiv z/\zeta$ and $n = N_w \hat{n}$. A firm with sales status a earns revenue $N_w \widetilde{W}_w (\Gamma_a u^{\sigma-1})^{1/\sigma} \hat{n}^{\rho_\sigma}$, with $\Gamma_D = 1$, and an informal firm earns the same expression with u replaced by $(1 - \delta^I)u$. Attracting $\hat{n}$ requires the wage $\widetilde{W}_w \hat{n}^{1/\eta}$, so a formal firm pays $\widetilde{W}_w \max\{m, \hat{n}^{1/\eta}\}$ per worker. Profit divided by $N_w \widetilde{W}_w$ is therefore a function of (u, m, Γ_a) minus the relevant fixed cost divided by $N_w \widetilde{W}_w$. Every status cutoff compares these normalized profits, and every regime boundary is a condition in (u, m, Γ_a). Hold m and $N_w \widetilde{W}_w$ fixed and raise Γ_X. Because firms at and below the formality cutoff do not export, the normalized values of z_F, z_D^e, z_D^s, and z_D^u do not change. The normalized exporter boundary $z_X^u = \Gamma_X^{-1/(\sigma-1)} z_D^u$ falls. The normalized export cutoff falls as well, because the gain from exporting is increasing in productivity by equation (C.18) and increasing in Γ_X.

When $z_x^* \geq z_D^s$, the argument above gives $\mathcal{C} = [\underline{z}, \bar{z})$ with $\bar{z} = \min\{\max\{z_x^*, z_X^u\}, z_D^u\}$. No exporter rations, and nonexporters are constrained only below z_D^u. With Pareto productivity, the share of formal firms in $\mathcal{C}$ is $(z_F/\underline{z})^k - (z_F/\bar{z})^k$. The first term does not change. If $z_x^* < z_D^u$,

then $\bar{z} = \max\{z_x^*, z_X^u\}$ falls relative to z_F and $\underline{z}$, and the share falls strictly, which is part (a). If $z_x^* \geq z_D^u$, then $\bar{z} = z_D^u$ and the share is unchanged, which is part (b).

C.9 Derivation of the Informality Condition

Define $q \equiv \eta/(\sigma + \eta)$, the employment elasticity of an unconstrained firm with respect to its own market access. R2 employment has elasticity zero, while R3 employment has elasticity one.

The informal wage-employment share is

$$s_{I,c} = \frac{N_{I,c}}{N_{I,c} + N_{F,c}}.$$

Differentiation gives the exact identity

$$\frac{ds_{I,c}}{d\ell} = s_{I,c}(1 - s_{I,c}) \left(\frac{d \log N_{I,c}}{d\ell} - \frac{d \log N_{F,c}}{d\ell} \right).$$

Let $\omega_{r,x,c}$ be the initial share of formal wage employment in regime $r \in \{1, 2, 3\}$ and export status $x \in \{0, 1\}$ in cell c, and let $\omega_{X,c} = \sum_r \omega_{r,1,c}$. Define $a_{D,c} \equiv d \log E_{D,c}/\, d\ell$ and $a_{X,c} \equiv d \log E_{X,c}/\, d\ell$ as the local elasticities of domestic-only and exporter market access with respect to bilateral liberalization. The decomposition below focuses on the local case $a_{D,c} < 0 < a_{X,c}$, in which domestic-only market access falls while exporter market access rises. A first-order decomposition of formal wage employment is

$$\frac{d \log N_{F,c}}{d\ell} = (q\omega_{1,0,c} + \omega_{3,0,c})\, a_{D,c} + (q\omega_{1,1,c} + \omega_{3,1,c})\, a_{X,c} + b_{F,c}^{\ell}, \tag{C.19}$$

where $b_{F,c}^{\ell}$ collects entry, exit, formality switching, export switching, and equilibrium wage responses. If informal wage firms remain unconstrained,

$$\frac{d \log N_{I,c}}{d\ell} = q a_{D,c} + b_{I,c}^{\ell}. \tag{C.20}$$

Substituting equations (C.19) and (C.20), using

$$\sum_{r=1}^{3} \sum_{x=0}^{1} \omega_{r,x,c} = 1,$$

and collecting the exporter terms gives

$$\frac{1}{s_{I,c}(1-s_{I,c})}\frac{ds_{I,c}}{d\ell} = |a_{D,c}|\left[(1-q)\omega_{3,0,c} - q\omega_{2,0,c} - q\omega_{X,c}\right] - a_{X,c}\left(q\omega_{1,1,c} + \omega_{3,1,c}\right) + (b^{\ell}_{I,c} - b^{\ell}_{F,c}). \tag{C.21}$$

Among nonexporters and with the b terms set to zero, the informal share rises if and only if $(1-q)\omega_{3,0,c} > q\omega_{2,0,c}$. An R3 firm cuts employment by $1-q$ more than an informal firm does, and an R2 firm by q less. The condition is equivalent to $\omega_{3,0,c}/(\omega_{2,0,c}+\omega_{3,0,c}) > q$. Rationing firms must account for more than a share $q = \eta/(\sigma+\eta)$ of the employment of constrained nonexporters. The b terms are first-order objects. Formality switching can occur in both high- and low-bite cells, and informal exit can offset an increase generated by contracting formal employment.

C.10 From Bilateral Iceberg Costs to the Colombian Tariff Reform

The delivered import-cost change in industry i can be written

$$\Delta\ell^{M}_{i} = -\Delta\log\left[(1+t_i)\tau^{M}_{i}\right].$$

If physical import costs are unchanged, the observed tariff component is $-\Delta\log(1+t_i)$. This shock does not directly reduce Colombian exporters' foreign iceberg costs. It can nevertheless affect export access through the real exchange rate. A depreciation raises e_x in equation (C.2). The actual reform also changes tariff revenue. The reduced-form analysis isolates the import-side variation, while the estimated spatial model evaluates the complete unilateral reform.

D Appendix to Section 4

D.1 Data Construction

The quantitative data are mapped to the model at the region, region–education, region–sector, exporter, and national levels. Worker activities differ from Section 2 in three ways. A wage worker is formal if the worker reports contributing to a pension fund; because formality in the model is a choice of the firm, wage workers without pension contributions who report an employer with 11 or more workers are also counted as formal in every quantitative mo-

ment; and the self-employed are all employed persons who are not wage workers, including employers and unpaid workers. Industry codes in household, customs, and tariff files are harmonized before aggregation to tradable and nontradable sectors. Regional trade flows form origin–destination matrices in which diagonal entries are local purchases and off-diagonal entries are interregional shipments.

