Trade and Minimum Wages in General Equilibrium: Theory and Evidence*

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Abstract

This paper develops a new model with heterogeneous firms under perfect competition in a Heckscher-Ohlin setting to show that a binding minimum wage, surprisingly, raises (lowers) firm and industry productivity in the labor (capital) intensive sector by making selection stricter (weaker). It reduces exports in the labor intensive sector, despite increasing price, and encourages substitution away from labor. Exploiting rich regional variation in minimum wages across Chinese cities and using Chinese Customs data matched with firm level production data, we find robust evidence in support of causal effects of minimum wage consistent with our theoretical predictions.

Keywords: Trade, Minimum Wage, General Equilibrium, Heterogeneous Firms
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1 Introduction

Countries from Afghanistan to Zambia set a minimum wage. Australia has among the highest minimum wage of about $\$13.00$ (Australian $\$18.93$) in 2019 compared to the federal minimum wage of $\$7.25$ in the U.S. The rationale for a minimum wage and the level at which it is set can vary with the circumstances. In the U.S. the minimum wage has traditionally been used to enable workers to have a "living wage" though in the last few decades, the real minimum wage has fallen so much that it may no longer serve that function.[1] As a result, states and even cities, have taken to setting their own, often far higher, minimum wage. Seattle, Los Angeles and Washington D.C. are among those with plans to phase in a $15 minimum wage in the next few years.

Minimum wages are clearly highly relevant for policy and all their implications should be well understood, both in terms of theory and practice. Despite its clear policy relevance and the extensive work in this area, the impact of minimum wage *on the economy as a whole* remains understudied. Our contribution is twofold. First, we provide a completely new competitive general equilibrium apparatus that builds on the Heckscher-Ohlin-Samuelson model, but with heterogeneous firms subject to capacity constraints. We then use the model to make novel but intuitive predictions about the effects of a minimum wage on selection and survival patterns of heterogeneous firms, as well as production and exports. In addition we provide less novel predictions on the effects of a minimum wage on product and export prices, and the factor intensity of production. Second, we use production and trade data from China, where different cities set and frequently change minimum wages, to test the predictions of the model.[2] We exploit the extremely rich regional variation and two plausible instruments to tease out the causal effect of minimum wages on a variety of firm level outcomes, such as survival, productivity and patterns of production.

The most novel prediction of the model is that with a higher minimum wage, selection in the labor intensive sector becomes stricter, while that in the capital intensive sector becomes weaker. In other words, higher cost capacity is shut down and less productive firms exit and more so in the labor intensive sector. This selection mechanism results in productivity growth at both the firm and industry level in the labor intensive sector. The model also predicts an increase in price, and more so in the labor intensive sector. Less obviously, it predicts a *fall* in output and exports in the labor intensive good, despite an increase in its price. Had wages just been rising, say because the price of labor intensive goods rose with the integration of China into the world market, we would

[1] "Democrats in the House and Senate have announced a bill to raise the federal minimum wage gradually from its current $7.25 to $15 by 2024. Advocates for the $15 minimum wage argue that it will help workers make ends meet and reduce inequality, improve child health and education outcomes, and stimulate the economy with more purchasing power for low-wage workers. Opponents argue that high minimum wages will kill jobs, hurt small businesses, and raise prices." See Michael Reich and Jesse Rothstein, Econofact.org, April 27, 2017.

[2] Note that in China the administrative division with the autonomy to set the minimum wage is the prefecture. We use the term *city* in place of prefecture for simplicity henceforth.

expect output and exports of the labor intensive good to *rise* as China moved along its production possibility frontier and produced/exported more labor intensive goods. Thus, minimum wages and a general rise in wages due to integration have *opposite* implications for output and exports. More standard predictions are that a binding minimum wage encourages substitution away from labor, though less so for skill and capital intensive goods.

We not only provide a new model, that makes new predictions, but we also test these predictions, and show they are very much present in the data. For example, an increase of 500 RMB a year, a roughly 10% increase in the minimum wage, leads to roughly 1 percentage point increase in the probability of exit from export for firms in the lowest quartile of wages. Similarly, Total Factor Productivity (TFP) rises for firms in the first quartile of wages by 3%, while capital intensity (K/L) rises by 4%. Labor share falls by very little. The magnitude of all these effects tend to be smaller in higher initial wage quartiles.

Our work is related to a number of areas. It is related to research in labor economics on the employment impact of the minimum wage, to the literature in international trade on the effects of minimum wages in general equilibrium, to empirical work on the Chinese economy that documents the effects on exports of the minimum wages in China, and to the recent literature on firm heterogeneity and trade.

The bulk of empirical research in labor economics has focused on effect of minimum wages on low-skill employment, in particular on fast food restaurants, with mixed results.[3] It is possible that the literature following Card and Krueger (1994) was looking in the wrong place for the effects of minimum wages. If fast food establishments have limited substitution possibilities between labor and capital, it would be hard to observe strong employment effects of higher minimum wages.[4] But in the US context, with low levels of minimum wages, fast food is typical of the kind of establishments where minimum wage is binding. This may change in near future as cities move to set minimum wages that are, in some cases, significantly higher than state or federal levels.[5] Recent work (see Jardim, Long, Plotnick, van Inwegen, Vigdor and Wething (2017)) on Seattle's hike of the minimum wage to $11-13 in 2016 (depending on business size, tips, and health insurance) suggests a much more central role for minimum wages. While restaurants may not reduce employment, other industries with greater substitution possibilities seem to do so. In addition, even

[3]See Neumark and Wascher (2008), Neumark, Salas and Wascher (2014), and Neumark (2017). The approach has for the most part been to use difference-in-differences comparisons to evaluate the effect of these policies on employment levels as in Card and Krueger (1994).

[4]Moreover, franchises may be further limited in how they can adjust. For example, McDonald's provides franchises with business manuals that lays out required operational procedures at a franchise. See the contract at https://www.scribd.com/doc/233487415/McDonalds-Franchise-Agreement.

[5]In the District of Columbia, the hourly minimum wage is $13.25 (effective Jul. 1, 2018) compared to a Federal one around $7.25, and is set to rise till it reaches $15.00 July of 2020. Similar rates are planned for many large cities, especially in California. See http://www.paywizard.org/main/salary/minimum-wage/California/california.

for restaurants, Luca and Luca (2019) show that higher minimum wages result in the exit of lower quality (rated by Yelp) restaurants.

The literature has also turned to looking at other relationships such as minimum wage and inequality, migration and factor substitution, and the valuation of firms. For example, Autor, Manning and Smith (2016) and Lee (1999) study the relationship between minimum wages and inequality using variation in state level minimum wages in the US, while DiNardo, Fortin and Lemieux (1996) follows a semi-parametric approach to do so. Monras (2019) argues that higher real minimum wages in a state in the US resulted in lower unskilled labor migration. Adjusting capital is discussed as a possible mechanism to limit the response of employment as in Sorkin (2013).

There has also been considerable work that suggests that the minimum wage may not reduce the level of employment in a discrete manner, and may in fact affect the growth of wages and employment due to search frictions in the labor market as in Flinn (2006). See Cahuc, Carcillo and Zylberberg (2014) for a summary of this work. Minimum wage effects will spillover to segments of the labor market that are not directly constrained via general equilibrium effects in search settings. Engbom and Moser (2018) quantifies the impact of minimum wage on earnings inequality using a search and matching model and matched employer-employee data from Brazil and concludes that about 70% of the decline in inequality can be attributed to higher minimum wages. There is also very recent work on the effect of an unanticipated hike in the minimum wage on the valuation of firms, for example Bell and Machin (2018), and on the incidence of this increase in cost, for example Harasztosi and Lindner (2019). Cooper, Luengo-Prado and Parker (2019) show that in the US, following minimum wage increases, both prices and nominal spending rise. and are associated with reduced total debt among households with low credit scores, higher auto debt.