The model's 24 regions are the departments covered by the GEIH; the nine remaining departments are outside the model. The tradable sector consists of ISIC Rev. 3 two-digit industries 01–37 (agriculture, mining, and manufacturing), corresponding to input–output sectors S1–S32; these are the industries of the reduced-form sample of Section 2 plus recycling (ISIC 37, which carries no tariff line and 0.4 percent of tradable employment), and electricity, gas, and water (ISIC 40) is excluded from both. The nontradable sector consists of services excluding domestic service (S33–S53); domestic service is dropped. College workers are those with any tertiary education. Unless stated otherwise, worker-side moments use the 2015 GEIH for February to December. January interviews are dropped because they report December earnings against the new minimum wage. In income totals, the average earnings behind the minimum-wage ratio and self-employment earnings, missing labor income of paid workers who report employment is filled with the survey-weighted mean of reported pay in the same year, region, schooling, sector, and employment-status cell. Unpaid workers keep zero, and hourly-wage moments use reported pay only. Table D.1 lists every data object.

Table D.1: Data construction for the quantitative model

Object	Source and unit	Construction
Workers and wages		
Population L_{hd}	GEIH 2015; region × education	Survey-weighted working-age population, employed or not, net of domestic-service workers, scaled so that the 24 regions sum to 24.
Activity allocation	GEIH 2015; region × education × sector	Formal wage workers, informal wage workers, and self-employed. A wage worker is formal if the worker contributes to a pension fund or reports an employer with 11 or more workers; the self-employed are all employed persons who are not wage workers, including employers and unpaid workers.
Formality (targeted)	GEIH 2015; region × sector × education	Formal share of wage employment.
Wages and earnings	GEIH 2015; region × sector, region × education	Hourly earnings. Wage-level, wage-gap, premium, and dispersion moments use wage earners with positive hourly wages between 0.22 and 10.09 times the hourly minimum wage. Self-employment earnings are labor income per self-employed worker.
Minimum wage	Decree; national	644,350 pesos per month in 2015, converted to 3,356 pesos per hour at 192 hours per month. Relative to average hourly earnings of tradable and nontradable workers, it equals 0.674.
Minimum-wage bite (targeted)	GEIH 2015; region × sector × education	Share of formal wage workers paid at or below 1.05 times the hourly minimum wage.

Continued on next page

Table D.1 – continued from previous page

Object	Source and unit	Construction
Firms and housing		
Formal firm count (targeted)	GEIH 2015; national	Number of formal firms in the tradable and nontradable sectors implied by workers' reports of employer size: each formal wage worker is weighted by the survey weight divided by the midpoint of the reported firm-size bracket, and the total is divided by the 11 survey months; 332,728 firms, targeted relative to population (0.218 when the 24 regions' population sums to 24).
Rents (matched exactly)	GEIH 2015 housing module; region	Renter households' paid rent, regressed on region fixed effects and housing characteristics (urban and rural areas); the fixed effects are expressed relative to Bogotá.
Housing expenditure share α_H	ENPH 2016–17; national	0.252.
Trade		
Exporter share (targeted)	DIAN 2015 export records; GEIH 2015	Exporting firms (deduplicated tax identifiers with goods exports in the tradable scope, 8,193) divided by the GEIH formal tradable firm count (the same construction restricted to the tradable sector, 80,503); 0.102.
Export sales ratio (targeted)	Interregional input–output table 2015 (IIOAS; Haddad, Araujo, and Galvis); 24 regions	Tradable value added embodied in the tradable exports of the 24 regions, computed with the Leontief inverse of the domestic input–output matrix, divided by tradable value added of the same regions; 0.300.
Tradable expenditure share $\alpha_{T,d}$	IIOAS 2015; region	Use-side expenditure share on tradable sectors; mean 0.29, range 0.25–0.32.
Domestic trade costs τ^T_{dk}, τ^N_{dk}	IIOAS 2015; region pairs	Head–Ries index $\tau_{dk} = (X_{dk}X_{kd}/X_{dd}X_{kk})^{1/(2(1-\sigma))}$ with $\sigma = 4$, where flows include intermediate and final demand of region k for region d's output in the sector. Tradable flows use S1–S32 and leave zero-flow pairs at infinite cost; nontradable flows use S33–S53.
International trade costs τ^M_d	IIOAS 2015, WIOD 2014; region	Head–Ries index against one rest-of-world aggregate, using IIOAS foreign exports by region of production, IIOAS foreign imports by region of use, the region's own flow, and WIOD world gross output of the corresponding industries, at 2,741.88 pesos per dollar, with a correction for the region's realized tariff (Appendix D.3).
Regional tariffs t_d (2015)	DIAN 2015 import records; region	Realized duty over CIF value by input–output sector from 3.04 million import records, mapped from NANDINA product codes to sectors, then averaged across sectors with weights equal to the region's IIOAS imports of each sector.
Trade elasticity σ	DIAN 2015 import records	Gravity regression of duty-exclusive CIF imports on $\ln(1 + t)$. The coefficient equals $-\sigma$ and gives 4.08, and σ is set to 4 (Appendix D.3).
Counterfactual tariff schedules		
2010–2011 reform	UNCTAD-TRAINS; GEIH 2007–2009	Applied (AHS) tariff reductions between 2009 and 2011 by two-digit industry, averaged within each region with 2007–2009 tradable employment weights; mean 2.66 percentage points.

Continued on next page

Table D.1 – continued from previous page

Object	Source and unit	Construction
2009 and high-protection regimes	WITS AHS 2009 and 2015; DIAN 2015; IIOAS 2015	The 2009–2015 change in national applied tariffs by sector, weighted by DIAN 2015 CIF values, is averaged within each region with its IIOAS import weights (mean 4.37 percentage points) and added to the 2015 regional tariff; high protection adds twice that change.

Notes: GEIH: Gran Encuesta Integrada de Hogares. ENPH: Encuesta Nacional de Presupuestos de los Hogares. DIAN: Colombian customs and tax authority. IIOAS: interregional input–output table for Colombia. WIOD: World Input–Output Database. Regional imports in the IIOAS are themselves estimated by applying national import coefficients to each region's sectoral output and final demand, so their regional variation reflects production and demand structure rather than observed customs flows.

D.2 Parameters and Estimation

This appendix records the parameterization behind Table 3, which sorts parameters by how they are set. I hold externally set parameters fixed throughout SMM, estimate externally estimated parameters in a separate data exercise and then hold them fixed, compute recovered objects from an exact inversion without searching over them, and search only over the internally estimated parameters. Recovered objects are recomputed from each candidate equilibrium and therefore vary with the parameter vector.

Table D.2: Complete parameter inventory and identification

Parameter block	Classification	Value or status	Source, construction, or identifying moments
Preferences: σ_c, ψ	External set	2.0, 0.40	Consumption curvature and the Frisch elasticity are maintained calibration values.
Housing and institutions: α_H, τ_p, ξ_F	External set	0.252, 0.25, 0.264	Housing share from ENPH 2016–17; payroll tax from statutory rates; formal amenity from benefits data.
Support and normalization: $\varphi_{\min}$, $\varphi_{\max}$, f_s^I, P^*	External set	1, 500, 0, 1	Productivity support and the informal operating cost are fixed by assumption; the foreign price is the external numeraire.

Continued on next page

Table D.2 – continued from previous page

Parameter block	Classification	Value or status	Source, construction, or identifying moments
Observed policy and endowments: w^{mw}, L_{hd}, $\alpha_{T,d}$, t_d	External set/data	Observed	Household, national-accounts, and customs data provide the minimum wage, population by type, sectoral expenditure shares, and tariffs.
Trade costs: τ^T_{od}, τ^N_{od}, τ^M_d	External set/data	Data-based matrices	Domestic costs are recovered by Head–Ries from 2015 interregional input–output flows. International costs use the same flows and world output, with a customs-based tariff correction (Appendix D.3).
Firm labor supply: η	External estimate	2.50	Amodio and de Roux (2024), Colombian plants; held fixed in the spatial SMM.
Activity substitution: θ_h	External estimate	5.0 (noncollege), 1.5 (college)	Shift-share tariff-IV estimate of substitution between wage work and self-employment by education group (Appendix D.3). Held fixed in the spatial SMM.
Trade elasticity: σ	External estimate	4.00	Gravity estimate using 2015 customs records, 4.08 (Appendix D.3), set to 4.00. The same value is used in demand and trade-cost construction. This is the elasticity denoted σ in Section 4.
Worker-side fundamentals: A^S_d, $\chi_{a,hd}$, $\bar{\phi}_{hd}$	Recovered	Data-implied	Closed-form inversion from observed self-employment earnings, activity shares, and labor supply conditional on the equilibrium and external elasticities.
Housing stocks: $\bar{H}_d$	Recovered	Table D.3	Set so that the model matches each region's rent relative to Bogotá exactly. Bogotá's stock fixes the housing unit.

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Table D.2 – continued from previous page

Parameter block	Classification	Value or status	Source, construction, or identifying moments
Regional fundamentals: A_d^T, A_d^N, δ_d^I	Internal SMM	Table D.3	Region-by-sector mean log hourly wages, tradable employment shares, and sectoral formality, minimum-wage bite, and formal–informal wage gaps. Bogotá productivity levels are normalized.
Entry costs: f_E^T, f_E^N	Internal SMM	4.018, 6.826	Tradable entry costs are national, and nontradables have a separate entry cost. Formal firm counts and sectoral employment/formality moments provide the main information.
Formal operating costs: f_T^F, f_N^F	Internal SMM	3.559, 1.089	National sector-specific costs, identified jointly from sectoral formality, minimum-wage bite, and formal–informal wage moments.
Foreign-market access: f_T^X, X^*	Internal SMM	26.744, 0.0671	Exporter participation and the all-tradables export-sales ratio identify the export fixed cost and foreign expenditure scale jointly.
Heterogeneity: σ_ε, s_C, λ_I, k	Internal SMM	1.2220, 2.4397, 0.2745, 2.5576	Wage dispersion, type-specific bite, formal/informal type premia, and wage gaps.

Let m_ℓ^{data} and $m_\ell^{model}(\Theta)$ denote moment ℓ in the data and model, and let se_ℓ be its sampling standard error on the same scale. The formal firm count, the exporter share, and the export-sales ratio enter as log deviations. I weight the exporter share by the sampling precision of its GEIH firm-count denominator (weight 1,397). The export-sales ratio is a national-accounts ratio without a sampling standard error; I assign it a weight of 4,748, the mean weight of the other targeted moments. The simulated-method-of-moments estimator minimizes

$$\widehat{\Theta} = \arg\min_{\Theta} \sum_{\ell=1}^{L} \left[\frac{m_\ell^{model}(\Theta) - m_\ell^{data}}{se_\ell} \right]^2 . \tag{D.1}$$

Table D.3: Regional parameters

Region	Tradable productivity A_d^T	Nontradable productivity A_d^N	Informal penalty δ_d^I	Housing stock $\bar{H}_d$
Antioquia	1.381	0.563	0.111	0.706
Atlántico	1.391	0.697	0.122	0.205
Bogotá D.C.	1.637	0.700	0.000	1.000
Bolívar	1.691	0.766	0.097	0.149
Boyacá	1.632	0.705	0.112	0.130
Caldas	1.482	0.584	0.256	0.108
Caquetá	2.130	0.780	0.148	0.038
Cauca	1.893	0.721	0.143	0.102
Cesar	1.585	0.771	0.142	0.058
Chocó	2.396	0.962	0.166	0.038
Cundinamarca	1.671	0.768	0.124	0.240
Córdoba	1.843	0.723	0.018	0.082
Huila	1.791	0.835	0.108	0.067
La Guajira	1.797	1.034	0.036	0.056
Magdalena	1.812	0.787	0.266	0.080
Meta	1.831	0.962	0.161	0.074
Nariño	1.736	0.649	0.111	0.129
Norte de Santander	1.863	0.822	0.150	0.086
Quindío	1.877	0.748	0.305	0.067
Risaralda	1.517	0.620	0.254	0.107
Santander	1.772	0.858	0.010	0.197
Sucre	1.845	0.739	0.145	0.043
Tolima	1.710	0.660	0.151	0.113
Valle del Cauca	1.517	0.603	0.153	0.515

Notes: Productivities and the informal penalty are estimated by simulated method of moments. Housing stocks are set so that the model matches each region's rent relative to Bogotá exactly. Bogotá's productivity levels and housing stock are normalizations. Bogotá's estimated productivity penalty is 8.7×10^{-7}, effectively zero.

I minimize the objective with warm-started Levenberg–Marquardt steps, coordinate sweeps, and parallel candidate evaluations. At every evaluation I set housing stocks outside Bogotá so that the model matches relative rents exactly, and I estimate the Pareto shape parameter jointly with the other national parameters. The objective at the reported estimates is 8,734.1 (Table D.6).

D.3 Externally Estimated Parameters

I estimate the trade elasticity from 2015 Colombian customs records (DIAN), which report the CIF value of each import transaction and the duty paid. I aggregate the records to partner-country × HS6-product cells and regress the log CIF import value on the log of one plus the realized tariff, defined as duties paid divided by CIF value within the cell, with country and product fixed effects. Because CIF values exclude duties, the coefficient equals $-\sigma$ under CES demand. Identification comes from differences in applied tariffs across origins within a product, mostly between preferential and most-favored-nation rates. The regression uses all 2015 goods imports. Table D.4 reports the estimates. The baseline estimate of σ is 4.08, with a standard error of 0.29 clustered by product, from 61,553 cells. Using declared rather than realized tariffs gives 3.60, and estimating on department-level cells gives 3.92 with additive department fixed effects and 3.90 with interacted fixed effects. I set $\sigma = 4.00$, a value commonly used in quantitative trade models.