In the context of the labor literature, our contribution is to provide a unified tractable general equilibrium framework to obtain and test for clean predictions regarding a number of outcomes of interest. These include factor returns and input substitution which have been empirically examined in isolation (and without a model that ties them together) to date, in addition to new outcomes of interest such as selection, pricing, the intensive and extensive margin of firms' production and exports. Our model is the competitive analogue of the monopolistically competitive heterogeneous firm setting common in international trade and industrial organization. To make the competitive model with heterogeneous firms internally consistent, we place limits on the extent of a firm's ability to supply at its marginal costs, i.e., it has capacity constraints. This allows us to embed the model in the simple Heckscher-Ohlin setting in a transparent fashion and obtain the essential insights.

In the context of the literature in international trade, our work extends the seminal work of Brecher (1974) and Davis (1998) that studies the effects of a minimum wage in general equilibrium in a homogeneous firm setup to allow for firm heterogeneity. Brecher looks at the effects of a minimum wage in a standard two good, two factor, two country Heckscher-Ohlin setting. As a minimum wage raises costs in the labor intensive sector by more than in the capital intensive one, it reduces the comparative advantage and exports of a labor abundant country while accentuating the comparative advantage of a capital abundant one.[6] Davis (1998) extends this work to show that trade between an economy with binding minimum wages and one without, can raise wages in the latter while increasing unemployment in the former. Put more simply, the economy without a minimum wage gets all the benefits of higher wages without incurring any of the costs.

Our addition of firm heterogeneity to the Heckscher-Ohlin setting is new in itself and extends the range of this workhorse model. In addition, we take the model to the data to understand the effects of minimum wages. Our empirical application to China is tailor-made for this. The importance of exports to the Chinese economy can not be overstated. Different cities in China set different minimum wages, often at fairly high levels, and then change them over time. This huge cross-sectional and over time variation in minimum wage in a country where many firms operate under binding minimum wage across a range of industries with varied substitution possibilities is the ideal setting to study our question.[7]

There is a recent empirical literature on minimum wages in China. Wang and Gunderson (2012) look at minimum wages and employment in Eastern China using the standard difference in difference approach using data from 2003. They find little effect, and speculate this may be because the minimum wages are not enforced very strictly before 2004. In contrast, Fang and Lin (2015) using data from household surveys, find significant effects of minimum wages on employment. Huang, Loungani and Wang (2014), studies the effects of minimum wages on firm employment exploiting the fact that cities in China set different minimum wages and these vary over time, and find that minimum wages reduce employment, particularly for low wage firms. Hau, Huang and Wang (2018) find that "minimum wages accelerate the input substitution from labor to capital in low wage firms, reduce employment growth, but also accelerate total factor productivity growth, particularly among the less productive firms under private Chinese or foreign ownership, but not among state owned enterprises." Interestingly, they argue that minimum wage increases do not reduce output and attribute this to increased TFP which is especially prevalent in the bottom half of the TFP distribution. They attribute these effects to differences in management practices and "catch up" by low productivity firms in the face of competitive pressures. Mayneris, Poncet and Zhang (2018) also document that wage cost and more interestingly productivity improved among surviving firms, even though survival productivity declined, using 2004 minimum wage reforms in China.

It is worth pointing out that in contrast to our paper, none of these papers have a general

[6]Schweinberger (1978) and Neary (1985) extend the model to allow for more goods and sectors.

[7]We provide more background on the institutional setting and the patterns of minimum wages set in Section 5.

equilibrium model which can guide them in terms of the entire set of predictions to test and through which they can interpret the data. As a result, their model specifications and some empirical results differ from ours.[8]

Our work also contributes to the recent literature on firm heterogeneity and its role in trade. The standard approaches in this area are based on Melitz (2003) or on Eaton and Kortum (2002). The former builds on the now standard models of monopolistic competition with constant marginal costs. The latter assumes that costs are random and that the lowest cost firm making each variety is the supplier and can supply all that is needed. In contrast, we assume perfect competition and that firms have capacity constraints. We provide a new and transparent competitive model with heterogeneous firms subject to capacity constraints in a Heckscher-Ohlin setting. We do so with a view to providing another option in terms of modeling approaches and because the existing approaches are, perhaps, less well suited to our problem. Our model makes clear the links between product and factor markets and the channels through which both trade and the minimum wage operate in the general equilibrium with heterogeneous firms. We also sketch a simple way to embed firms in an industry so that the model can provide firm (as well as industry) level predictions in our competitive setting which we take to the data.

One could incorporate Melitz (2003) in a Heckscher-Ohlin setting as in Bernard, Redding and Schott (2007). Melitz (2003) highlights the cleansing effect of trade, and Bernard et al. (2007) show that this cleansing effect of trade liberalization is greater in the comparative advantage sector but only *in the presence of costly trade*. There is no such prediction if trade is costless. The intuition for their result is simple. Trade reduces prices overall since goods can be more widely sourced. In the presence of trade costs, trade liberalization reduces the *relative* price index of the comparative advantage sector since imported goods incur trade costs while domestically produced ones do not. Competitive pressures rise by more in the comparative advantage sector which makes selection stricter there. The selection effect that are at the heart of our model come from allowing factor intensity to differ in entry costs relative to production costs. By assuming that factor intensity is the same in both entry and production costs within a sector, Bernard et al. (2007) rule out the selection effects at work in our model. While the predictions of trade on selection are the same in our work and in Bernard et al. (2007), the channels differ.

Our interest is in building a simple framework which is capable of capturing selection effects that arise due to an increase in minimum wage. One reason that we chose not to use Bernard et

[8] For example, though Hau et al. (2018) look at the response of labor substitution, productivity, exit, export value and volume to the minimum wage as do we, their specification only uses one dimension of "bindingness", namely the minimum wage exposure defined as the elasticity of the average wage paid to the minimum wage. The idea is that if the average wage paid is low, the minimum wage will be more binding and will have to rise by more, something we also check for and find. In contrast, our model suggests that factor intensity will also affect such "bindingness" and our specification is geared to look for this and part of the reason why our findings differ from theirs is that our specifications differ.

al. (2007)'s approach as the benchmark model is that their assumptions regarding factor intensities of entry and production costs specifically exclude selection effects that arise due to changes in factor prices which occur with minimum wages. Their model *can* be extended to allow for such effects at some cost in complexity. It would deliver similar results, as the forces that operate with minimum wages tend to do so in similar ways across a range of standard models. Minimum wages would raise costs, and more so in the labor intensive sector so that there would tend to be a loss of comparative advantage in this sector with consequent effects on prices, production and exports. We choose to use our competitive model both because it is new and because its workings end up being analogous to those of a standard Heckscher-Ohlin setting in a number of ways, making it easy to follow.

The Eaton and Kortum (2002) approach to firm heterogeneity works elegantly in the Ricardian setting and is particularly well-suited for quantitative analysis. Their Ricardian model can be augmented to include two factors with different substitution possibilities across industries to obtain the kind of insights we obtain in our framework. In their setting, the higher costs, especially of the labor intensive sector, will reduce the probability of it being the lowest cost supplier of such varieties so that a higher minimum wage will result in lower exports. We chose not to use their approach as we want to focus on the qualitative channels through which minimum wages affect outcomes, rather than estimate a quantitative model in this paper.

The paper proceeds as follows. The setting is explained in Section 2. Section 3 characterizes the equilibrium with heterogeneous firms in the absence of minimum wages. Section 4 incorporates minimum wages, and lays out the key predictions of the model. It is the heart of the paper. Section 5 explains how minimum wages are set in China, points to some patterns in minimum wages over space, and explains our identification strategy. Section 6 tests the predictions of the model in the data. Section 7 offers some directions for future work and concludes. Details of some proofs, additional empirical and simulation results are in the Appendix.

2 The Setting

All markets are perfectly competitive. Consumers in each city consume a homogenous good A and an aggregate good, S, which is a composite of two aggregate goods X and Y. These aggregate goods are made up of the different varieties of x and y, with each city producing its own unique variety. Thus, each city has two industries, x and y.

Consumers have a utility function

$$U = U(S, A)$$

which is homothetic. In particular, we will assume that

$$U = A^{\alpha} S^{1-\alpha}$$

and

$$S = (X^{\rho} + Y^{\rho})^{\frac{1}{\rho}}$$

where $\sigma = \frac{1}{1-\rho}$ is the constant elasticity of substitution between X and Y. Also,

$$X = \left[\sum_{j=1}^{J} (x_j)^{\rho_x}\right]^{\frac{1}{\rho_x}}, \; Y = \left[\sum_{j=1}^{J} (y_j)^{\rho_y}\right]^{\frac{1}{\rho_y}}$$

and $\sigma_x = \frac{1}{1-\rho_x}$ ($\sigma_y = \frac{1}{1-\rho_y}$) is the constant elasticity of substitution between varieties of X (Y). We assume that there are $j \in J$ cities, each with its agricultural hinterland.

Each city j has a capital endowment K^j and labor endowment L^j. These factors earn rental rate r^j and wage w^j. We will suppress j for simplicity hereon till needed. Firms in a city can make the city's variety of the two manufactured goods, x and y. How much a firm can make depends on its capacity as explained below. These goods differ in their factor intensities, and we assume that good x is labor intensive. Thus, within a city and for a given industry all manufacturing firms make the *same* variety of the manufactured good. Moreover, producers of manufactured goods do not know their costs *ex-ante*, but discover them *ex-post*. First they pay the fixed entry costs in an industry of $f_e c^e(w, r)$. This entitles them to produce a *single* unit of the good at the cost $c(w, r)\theta$ where $c(\cdot)$ is the base unit cost and θ is the inverse of its realized productivity. Firms draw their θ from the distribution $f(\theta)$. A higher θ denotes lower productivity or higher costs. A firm with many draws will pay the fixed cost for each draw and have a higher potential capacity. Firms use all their capacity that is profitable. There is free entry so that the number of draws made is endgenously determined. In the competitive setting, what defines a firm is irrelevant: here we define a firm to be just a collection of draws. Each firm in a city is competitive and takes the price for the city's variety as given. However, as firms are ex-post heterogeneous, some firms earn quasi rents. There are no financing frictions or credit constraints.

Each city also makes a homogeneous good, A, in its rural area. This agricultural good, A, uses one unit of effective labor per unit of output and has a price of unity. Workers have different effective units embodied in them if they work in agriculture but all workers have the same productivity in manufacturing. In agriculture, type γ labor produces γ units of output. W is the earnings of an effective unit of labor and equals unity by definition. Note that a worker of type γ would make γ units of A and so earn γ in agriculture and w in manufacturing and choose to go where his earnings are higher. $g(\cdot)$ is the distribution of labor productivity in agriculture. As all workers are assumed to be equally productive in manufacturing, workers with a high γ choose not to migrate from the rural to urban areas of a city. Those with a low γ migrate to the urban area to look for work in manufacturing. As the wage in manufacturing increases, agriculture contracts, and the productivity of the marginal worker in agriculture rises. This results in the usual bowed out shape for the production possibility frontier in each city.

Recall that each city produces its own variety of each of the two goods and all firms in a given city produce the *same* variety. X and Y are aggregate goods and made in a constant elasticity of substitution (CES) fashion from the individual varieties (x and y) made in different cities. Let p^{jx} and p^{jy} denote the *factory price* of the variety made in city j. There is an integrated domestic market for each variety of each good so that each city pays the factory price (which is obtained by the producer) plus any transport costs. Domestic demand for a variety j of x (similarly for y) in city k is denoted by $x_k^{jD}(p_k^{jx}, P_k^X, P_k^Y, I_k)$. N^{jx} is the mass of firms that enter into variety x^j. p_k^{jx} and p_k^{jy} will denote the prices in city k of the variety manufactured in city j. We assume there are no transport costs incurred for a city's own variety and that transport costs take an iceberg form. As a result, $p_k^{jx} = p^{jx}T^{jk}$ and $p_k^{jy} = p^{jy}T^{jk}$. Note that the price of the aggregate good, P_k^X and P_k^Y will vary by city: well connected cities will tend to have lower aggregate prices than cities that are remote.

Demand for a typical variety comes from all the cities and from the rest of the world (which can be treated as another city). The demand for variety $j \in J$ made by city j of good x for example comes from all cities $k = 1...J$

$$D^{jx}(\cdot) = \sum_{k=1,..J} T^{jk} \left(\frac{p^{jx}T^{jk}}{P_k^X}\right)^{-\sigma_x} \left(\frac{P_k^X}{P_k}\right)^{-\sigma} \frac{(1-\alpha)\, I_k}{P_k}$$

where p^{jx} is the factory price of variety j of good x, T^{jk} is the iceberg transport cost between j and k, P_k^X (P_k^Y) is the aggregate price index for X (Y) in city k which take the usual form:

$$\begin{aligned} P_k^X &= \left(\sum_{j=1,..J} (p^{jx}T^{jk})^{1-\sigma_x}\right)^{\frac{1}{1-\sigma_x}} \\ P_k^Y &= \left(\sum_{j=1,..J} \left(p^{jy}T^{jk}\right)^{1-\sigma_y}\right)^{\frac{1}{1-\sigma_y}} \end{aligned}$$

where σ_i is the elasticity of substitution between varieties of good $i,\ i = x, y$. Similarly, P_k is the price index of the overall aggregate good

$$P_k = \left(\sum_{s=X,Y} (P_k^s)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}$$

We will use these definitions when we come to the market equilibrium defined below. We will first analyze what happens in a single city and then extend our model to many cities.

Take a representative city (j) and sector (x or y) to begin with. We first show how factory prices (p) define selection of the ex-post heterogeneous firms making each good. Then we show how to solve for factor prices and outputs. Once we have this, we are able to write down supply and together with demand to solve for equilibrium prices.

If the price of the good is p, only those suppliers who draw a cost below price will produce, that is, $\theta c(w,r) \leq p$, or $\theta \leq \tilde{\theta}(\cdot) = \frac{p}{c(w,r)}$ will choose to produce the good. This defines the marginal firm as having $\theta = \tilde{\theta}(\cdot)$. Supply of the city's variety at price p, given N, the mass of firms, and $f(\theta)$, the density of θ is thus:

$$s(p, N, c(w,r)) = N\left[F\left(\frac{p}{c(w,r)}\right)\right]. \tag{1}$$

This defines the industry supply curve in the short run (i.e., for given N). In the long run, as there is a cost of entry, and firms only discover their productivity after incurring this cost, N is endogenous.