Table D.4: Trade elasticity from 2015 customs records

Specification	$\widehat{\sigma}$	Std. err.	Cells
Country × HS6, realized tariff (baseline)	4.08	0.29	61,553
Country × HS6, declared tariff	3.60	0.32	61,553
Department × country × HS6, additive fixed effects	3.92	0.20	161,815
Department × country × HS6, interacted fixed effects	3.90	0.23	148,202

Notes: Regressions of the log CIF import value on $\ln(1+t)$, where t is duties paid over CIF value within the cell. The table reports minus the coefficient. All specifications include partner-country and HS6 fixed effects. The department rows add department fixed effects, additively or interacted with country and with product. Standard errors are clustered by HS6 product. *Source:* DIAN 2015 import records.

I estimate θ from the response of relative earnings to relative employment across Colombian local labor markets between 2007 and 2019. The unit is a department × demographic cell, defined by sex, three schooling groups, and three age groups. For each cell I compute the 2007–2019 change in the log ratio of wage workers, formal and informal, to self-employed workers, and in the log ratio of their mean hourly earnings, using GEIH survey weights. Under the activity CES of Section 3, the earnings ratio responds to the employment ratio with elasticity $1/\theta$. Because both ratios respond to local demand shocks, I instrument the change in relative employment with shift-share tariff exposure, the cell's 2007 industry employment shares times each industry's change in $\log(1+\text{MFN tariff})$, include department fixed effects, cluster standard errors by department, and keep cells with at least 50 workers in each group at both dates. Pooling the two education groups, the estimate of $1/\theta$ is 0.670 (standard error 0.267, 347 cells, first-stage F-statistic 18.2), which gives $\theta = 1.49$. Requiring at least 25 or

10 workers per cell gives 1.53 and 1.45, and the weak-instrument-robust (Anderson–Rubin) 95 percent confidence interval for θ is [0.68, 5.30]. The model uses a separate elasticity for each education group, so I estimate the same specification with the instrument interacted with the education group. The estimate of $1/\theta$ is 0.21 (standard error 0.37, 234 cells) for noncollege workers and 0.66 (0.29, 113 cells) for college workers, which gives $\theta = 4.8$ and $\theta = 1.5$. The group-specific instruments are weak, with first-stage F-statistics of 4.8 and 7.2 (Sanderson–Windmeijer 4.9 and 11.0), and the Anderson–Rubin 95 percent confidence set for $1/\theta$ is $[-0.44, 2.99]$ for noncollege workers and unbounded for college workers. I set $\theta = 5.0$ for noncollege workers and $\theta = 1.5$ for college workers. The estimates concern the margin between wage work and self-employment, and the model applies the same elasticity to the choice between tradable and nontradable self-employment.

Domestic iceberg costs are recovered from the 2015 interregional input–output table for Colombia (IIOAS; Haddad, Araújo, and Galvis), which reports flows among 33 departments and 54 sectors. For each pair of the 24 GEIH departments and each sector group, I sum the destination's intermediate and final demand for goods produced in the origin, with intermediate demand restricted to using sectors in the same group. Under symmetric costs, the Head–Ries index gives $\tau_{dk} = [X_{dk}X_{kd}/(X_{dd}X_{kk})]^{1/(2(1-\sigma))}$, with $\sigma = 4$. The tradable matrix uses sectors 1–32 and the nontradable matrix sectors 33–53, excluding household services. Six department pairs have no tradable flows, and the model treats them as unable to trade tradable goods with each other. The median off-diagonal cost is 2.60 for tradables and 5.66 for nontradables.

International costs use the same table and world output. For each department d, τ_d^M satisfies $(\tau_d^M)^{2(1-\sigma)} = E_d M_d (1+t_d)^\sigma / (X_{dd} X_W)$, where E_d and M_d are the department's foreign exports and imports of tradable goods in the input–output table, X_{dd} its own tradable flow, X_W world gross output in agriculture, mining, and manufacturing from the 2014 World Input–Output Database, converted at 2,741.88 pesos per dollar, and t_d the department's realized import tariff. The tariff t_d weights national realized tariffs by sector, computed from 3.04 million 2015 customs records as duties paid over CIF value, by the department's import composition. The tariff term removes the part of the import barrier that the model represents separately as a tariff. The median τ_d^M is 6.10, ranging from 4.12 in La Guajira to 25.3 in Caquetá. World output is for 2014 rather than 2015, and Colombia is not removed from the world aggregate.

D.4 Moments and Identification

Table D.5 lists the 318 moments by block.

Table D.5: Targeted moments and their role in estimation

Moment	Count	Variation used in estimation
Formality by region, type, and sector	96	Formal wage-work shares in the two sectors and two worker types.
Minimum-wage bite by region, type, and sector	96	Share of formal wage workers paid at or below 1.05 times the hourly minimum wage.
Mean log hourly wage by region and sector	48	Wage levels in the tradable and nontradable sectors.
Formal–informal mean log hourly wage gap	48	Status-specific wage differences by region and sector.
Formal and informal type premia	2	College–noncollege wage premia by activity.
Regional tradable wage-employment shares	24	Regional sectoral specialization.
Within-cell log-wage variance	1	Dispersion of hourly wages in the trimmed estimation window.
Formal firm count	1	Formal entry and the mass of observed firms.
Exporter participation	1	Share of formal tradable firms that export.
All-tradables export-sales ratio	1	Foreign sales relative to total tradable sales.
Total	318	

Domestic trade flows recover bilateral iceberg costs before estimation and therefore do not add rows to the 318-moment SMM vector. Regional rents are matched exactly through the housing stocks and are likewise not counted as moments. Aggregate exports and imports are not targeted; the model imposes balanced trade. The response to the 2010–2011 tariff reform remains untargeted.

D.5 Full Model Fit

Table D.6 summarizes the fit by block of the objective, and Figure D.1 shows the regional fit of three targeted blocks. Three blocks account for most of the remaining misfit, region-by-sector formal–informal wage gaps, formality, and region-by-sector mean log wages. The model's average wage level across cells is above the data, its formal–informal wage gap is larger than in the data (0.66 against 0.53 log points on average), and it places too small a share of formal workers at or below 1.05 times the minimum wage, especially among college

workers and in tradables. The model understates the export-sales ratio, 0.26 against 0.30 in the data, and exports relative to GDP, 0.10 against 0.14 (Table D.6).