Firms enter until their expected profits equal the fixed cost of entry. Clearly, selection depends on the specification of entry costs.

Lemma 1. *(i) If entry costs in a sector are paid solely in terms of the good being made in that sector, the identity of the marginal firm, $\tilde{\theta}$, is fixed and there are no selection effects. (ii) If entry requires the use of both goods x and y, then an increase in the price of a factor makes selection stricter in the good that uses the factor intensively. (iii) If entry costs are in terms of the numeraire good, then an increase in costs of production makes selection stricter in both sectors.*

Proof. A firm pays a fixed cost of entry, f_e, draws a θ, then decides to produce or not. A firm with cost $\theta c(\cdot)$ makes 1 unit of output by hiring $a_L(w,r)\theta$ units of labor and $a_K(w,r)\theta$ units of capital and earns p, where $a_L(w,r)$ and $a_K(w,r)$ are the unit input requirements. It pays $\theta c(w,r)$ for its inputs and $f_e c^e(w,r)$ for its entry costs. Integrating over the range of productivity such that a firm chooses to produce gives:

$$\begin{aligned}
\int_0^{\frac{p}{c(w.r)}} (p - \theta c(w,r))\, f(\theta) d\theta &= c^e(w,r) f_e \\
\left[c(w,r)\int_0^{\tilde{\theta}} F(\theta) d\theta\right] &= c^e(w,r) f_e
\end{aligned}$$

where the second line above follows from integration by parts.[9] Thus,

$$\left[\int_0^{\tilde{\theta}} F(\theta)d\theta\right] = \frac{c^e(w,r)}{c(w,r)}f_e. \tag{2}$$

If $c(w,r) = c^e(w,r)$, then $\int_0^{\tilde{\theta}} F(\theta)d\theta = f_e$ which pins down $\tilde{\theta}$. In this event, $\tilde{\theta}$ does not depend on anything other than the distribution of productivity and the entry cost, f_e. More generally, $\frac{c^e(w,r)}{c(w,r)}$ moves in the same direction as $\tilde{\theta}$. If $c^e(w,r)$ uses a mix of good x and y, then the intensity of factor usage in entry costs will lie in between that of x and y. Therefore, an increase in the price of a factor will raise costs of the good using it intensively relative to entry costs so that $\frac{c^e(w,r)}{c(w,r)}$ will fall and selection will become stricter. If f_e is in terms of the numeraire good, A, then p rises with $c(\cdot)$ but less than proportionately. Free entry requires

$$\left[c(w,r)\int_0^{\frac{p}{c(w.r)}} F(\theta)d\theta\right] = f_e.$$

Clearly, $\frac{p}{c(w,\, r)}$ must fall as $c(\cdot)$ rises so selection becomes stricter in both sectors. $\square$

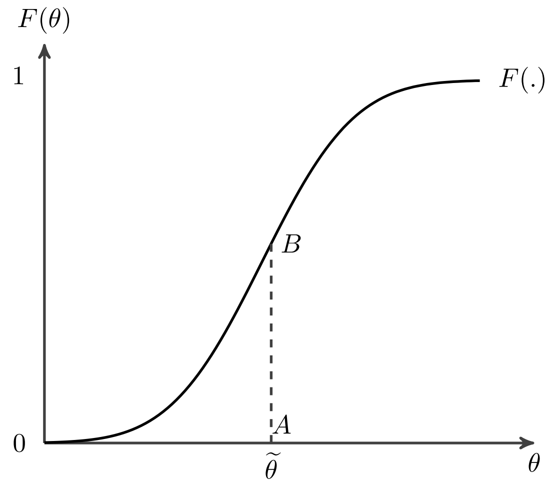
We will work with case (ii) above for the rest of the paper. The free entry condition in equation (2) can be interpreted as the expected quasi rents, $\int_0^{\tilde{\theta}} F(\theta)d\theta$, being equal to the real cost of entry $\frac{c^e(w,r)}{c(w,r)}f_e$. With a unit mass of firms entering, supply at a cutoff θ is just $F(\theta)$.[10] The area OAB in Figure 1 then is just the area between the supply curve and the cutoff, which is analogous to producer surplus (the area between the price and the supply curve) in a competitive setting. Free entry requires that this area equals $\frac{c^e(w,r)}{c(w,r)}f_e$ which can be thought of as the cost of entry in terms of the units of the good being made or the real cost of entry. This is what drives cutoffs.

Without selection effects, because $\tilde{\theta}$ is independent of price, the model will look similar in many ways to the standard Heckscher-Ohlin two good, two factor, two country model. There are three twists even without any selection effects. First, the analogue to the standard unit input requirements of input i for good j, denoted by A_{ij}, includes both the requirement in entry and in production. With some work we show that without selection, though $A_{ij} \neq a_{ij}$, where a_{ij} denotes the unit input requirement in production, we will still have $\frac{A_{Lj}}{A_{Kj}} = \frac{a_{Lj}}{a_{Kj}}$ which is what ensures that the Rybczynski result goes through. The second twist is that because of a numeraire good,

[9]Recall that for the marginal firm, price equals cost, we have $p = \tilde{\theta}c(w,r)$.

[10]If a mass N enters, both costs and returns increase proportionately.

Figure 1: Cutoff Productivity



both the price of x and y are endogenously determined, not just their ratio, so that we need to first solve for the price of one good given the price of the other and then solve for the equilibrium prices themselves. Third, migration makes labor supply endogenous. Consequently, product price changes bleed over into factor availability. For example, an increase in the price of the capital intensive good will raise r and reduce w, reducing capital intensity and thereby raising the supply of the capital intensive good. The fall in w also affects the labor supply available to industry due to migration. If migration falls with a fall in w, then there is a magnified supply response coming from migration via a Rybczynski like effect.

Selection adds new challenges and insights, but in essence, the same approach works by continuity when we limit selection by assuming each good uses mostly its own good in entry costs. When both goods are used in entry costs, an increase in the price of the labor intensive good (say due to trade with a capital abundant country) will raise wages. This increase in wages reduces the cutoff for costs in the labor intensive sector making selection stricter there, and raises it in the capital intensive sector making selection weaker.[11] Output and exports of the labor intensive sector expand and those of the capital intensive sector contract as in the standard HOS setting as entry in a sector rises with a rise in price.

We then incorporate minimum wage into the model and derive comparative static properties of the model with a change in minimum wage, both without and with limited selection. A binding minimum wage acts like a negative supply shock: price rises but quantity falls. Note the contrast to the effect of a increase in the price of the labor intensive good. In the Appendix we show using simulated examples that even when selection effects are relatively prominent, the key comparative

[11]Note the prediction on trade and selection: trade makes selection stricter in the comparative advantage sector.

statics of the model continue to hold.

3 Solving the Model

In this section we look at the different modules that make up the model before turning to the effects of a minimum wage. Throughout we assume that there are no factor intensity reversals and that endowments put us in no specialization region in any given city. Note that as each city makes a different variety of the two manufactured goods, the equilibrium price of these goods can differ across cities: those with low transport costs would tend to have higher demand for their manufactured goods, and so face higher product and factor prices, than would less well connected cities. Trade is implicit in the model. The difference in demand from domestic cities and supply from a domestic city is exports of that city's variety while demand for foreign varieties is met by imports.