Table D.6: Fit of the estimated model by moment block

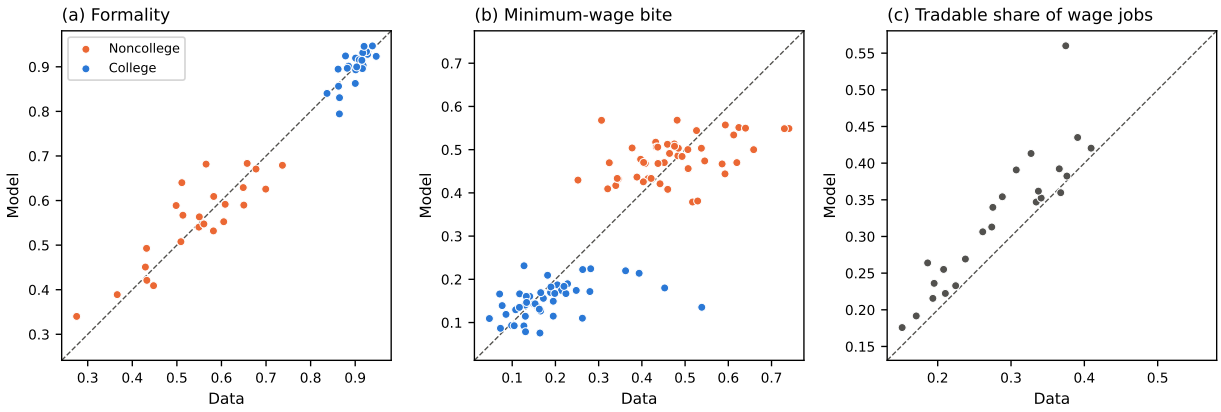
Moment block	Data	Model	Objective
Targeted			
Formality (correlation, noncollege / college)	0.87 / 0.76		1,912.7
Minimum-wage bite, median: noncollege	0.469	0.476	951.4
college	0.163	0.149	
Mean log hourly wage (mean over cells)	0.164	0.264	1,841.0
Formal–informal log wage gap (mean over cells)	0.529	0.659	2,593.4
College premium, formal / informal	0.570 / 0.178	0.473 / 0.256	327.2
Regional tradable share of wage jobs (correlation)	0.90		995.8
Within-cell variance of log wages	0.249	0.247	2.0
Export sales ratio, value-added basis	0.300	0.261	96.7
Share of tradable firms that export	0.102	0.112	13.4
Formal firm count (model units)	0.218	0.216	0.5
Total objective			8,734.1
Untargeted			
Tradable share of wage employment, national	0.277	0.343	
Informal share of wage jobs, nontradables minus tradables	−0.130	−0.091	
Exports / GDP	0.143	0.0984	
Imports / GDP	0.215	0.0984	

Notes: The last column is each block's sum of squared, weighted deviations; the blocks sum to the objective. Formality, bite, wage levels, and wage gaps are targeted by region, sector, and education group (wage levels and gaps by region and sector); correlations for formality are across region–education cells, pooled over sectors. The largest regional miss in the tradable share is 0.19. Wage moments use hourly wages on the estimation sample trimmed to 0.22–10.09 times the minimum wage. Imports equal exports in the model by the external-balance closure. Regional rents are matched exactly and are not part of the objective.

D.6 The Tariff Reform Simulation

Figure D.2 maps the simulated 2010–2011 reform by region. The reform is the 2015 equilibrium minus a counterfactual in which each region's tariff is raised by its pre-reform-employment-weighted reduction, holding the minimum wage at its 2015 ratio to average earnings. A uniform 1 percent fall in tradable productivity in every region, the exercise of Dix-Carneiro et al. (2026), raises national informality by 0.07 percentage points and tradable informality by 0.35, lowers formal tradable employment by 0.6 percent, and lowers worker welfare by 0.13 percent. In their search model the same shift raises the informal share by 5.4 percentage points and lowers real income by 10 log points, since displaced workers there

Figure D.1: Spatial fit of the estimated model



Notes: Each point is a region–education cell (panel (a)), a region–sector–education cell (panel (b)), or a region (panel (c)); the dashed line is the forty-five-degree line. (a) Formal share of wage employment, pooled over sectors. (b) Share of formal wage workers paid at or below 1.05 times the hourly minimum wage. (c) Tradable share of wage employment. Panels (b) and (c) plot targeted 2015 moments; panel (a) aggregates the targeted formality cells over sectors. Model values are at 2015 tariffs and the current minimum wage.

pass through unemployment and informal firms post vacancies. Here displaced workers move into self-employment within the period. The regional slope of the uniform version is 0.09 percentage points per point in the tradable sector, close to zero as a uniform shock requires.

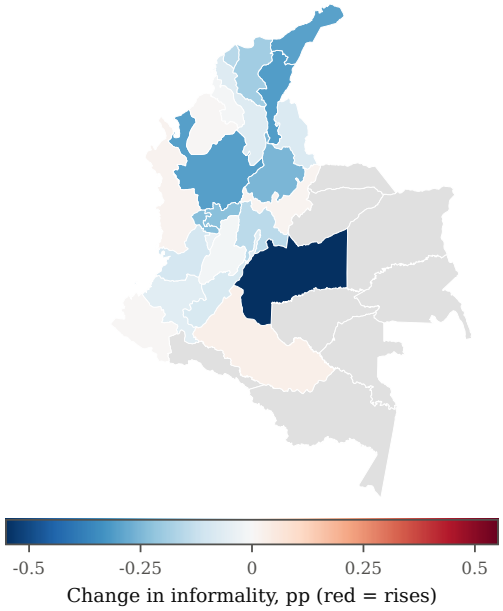
D.7 Gains from Trade

Table D.7 reports the worker gains of Section 4.4 by education group, and Figure D.3 plots them against the minimum wage. It also reports a second experiment, the move from 2015 tariffs to free trade (Figure D.4). Free trade lowers worker welfare in every economy and at every minimum wage, by 0.50 percent in the baseline at the current minimum wage. Removing tariffs worsens Colombia's terms of trade, as the peso depreciates by 1.1 percent, and removes the tariff revenue that the model rebates to workers. Noncollege workers lose 0.55 percent and college workers 0.03 percent, because the equal rebate is a larger share of noncollege income. As with the trade-cost cut, the minimum wage barely changes these effects, except in the economy without informal firms or self-employment, where the loss of noncollege workers reaches 0.89 percent at 1.25 times the current minimum wage.

D.8 Supplementary Policy Results

Table D.9 reports welfare and informality at selected minimum wages under the 2015 tariff schedule. Table D.10 reports the elasticity ladder, Table D.11 decomposes the welfare change,

Figure D.2: Regional incidence of the 2010–2011 tariff reform in the estimated model



Notes: Change in informality (informal wage workers and the self-employed, both sectors, all workers) by region. Each region's 2015 tariff is raised by its pre-reform-employment-weighted industry tariff reduction (equation (18)); the map reports the 2015 equilibrium minus that pre-reform counterfactual, holding the minimum wage at its 2015 ratio to average earnings. Gray regions are not in the model.

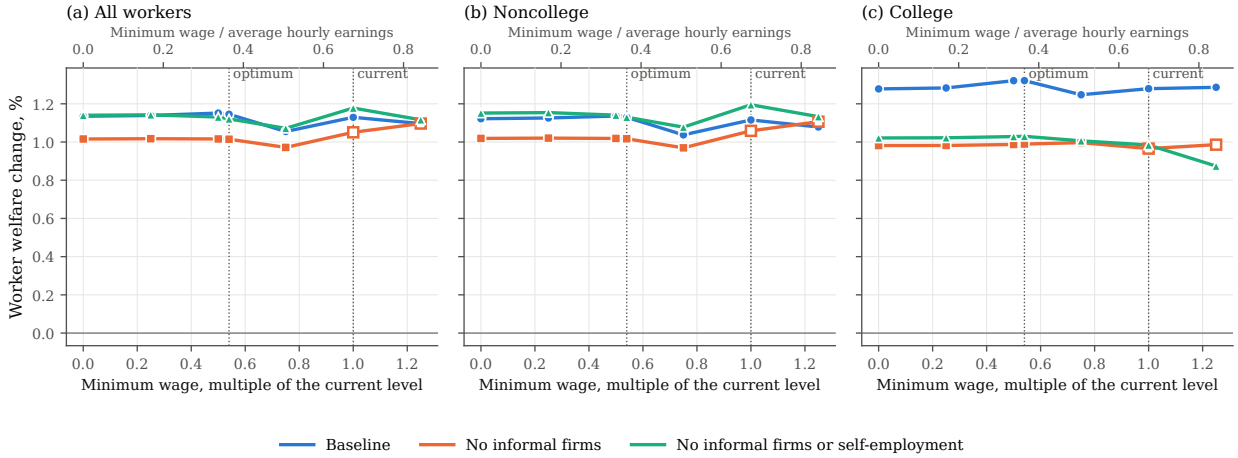
Table D.12 reports the robustness checks, and Table D.13 the four tariff regimes. Table D.14 crosses the elasticity ladder with the tariff regimes, and Figure D.5 varies international trade costs. Table D.8 reports the regional welfare changes of Figure 8 under each of the four tariff regimes. The trade regime shifts every region's gain or loss by at most 0.12 percentage points relative to no minimum wage and by at most 0.24 relative to the current policy.

Table D.7: Worker gains from trade by minimum wage

	Minimum wage, multiple of the current level				Range over
	None	Optimum (0.54)	1.00	1.25	seven levels
International trade costs cut by 10 percent					
Baseline					
All workers	+1.13	+1.15	+1.13	+1.10	0.10
Noncollege	+1.12	+1.13	+1.12	+1.08	0.10
College	+1.28	+1.32	+1.28	+1.29	0.07
No informal firms					
All workers	+1.02	+1.01	+1.05	+1.10	0.12
Noncollege	+1.02	+1.02	+1.06	+1.11	0.14
College	+0.98	+0.99	+0.97	+0.99	0.03
No informal firms or self-employment					
All workers	+1.14	+1.12	+1.18	+1.12	0.11
Noncollege	+1.15	+1.13	+1.20	+1.13	0.12
College	+1.02	+1.03	+0.98	+0.87	0.16
2015 tariffs to free trade					
Baseline					
All workers	−0.50	−0.49	−0.50	−0.47	0.04
Noncollege	−0.55	−0.54	−0.55	−0.52	0.04
College	−0.01	−0.00	−0.03	−0.02	0.02
No informal firms					
All workers	−0.54	−0.53	−0.55	−0.52	0.03
Noncollege	−0.58	−0.57	−0.59	−0.56	0.03
College	−0.06	−0.06	−0.05	−0.03	0.03
No informal firms or self-employment					
All workers	−0.65	−0.64	−0.63	−0.84	0.20
Noncollege	−0.70	−0.69	−0.68	−0.89	0.21
College	−0.15	−0.14	−0.13	−0.09	0.06

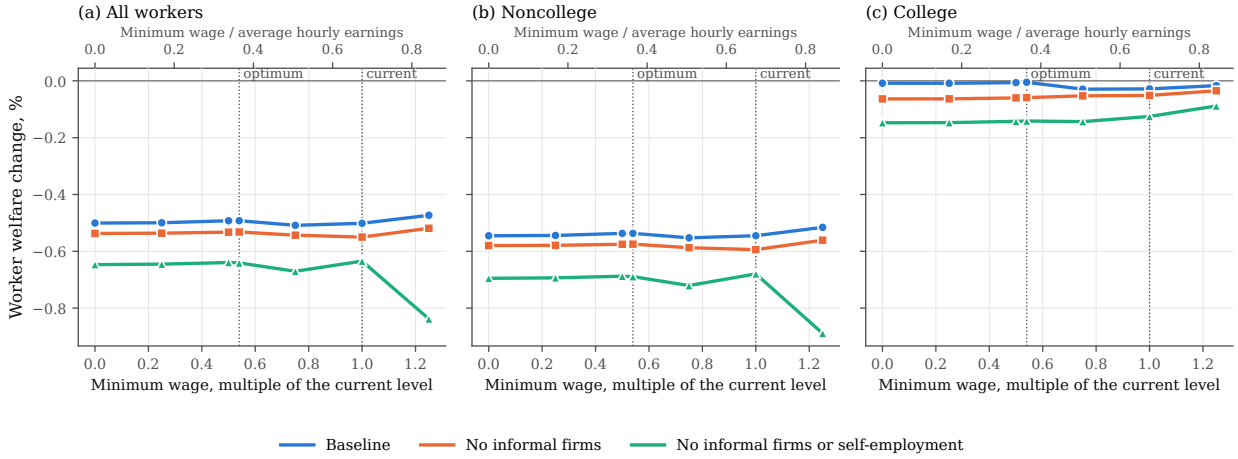
Notes: Consumption-equivalent change in worker welfare, in percent, of the economy after the trade change relative to the same economy at 2015 tariffs and trade costs and the same minimum wage, held fixed relative to average earnings. The optimum is the welfare-maximizing minimum wage under 2015 tariffs, 0.54 times the current level. The range is the largest minus the smallest worker welfare change over the minimum-wage levels 0, 0.25, 0.50, 0.54, 0.75, 1.00, and 1.25. In the economy without informal firms or self-employment, the self-employment shifters are set to zero. Every economy keeps the estimated parameters.

Figure D.3: Worker gains from a 10 percent cut in international trade costs, by minimum wage



Notes: Consumption-equivalent change in worker welfare, in percent, from cutting international iceberg trade costs by 10 percent, relative to the same economy at 2015 trade costs and the same minimum wage, held fixed relative to average earnings. In the economy without informal firms or self-employment, the self-employment shifters are set to zero. Every economy keeps the estimated parameters. Dotted lines mark the current minimum wage and the welfare-maximizing one (Section 4.3). Open markers are the two cells of the economy without informal firms in which a tradable sector shuts down.

Figure D.4: Worker gains from moving to free trade, by minimum wage



Notes: Consumption-equivalent change in worker welfare, in percent, from removing all tariffs, relative to the same economy at 2015 tariffs and the same minimum wage, held fixed relative to average earnings. Economies as in Figure D.3. Dotted lines mark the current minimum wage and the welfare-maximizing one.