3.1 Product Prices and Factor Prices

Cutoffs in a sector depend on w and r as shown in (2). For our two sectors in a city we have[12]

$$\left[\int_0^{\tilde{\theta}^x} F^x(\theta)d\theta\right] = \frac{c^{ex}(w,r)f_e^x}{c^x(w,r)} \tag{3}$$

$$\left[\int_0^{\tilde{\theta}^y} F^y(\theta)d\theta\right] = \frac{c^{ey}(w,r)f_e^y}{c^y(w,r)} \tag{4}$$

Given (w,r) we can get $\left(\tilde{\theta}^x, \tilde{\theta}^y\right)$ from the free entry conditions equations (3) and (4). This then fixes the position of the price equal cost curves of the marginal firm. Let us call these cutoffs $\left(\tilde{\theta}^x\left(w,r\right), \tilde{\theta}^y\left(w,r\right)\right)$.

With two sectors and each city making its unique variety of the good in each sector,

$$p^x = \tilde{\theta}^x(w,r)c^x(w,r) \tag{5}$$

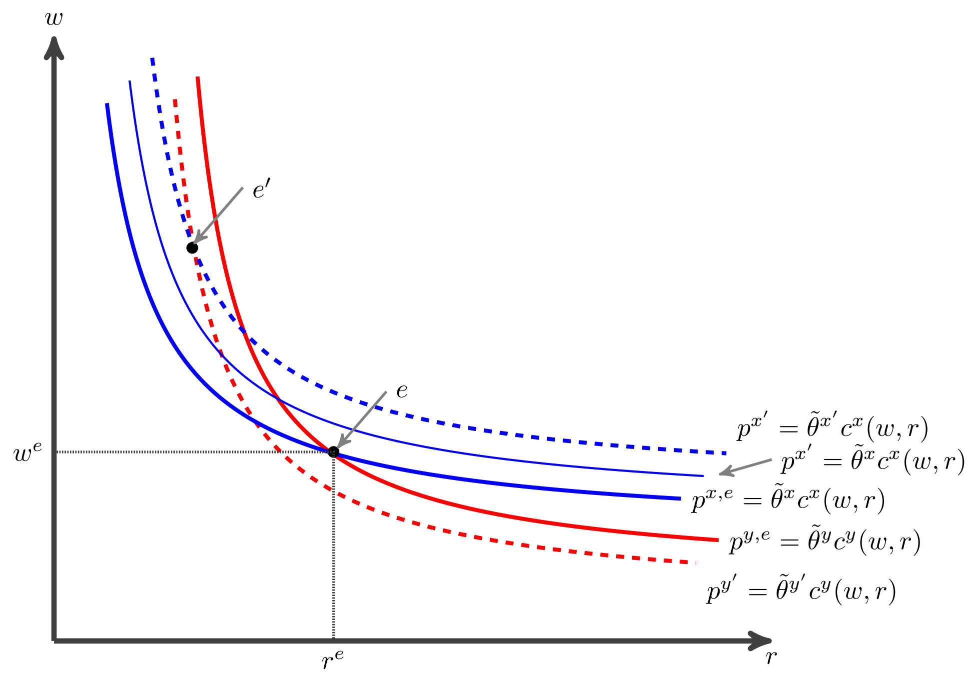
$$p^y = \tilde{\theta}^y(w,r)c^y(w,r) \tag{6}$$

$$1 = W. \tag{7}$$

W is the wage per effective unit of labor and equals unity. As there is free entry, once we know prices, we know w, r. As a result, given product prices, we know factor prices in a manner anal-

[12] We allow the draw of costs to differ across sectors.

Figure 2: Product Prices and Factor Prices



ogous to that in the simple Heckscher-Ohlin setting.[13] Note that as $p^j = \tilde{\theta}^j(w,r)c^j(w,r)$ for $j = x, y$, a fall in $\tilde{\theta}^j(w,r)$ occurs because price rises by less than costs or falls by more than costs.

Lemma 2. *When entry costs use both goods, the Stolper-Samuelson theorem remains valid and is magnified by selection effects. An increase in the price of the labor intensive good raises w and reduces r while making selection stricter in the labor intensive good and weaker in the capital intensive one. An increase in the price of the capital intensive good raises r and reduces w while making selection stricter in the capital intensive good and weaker in the labor intensive one.*

For this reason, we can write cutoffs in terms of product prices as $\tilde{\theta}^x(\overset{-}{p^x}, \overset{+}{p^y}), \tilde{\theta}^y(\overset{+}{p^x}, \overset{-}{p^y})$. To understand how a price increase would affect factor prices it is useful to think of this as happening in two steps. In the first step, keep the cutoffs fixed. This is the direct effect of price changes without incorporating selection. In the second step, let cutoffs change to reflect the selection effect.

Figure 2 depicts the increase in the price of x, from $p^{x,e}$ to $p^{x'}$. As a result, the equilibrium moves from e to e'. Suppose we keep the selection cutoff fixed at $\tilde{\theta}^x$ and $\tilde{\theta}^y$. Then the price change results in w rises and r falls *á la* Stolper-Samuelson. This in turn reduces $\tilde{\theta}^x$ to $\tilde{\theta}^{x'}$ and raises $\tilde{\theta}^y$ to $\tilde{\theta}^{y'}$ which shifts the curve for x further out and for y further in as shown in Figure 2. In effect, the selection effects further increase $\frac{p^x}{\tilde{\theta}^x}$ while reducing $\frac{p^y}{\tilde{\theta}^y}$. Note, both direct and indirect effects

[13]If there are no selection effects, as is the case when entry costs in each sector are in terms of the good made in that sector, then $\tilde{\theta}^X, \tilde{\theta}^Y$ are fixed and factor prices are homogeneous of degree one in product prices.

work in the same direction. So the Stolper-Samuelson theorem remains, but is *magnified* due to the selection effect.

Of course, in an analogous manner, an increase in the price of the capital intensive good raises the rental rate and reduces the wage. It also reduces the "real cost" of entry ($\frac{c^{ey}(w,r)}{c^{y}(\cdot)}$) in the capital intensive good, making selection tighter there, and as it raises the real cost of entry ($\frac{c^{ex}(w,r)}{c^{x}(\cdot)}$) in the labor intensive good, making selection looser there. A more formal proof is in the Appendix.

3.1.1 Migration and Income

Let $G(\cdot)$ be the cumulative density function of productivity of labor in agriculture. There is overall a mass L of labor. If the wage is w, agents with agricultural productivity below w will be better off working in the manufacturing sector and move there. Recall, that all agents are homogeneous in terms of their productivity in manufacturing. K denotes the exogenous availability of capital which is used only in manufacturing.[14] For simplicity, we assume agriculture uses only effective labor.

Given prices, we can get factor prices and hence total income which is the value of factor payments:

$$\begin{aligned} I &= \bar{\gamma}(w)L + wG(w)L + rK \qquad (8) \\ &= \bar{\gamma}(w)L + p^x x + p^y y \end{aligned}$$

where

$$\bar{\gamma}(w) = \int_{w} \gamma g(\gamma) d\gamma = (1 - G(w))\, E(\gamma|\gamma > w) \qquad (9)$$

is the number of effective units of labor in agriculture (per unit mass of labor, i.e, assuming $L = 1$) when the manufacturing wage is w. If the mass is L these workers will earn $\bar{\gamma}(w)L$ in agriculture. Clearly $\bar{\gamma}(w)$ is decreasing in w. We assume that migration is only from the agricultural hinterland of a city to its urban area for simplicity.[15]

$$\begin{aligned} dI &= L\left[-wg(w) + G(w) + wg(w)\right] dw + Kdr \\ &= LG(w)dw + Kdr \end{aligned}$$

In other words, the change in the labor income is just the change in wage times the number of

[14]Capital is owned by some agents but as preferences are homothetic, who owns it does not matter. Nor does migration confer ownership rights to capital so that migrants respond only to differences in their expected earnings between agriculture and manufacturing in any given city.

[15]A recent paper, Pérez (2018), studies the effect of city level minimum wages in the US on commuting patterns and migration decisions using both reduced form and structural models.

workers not in agriculture. This makes sense: workers on the margin of switching out of agriculture are indifferent between working in agriculture or manufacturing, and so gain nothing from the switch. The income of those that remain in agriculture is unchanged, while the income of workers in industry rises with an increase in the wage. Capital income, of course, rises with the rental rate.

3.2 Outputs and Factors

Let $\bar{\theta}^x(\tilde{\theta}^x) = \int_0^{\tilde{\theta}} \theta f(\theta) d\theta$. Clearly, $\bar{\theta}^x(\tilde{\theta}^x)$ moves in the same direction as $\tilde{\theta}$. A firm of type θ demands $\theta c_w(w,r) + f_e c_w^e(w,r)$ units of labor and $\theta c_r(w,r) + f_e c_r^e(w,r)$ units of capital. All firms that enter incur f_e, but only firms with θ below $\tilde{\theta}$ are active. Let N^x and N^y denote the mass of firms which enter in sector x and y respectively. Hence, factor market clearing (FMC) gives:

$$N^x \left(c_w^x(\cdot)\bar{\theta}^x(\cdot) + f_e c_w^e(\cdot) \right) + N^y \left(c_w^y(\cdot)\bar{\theta}^y(\cdot) + f_e c_w^e(\cdot) \right) = G(w)L \quad (10)$$

$$N^x \left(c_r^x(\cdot)\bar{\theta}^x(\cdot) + f_e c_r^e(\cdot) \right) + N^y \left(c_r^y(\cdot)\bar{\theta}^y(\cdot) + f_e c_r^e(\cdot) \right) = K \quad (11)$$

So at given prices and hence at given factor prices, only N^x, N^y are unknown. Rewriting this more compactly gives

$$N^x A_{Lx}(w,r) + N^y A_{Ly}(w,r) = G(w)L \quad (12)$$

$$N^x A_{Kx}(w,r) + N^y A_{Ky}(w,r) = K \quad (13)$$

where A_{ij}, the total unit input requirement in equilibrium of factor i in sector j, is given by:

$$\begin{aligned}
\left[c_w^x(w,r)\bar{\theta}^x(\tilde{\theta}^x(w,r)) + f_e c_w^e(w,r) \right] &= A_{Lx}(w,r) \\
\left[c_w^y(w,r)\bar{\theta}^y(\tilde{\theta}^y(w,r)) + f_e c_w^e(w,r) \right] &= A_{Ly}(w,r) \\
\left[c_r^x(w,r)\bar{\theta}^x(\tilde{\theta}^x(w,r)) + f_e c_r^e(w,r) \right] &= A_{Kx}(w,r) \\
\left[c_r^y(w,r)\bar{\theta}^y(\tilde{\theta}^y(w,r)) + f_e c_r^e(w,r) \right] &= A_{Ky}(w,r)
\end{aligned}$$

At given product prices, we have given factor prices and cutoffs and so given A_{ij}'s. As a result, we can solve the factor market clearing conditions (equations (12) and (13)) for entry. Factor market clearing is depicted in Figure 8.

Note that the A_{ij}'s themselves do not always move in line with the a_{ij}'s. For example, an increase in $\frac{w}{r}$ reduces the unit labor input requirement in production and in entry for good x, and as it reduces $\bar{\theta}^x$, it also reduces $A_{Lx}(w,r)$. Similarly, an increase in $\frac{w}{r}$ raises A_{Ky}. However, as an increase in $\frac{w}{r}$ reduces the unit labor input requirement in production and in entry for good y, but as it raises $\bar{\theta}^y$, it is not clear how it affects $A_{Ly}(w,r)$. Similarly, it is not clear how an increase in

$\frac{w}{r}$ affects $A_{Kx}(w,r)$. For this reason, assuming no selection makes things easier to follow, though this assumption is by no means critical to any of the results.

Assumption 1. Entry costs are in terms of the good being made. In other words, $c^x(w,r) = c^{ex}(w,r)$ and $c^y(w,r) = c^{ey}(w,r)$.

When Assumption 1 holds, then we can show that even though $A_{ij} \neq a_{ij}$, it remains true that $\frac{A_{Kj}}{A_{Lj}} = \frac{a_{Kj}}{a_{Lj}}$, $j = x, y$.

Lemma 3. *When Assumption 1 holds,* $\frac{A_{Lx}(\cdot)}{A_{Kx}(\cdot)} = \frac{a_{Lx}(\cdot)}{a_{Kx}(\cdot)} > \frac{A_{Ly}(\cdot)}{A_{Ky}(\cdot)} = \frac{a_{Ly}(\cdot)}{a_{Ky}(\cdot)}$.

Proof.

$$\begin{aligned}
A_{Lx} &= \left[c_w^x(w,r)\bar{\theta}^x(\tilde{\theta}^x) + f_e c_w^{ex}(w,r)\right] \\
&= c_w^x(\cdot)\left[\tilde{\theta}^x F(\tilde{\theta}^x) - \int_0^{\tilde{\theta}^x} F(\theta)d\theta\right] + f_e c_w^{ex}(\cdot) \\
&= c_w^x(\cdot)\left[\tilde{\theta}^x F(\tilde{\theta}^x) - \frac{c^{ex}(w,r)f_e}{c^x(w,r)} + \frac{f_e c_w^{ex}(\cdot)}{c_w^x(\cdot)}\right] \\
&= c_w^x(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x)
\end{aligned}$$