Table D.8: Regional incidence of the welfare-maximizing minimum wage under four tariff regimes

	Free trade		2015 tariffs		2009 tariffs		High protection	
Region	Non-college	College	Non-college	College	Non-college	College	Non-college	College
Antioquia	0.45	−0.21	0.44	−0.22	0.43	−0.22	0.43	−0.22
Atlántico	0.26	−0.05	0.26	−0.05	0.25	−0.05	0.24	−0.05
Bogotá D.C.	0.29	−0.13	0.28	−0.13	0.27	−0.13	0.26	−0.13
Bolívar	0.06	−0.20	0.05	−0.20	0.04	−0.21	0.04	−0.21
Boyacá	0.50	−0.83	0.48	−0.82	0.46	−0.81	0.44	−0.79
Caldas	0.49	−0.71	0.49	−0.71	0.48	−0.70	0.47	−0.69
Caquetá	0.13	−0.84	0.11	−0.82	0.09	−0.80	0.08	−0.78
Cauca	0.03	−0.58	0.02	−0.58	0.00	−0.58	−0.01	−0.58
Cesar	0.27	−0.42	0.25	−0.49	0.24	−0.56	0.22	−0.57
Córdoba	0.10	−0.76	0.08	−0.75	0.06	−0.74	0.05	−0.73
Cundinamarca	0.56	−0.61	0.55	−0.61	0.56	−0.62	0.55	−0.62
Chocó	−0.11	−0.48	−0.12	−0.47	−0.13	−0.46	−0.14	−0.44
Huila	0.24	−0.52	0.20	−0.46	0.16	−0.40	0.14	−0.34
La Guajira	−0.03	−0.34	−0.02	−0.36	−0.01	−0.40	0.00	−0.44
Magdalena	0.14	−0.16	0.13	−0.16	0.13	−0.17	0.13	−0.18
Meta	0.54	−0.52	0.55	−0.55	0.55	−0.55	0.53	−0.65
Nariño	0.14	−0.74	0.12	−0.73	0.11	−0.72	0.10	−0.71
Norte de Santander	0.02	−0.12	0.01	−0.13	0.00	−0.13	−0.01	−0.13
Quindío	0.26	−0.13	0.25	−0.14	0.25	−0.15	0.24	−0.16
Risaralda	0.45	−0.07	0.45	−0.07	0.46	−0.08	0.45	−0.09
Santander	0.50	−0.57	0.49	−0.58	0.49	−0.58	0.48	−0.59
Sucre	−0.01	−0.05	−0.02	−0.06	−0.03	−0.08	−0.03	−0.09
Tolima	0.64	−1.05	0.62	−1.04	0.61	−1.02	0.59	−1.01
Valle del Cauca	0.31	−0.20	0.31	−0.22	0.31	−0.22	0.30	−0.22
Regions gaining (of 24)	21	0	21	0	21	0	20	0
Smallest	−0.11	−1.05	−0.12	−1.04	−0.13	−1.02	−0.14	−1.01
Largest	0.64	−0.05	0.62	−0.05	0.61	−0.05	0.59	−0.05
Rank correlation with 2015	1.00	0.99	1.00	1.00	1.00	1.00	0.99	0.99

Notes: Consumption-equivalent change in worker welfare, in percent, from introducing the welfare-maximizing minimum wage, 0.54 times the current level, relative to the same tariff regime without a minimum wage, by region and education group. Each regime is solved at both levels of the minimum wage, which is held fixed relative to average earnings, with tariff revenue rebated to workers. Mean tariffs are 0 (free trade), 3.5 percent (2015), 7.9 percent (2009), and 12.3 percent (high protection). The 2015 columns are the values mapped in the left panels of Figure 8. The rank correlation is the Spearman correlation across the 24 regions between a regime's column and the 2015 column of the same education group. Relative to the current minimum wage, college workers gain from the optimum in every region under every regime, and noncollege workers gain in 22 of the 24 under every regime, with Bogotá D.C. and Santander losing in each. The wage-work versus self-employment elasticity is 5 for noncollege and 1.5 for college workers.

Table D.9: Welfare and informality over the minimum-wage grid, 2015 tariffs

Minimum wage		Welfare vs no minimum wage (CEV, %)			Inclusive informality	
(multiple of current)	κ	All	Noncollege	College	All	Noncollege
0.00	0.00	0.000	0.000	0.000	0.533	0.602
0.20	0.13	+0.011	+0.012	−0.007	0.533	0.602
0.40	0.27	+0.144	+0.169	−0.125	0.538	0.608
0.54	0.36	+0.212	+0.263	−0.342	0.551	0.626
0.60	0.40	+0.172	+0.232	−0.481	0.561	0.638
0.80	0.54	−0.372	−0.278	−1.389	0.608	0.697
1.00	0.67	−1.262	−1.134	−2.636	0.663	0.762
1.20	0.81	−2.086	−1.921	−3.853	0.712	0.814
1.40	0.94	−2.981	−2.787	−5.051	0.755	0.858
1.60	1.08	−3.818	−3.590	−6.249	0.792	0.892

Notes: κ is the minimum wage relative to average hourly earnings. Welfare is the consumption-equivalent change for workers relative to the no-minimum-wage equilibrium under the same tariff schedule. Informality includes informal wage workers and the self-employed, pooled over education groups with employment weights. College informality rises from 0.340 without a minimum wage to 0.401 at the current policy.

Table D.10: The optimal minimum wage and employer wage-setting power

		Optimal minimum wage		Welfare vs no minimum wage (CEV, %)	
η	Wage/MRPL, $\eta/(1+\eta)$	Multiple of current	κ	At the optimum	At the current policy
1.5	0.60	0.72	0.49	+0.922	+0.242
2.0	0.67	0.61	0.41	+0.438	−0.751
2.5	0.71	0.54	0.36	+0.212	−1.262
3.0	0.75	0.48	0.32	+0.105	−1.540
4.0	0.80	0.37	0.25	+0.014	−1.746
5.0	0.83	0.32	0.22	+0.003	−1.780

Notes: Each row re-solves the minimum-wage grid under the 2015 tariff schedule with the firm-level labor-supply elasticity η changed and all other parameters at their estimates; the baseline is $\eta = 2.5$. The reported optimum maximizes worker welfare among the solved grid points, and welfare is evaluated at that policy. Because η also governs wage dispersion, each row is a comparative static, not an alternative estimate.