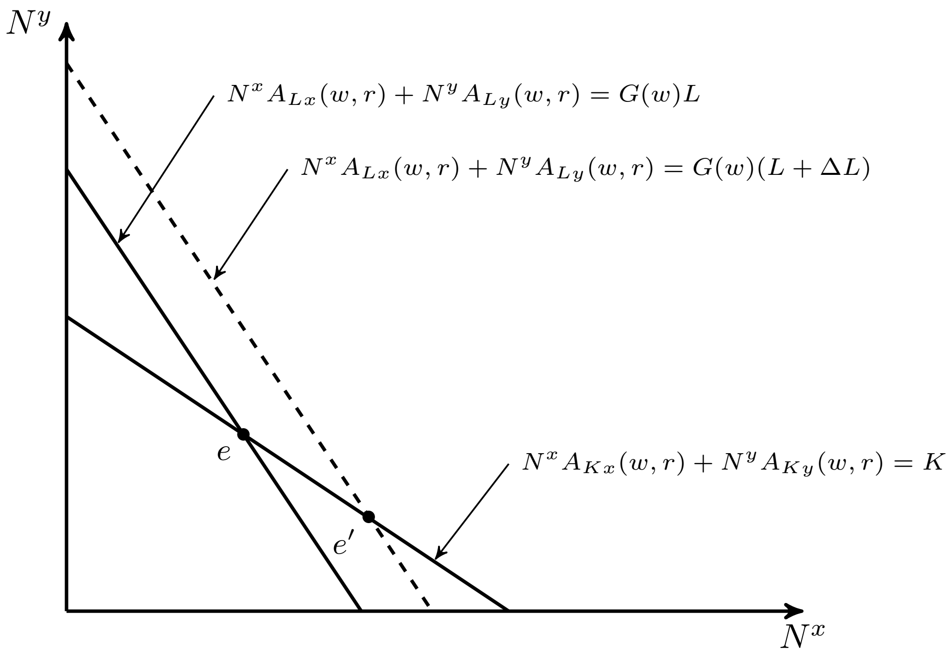
where the second line follows from integrating by parts, the third follows from the free entry condition. If $c^{ex}(w,r) = c^x(w,r)$, then $\frac{c^{ex}(w,r)f_e}{c^x(w,r)} = f_e = \frac{f_e c_w^{ex}(\cdot)}{c_w^x(\cdot)}$ so that $A_{Lx} = c_w^x(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x)$ and as a result, $\frac{A_{Lx}(\cdot)}{A_{Kx}(\cdot)} = \frac{a_{Lx}(\cdot)}{a_{Kx}(\cdot)}$. The analogous proof works for other total input requirements. □

In all the following results summarized in the lemmas, we first consider the case of no selection such that Assumption 1 holds, and then extend our results to the case of limited selection. First we turn to look at the effects of endowment changes on entry.

Lemma 4. *At given prices, and with limited selection effects, an increase in L raises entry in x, the labor intensive product, while reducing it in y, the capital intensive one. Similarly, an increase in K raises entry in y and reduces it in x.*

Proof. Given product prices, we have factor prices and these pin down the $A_{ij}(\cdot)$ values. Thus the factor market clearing conditions (13) and (12) are just straight lines. These are depicted in Figure 3. With N^y on the vertical axis and N^x on the horizontal axis, the labor market clearing line given by equation (12) is steeper than the capital market clearing one given by equation (13) as long as $\frac{A_{Lx}(\cdot)}{A_{Ly}(\cdot)} > \frac{A_{Kx}(\cdot)}{A_{Ky}(\cdot)}$, that is, $\frac{A_{Lx}(\cdot)}{A_{Kx}(\cdot)} > \frac{A_{Ly}(\cdot)}{A_{Ky}(\cdot)}$. With no selection effects, this is ensured by Lemma 3 since $\frac{a_{Lx}(\cdot)}{a_{Kx}(\cdot)} > \frac{a_{Ly}(\cdot)}{a_{Ky}(\cdot)}$ by assumption. This is what drives the Rybczynski type result. An increase in L, at given prices, shifts the labor market clearing curve outwards in a parallel manner.

Figure 3: Entry and Endowments



This raises the mass of entry in the labor intensive sector and reduces it in the capital intensive one. Similarly, an increase in K raises the mass of entry in the capital intensive sector and reduces it in the labor intensive one. In essence, entry responds to endowments just as output does in the Heckscher-Ohlin model. $\square$

Even with selection effects, the same argument works as long as $\frac{A_{Lx}(\cdot)}{A_{Kx}(\cdot)} > \frac{A_{Ly}(\cdot)}{A_{Ky}(\cdot)}$. Lemma 3-A in the Appendix shows that in the presence of selection effects, $\frac{A_{Lx}}{A_{Kx}} < \frac{a_{Lx}}{a_{Kx}}$ and $\frac{A_{Ly}}{A_{Ky}} > \frac{a_{Ly}}{a_{Ky}}$. In other words, selection effects bring the total labor intensities closer together. However, if $c^{ex}(w,r)$ is close enough to $c^x(w,r)$, $\frac{A_{Lx}}{A_{Kx}}$ remains above $\frac{A_{Ly}}{A_{Ky}}$ so that the labor market clearing line in the presence of limited selection effects, and for given product prices, remains steeper than the capital market clearing one. This is all we need for the Rybczynski style result to go through.

3.3 Supply, Demand and Equilibrium Prices

By changing the price we can trace out the supply curve at any price. As prices change, so do factor prices and with them the unit and total unit input requirements, a_{ij} and A_{ij}.

Lemma 5. *As long as selection effects are limited, there is a positive own price effect and a negative cross price effect on entry so we can write* $N^x(\overset{+}{p^x}, \overset{-}{p^y}; \overset{+}{L}, \overset{-}{K})$, $N^y(\overset{-}{p^x}, \overset{+}{p^y}; \overset{-}{L}, \overset{+}{K})$. *Moreover, there is a positive own price effect and a negative cross price effect on supply as well.*

Proof. Again we first show the logic of the result without selection, and then argue it remains valid as long as selection effects are limited. As $\tilde{\theta}^x$ is fixed without selection effects, so is $\bar{\theta}^x(\tilde{\theta}^x(w, r))$. As a result, the $A_{ij}(\cdot)$'s move exactly as the $a_{ij}(\cdot)$'s do. An increase in the price of x, the labor intensive good, raises w and reduces r, making both goods less intensive overall in their use of labor. Factor market clearing conditions (given labor availability) then require the entry in x (the labor intensive good) to rise and y to fall to use up the available labor. This is the logic of the usual supply response in the Heckscher-Ohlin model. In addition to this, as migration rises with wages, the increase in w increases the available labor through migration, resulting in a magnified response as more available labor further raises entry in x and further reduces entry in y. Thus, an increase in own price raises own entry while an increase in the other good's price reduces own entry. Analogous arguments can be made for the effects of an increase in the price of good y.

When we allow for selection there is an additional channel that operates through the effect on the A_{ij}'s via $\bar{\theta}$. This effect can work against the A_{ij}'s behaving analogously to the a_{ij}'s though it does not always have to do so. For example, an increase in the price of y reduces $\frac{w}{r}$ and so raises $c^y_w(w, r)$ and $c^e_w(w, r)$ but makes selection stricter in y and so *reduces* $\bar{\theta}^y(\tilde{\theta}^y(w, r))$. As selection effects are constrained, so is the change in $\bar{\theta}^y(\tilde{\theta}^y(w, r))$ induced by them. Once again, by continuity, we can ensure that the $A_{ij}(\cdot)$'s move in the same direction with and without selection. This allows the logic of the normal supply response in these models to operate.

Turning to the effects on supply, since each firm makes one unit of output, supply is just $N(\cdot)F(\tilde{\theta})$. Without selection effects, supply is driven entirely by the effects on entry as described above. Consequently, there is a positive own price response for supply and a negative cross price one. When selection effects are present, there is an additional channel that operates directly on supply through selection. An increase in the price of a good makes selection stricter in the sector so $F(\tilde{\theta})$ in the sector falls while entry rises. As

$$\Delta Supply \simeq F(\tilde{\theta})\Delta N + Nf(\tilde{\theta})\Delta\tilde{\theta}$$

by limiting selection, i.e., $\Delta\tilde{\theta}$, we can argue that the sign of $\Delta Supply$ is the same as that of ΔN. Again, continuity arguments limit the effect of selection on the outcome. Thus, in an open interval around the no selection model, supply will remain increasing in own price and decreasing in the other price. □

Setting supply equal to demand will give the equilibrium price in a representative city for the two goods (we are suppressing the index j).

$$\begin{aligned} N^x(\overset{+}{p^x}, \overset{-}{p^y}; \overset{+}{L}, \overset{-}{K}) F^x(\tilde{\theta}^x(\overset{-}{p^x})) &= D^x(p^x; P^X, P^Y, P, I) & (14) \\ N^y(\overset{-}{p^x}, \overset{+}{p^y}; \overset{-}{L}, \overset{+}{K}) F^y(\tilde{\theta}^y(\overset{-}{p^y})) &= D^y(p^y; P^X, P^Y, P, I). & (15) \end{aligned}$$

Demand for a city's variety depends only on the price of its own variety, given I, P^X, P^Y and P. Of course, in equilibrium, these indices are consistent with the ones derived in equilibrium. The demand for variety j of x depends on its own price, and is downward sloping in price, while supply depends on the price of both the x and y varieties made. With limited selection, supply rises in own price and falls with the other price. Equilibrium is given by the intersection of demand and supply in all markets such that these prices are mutually consistent.