Table D.11: Decomposition of the welfare effect of the minimum wage, 2015 tariffs

	Total	Relative prices and transfers	Labor wedges	Entry and composition	Efficiency (wedges + entry)
Optimum (0.54) vs no minimum wage					
All workers	+0.212	+0.383	+0.538	−0.709	−0.171
Noncollege	+0.263	+0.435	+0.539	−0.711	−0.172
College	−0.343	−0.187	+0.523	−0.679	−0.156
Current policy (1.00) vs no minimum wage					
All workers	−1.270	+0.355	+1.771	−3.396	−1.625
Noncollege	−1.140	+0.491	+1.774	−3.406	−1.632
College	−2.671	−1.120	+1.740	−3.291	−1.551

Notes: Cumulative change from the no-minimum-wage equilibrium, 100 times the change in log consumption-equivalent welfare, following the first-order decomposition in Atkin and Donaldson (2022). Relative prices and transfers collect the worker's own wage, rents, the payroll and tariff rebates, the foreign transfer, and the cost of living. Labor wedges are the employment effects of the gap between the marginal revenue product of labor and the wage, which the minimum wage narrows at constrained firms. Entry and composition collect firm entry, formality status, the productivity composition of firms, job premia, the composition of workers within cells, and self-employment. Each block is invariant to the choice of numeraire, while the individual terms within a block are not, so only blocks are reported. Totals differ slightly from the consumption-equivalent changes in the text because they are log changes. Maximizing the sum of the labor-wedge and entry-and-composition blocks alone for all workers gives 0.22 times the current minimum wage, worth 0.001 percent (every policy from 0.17 to 0.27 is within 0.001 percentage points of it).

Table D.12: Robustness of the welfare-maximizing minimum wage, 2015 tariffs

	Optimal minimum wage	Within 0.001 pp	Worker welfare vs no minimum wage (CEV, %)	
	(multiple of current)	of the best	At the optimum	At the current policy
Headline estimate	0.54	0.54–0.55	+0.212	−1.262
Migration across regions, average elasticity 1	0.55	0.54–0.55	+0.220	−1.150
Migration across regions, average elasticity 2	0.55	0.54–0.56	+0.224	−1.074
Migration across regions, average elasticity 3	0.56	0.55–0.56	+0.227	−1.019

Notes: Each row solves the minimum-wage path under the 2015 tariff schedule, with the minimum wage held fixed relative to average earnings. The rows use steps of 0.01 (for migration, steps of 0.01 between 0.30 and 0.80 and of 0.10 elsewhere) and report the policy that maximizes worker welfare among the solved grid points. With migration, workers choose a region with a logit choice whose average elasticity across regions is 1, 2, or 3, and welfare is the consumption equivalent of expected utility, amenities included.

Table D.13: The optimal minimum wage under alternative tariff regimes

	Free trade	2015 tariffs	2009 tariffs	High protection
Mean tariff (%)	0	3.54	7.91	12.29
Optimal minimum wage (multiple of current)	0.54	0.54	0.54	0.54
Optimal κ	0.36	0.36	0.36	0.36
Worker welfare relative to no minimum wage, same regime (CEV, %)				
At the optimum	+0.221	+0.212	+0.204	+0.196
Labor-wedge term at 0.54 times the current minimum wage (log points)	+0.540	+0.538	+0.536	+0.534
At the current policy	−1.262	−1.262	−1.258	−1.251
Worker welfare at the optimum relative to 2015 tariffs and the current policy (CEV, %)				
All workers	+1.000	+1.503	+2.034	+2.455
Informality at the current policy	0.662	0.663	0.665	0.667
Informality response to a 10% higher minimum wage (pp)	2.585 to 2.625 across regimes			

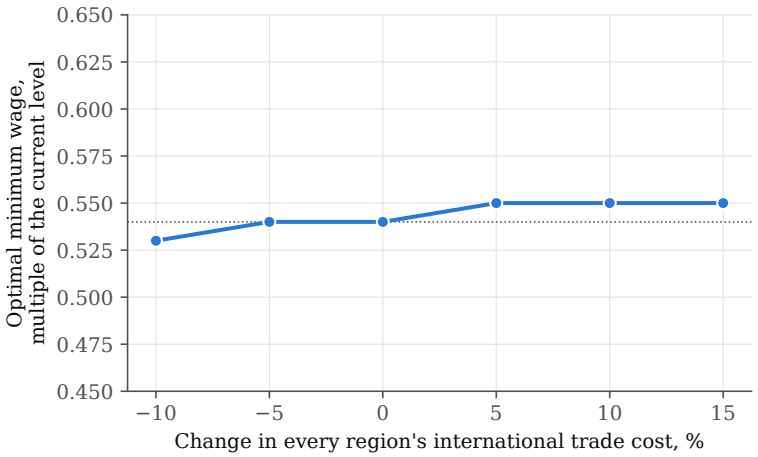
Notes: Regional tariffs are import-weighted averages by region of use. The 2009 regime adds to each region's 2015 tariff the 2009–2015 change in applied national sector tariffs, weighted by the region's import composition (mean increase 4.37 percentage points); high protection adds twice that change. The reported optimum maximizes worker welfare among the solved grid points, spaced 0.01 apart, and welfare is evaluated at that policy. The labor-wedge term is the corresponding block of Table D.11, in log points. The last welfare row uses the 2015 equilibrium at the current minimum wage as the common reference, so it includes the effect of the tariff regime itself.

Table D.14: The optimal minimum wage by wage-setting power and tariff regime

η	Free trade	2015 tariffs	2009 tariffs	High protection
1.5	0.72 (0.71–0.72)	0.72 (0.71–0.72)	0.72 (0.71–0.72)	0.72 (0.70–0.72)
2.0	0.61 (0.61–0.61)	0.61 (0.61–0.61)	0.61 (0.61–0.62)	0.62 (0.61–0.62)
2.5	0.54 (0.54–0.55)	0.54 (0.54–0.55)	0.54 (0.54–0.55)	0.54 (0.54–0.55)
3.0	0.48 (0.46–0.49)	0.48 (0.46–0.49)	0.48 (0.47–0.49)	0.49 (0.45–0.49)
4.0	0.37 (0.35–0.38)	0.37 (0.35–0.38)	0.36 (0.34–0.39)	0.36 (0.33–0.38)
5.0	0.32 (0.30–0.35)	0.32 (0.30–0.35)	0.32 (0.30–0.34)	0.32 (0.30–0.34)

Notes: Minimum wage that maximizes aggregate worker welfare among the solved grid points, expressed as a multiple of its current level, with the range of policies within 0.001 percentage points of it in parentheses. Each row re-solves the minimum-wage path with the firm-level labor-supply elasticity η changed and all other parameters at their estimates. The minimum wage is held fixed relative to average earnings.

Figure D.5: The optimal minimum wage and international trade costs



Notes: Minimum wage that maximizes aggregate worker welfare among the solved grid points, expressed as a multiple of its current level, when every region's international iceberg trade cost, for exports and imports, is scaled by the same percentage, under 2015 tariffs. The dotted line marks 0.54. At 2015 trade costs the full range of minimum wages is solved in steps of 0.01. At the other levels, from a 10 percent cut to a 15 percent increase, the model is solved in steps of 0.01 on a band around the optimum, extended until welfare falls on both sides.