Equilibrium (given the price of the other good) is depicted in Figure 4 for good x and in Figure 5 for good y. Equilibrium, given a price of the other good, is where demand and supply intersect. To find the the consistent equilibrium prices in both markets simultaneously it will be useful to depict the equilibrium as the market clearing price of a variety of x, given a price of the variety of y, and vice versa. This is done in Figure 7 with p^y on the y axis and p^x on the x axis. As the price of the city's variety of x rises, there is a positive supply response in x (the supply curve is upward sloping as drawn in Figures 4 and 5) and a negative one in y (the supply of y shifts inwards so that the equilibrium price in y rises with an increase in the price of x). This is depicted in Figure 7 by the line $p^y(p^x; L, K)$ which defines the equilibrium price of y for a given price in of x. Similarly, as the price of y rises, there is a positive supply response in y (the supply curve is upward sloping as drawn in Figures 4 and 5) and a negative one in x (the supply of x shifts inwards so that the equilibrium price in x rises with an increase in the price of y). This relationship between the price in of y and the equilibrium price of x is depicted in Figure 7 by $p^x(p^y; L, K)$. Note that $p^y(p^x; L, K)$ and $p^x(p^y; L, K)$ are upward sloping. For stability, $p^x(p^y; L, K)$ needs to be steeper than $p^y(p^x; L, K)$. This requires own price effects to dominate cross price ones. Equilibrium prices are given by the intersection of these two curves at $(p^{x,e}, p^{y,e})$ in Figure 7.

Before we turn to minimum wages let us ask what the new predictions of the model are for the effects of trade. Recall that the only way trade enters the model here is through the demand side. In equilibrium, trade will raise the price of the comparative advantage good and so make selection stricter in the comparative advantage sector and weaker in the comparative disadvantage sector. Thus, existing firms will exit the comparative advantage sector. However, the price increase will also raise the mass of firms so that entry will rise. Note that trade will raise both exit of existing firms and entry of new firms in the comparative advantage sector, that is, there will be more churning in this sector. In the other sector, selection will become easier but fewer firms will enter. In other words, there will be less churning in the comparative disadvantaged sector. This

Figure 4: Supply, Demand and Minimum Wages in x

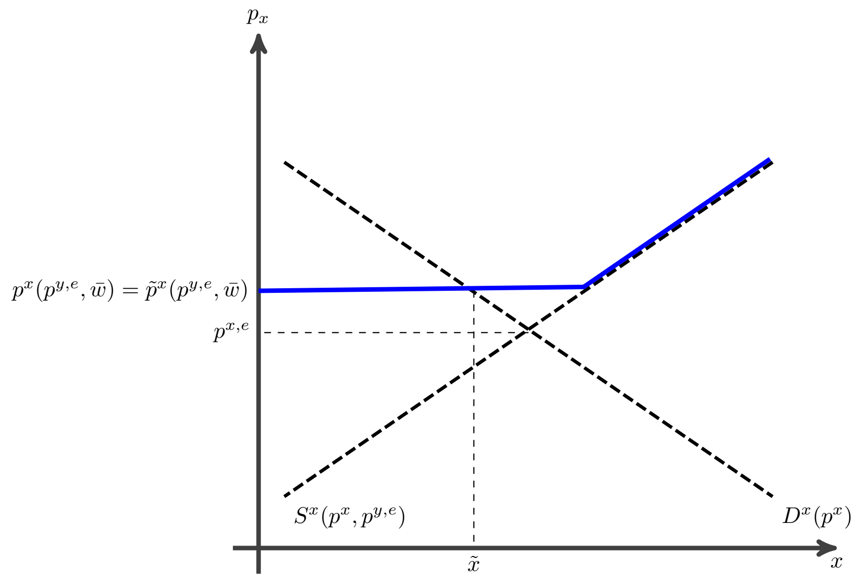
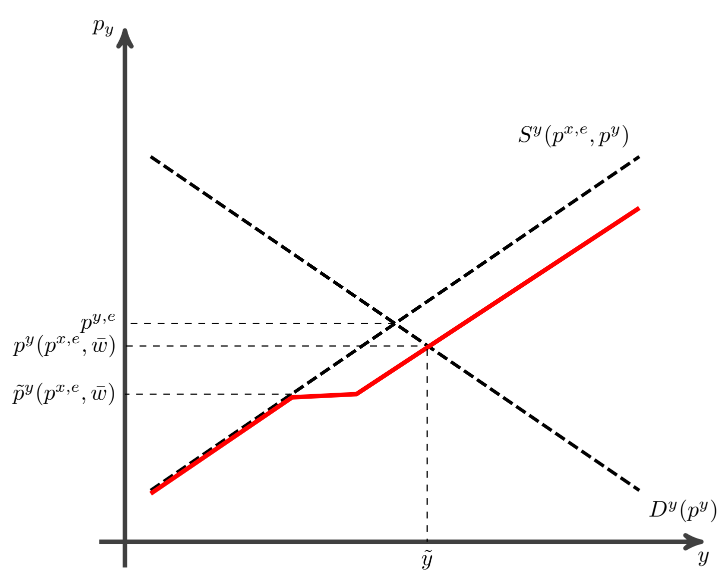


Figure 5: Supply, Demand and Minimum Wages in y



result is much like that in Bernard et al. (2007) though the mechanism differs. We are now finally in a position to look at the effects of a minimum wage in our model.

4 Minimum Wages and Outcomes

How would a minimum wage affect equilibrium? Recall that there are three goods, A, x and y in each city and we have fixed the price of A at unity. As each variety is unique, and all goods are essential in demand, all goods are made and price equals cost for the marginal firm making each good. Consider a particular city. Equilibrium will be given by the system of equations.

$$p^x = \tilde{\theta}^x(\bar{w}, r)c^x(\bar{w}, r) \tag{16}$$

$$p^y = \tilde{\theta}^y(\bar{w}, r)c^y(\bar{w}, r) \tag{17}$$

$$1 = W = p^A \tag{18}$$

where $\bar{w}$ is the minimum wage.

Again, free entry gives

$$\left[\int_0^{\tilde{\theta}^x} F^x(\theta)d\theta\right] = \frac{c^{ex}(\bar{w}, r)f_e^x}{c^x(\bar{w}, r)} \tag{19}$$

$$\left[\int_0^{\tilde{\theta}^y} F^y(\theta)d\theta\right] = \frac{c^{ey}(\bar{w}, r)f_e^y}{c^y(\bar{w}, r)}. \tag{20}$$

If the minimum wage is binding, labor markets do not clear. The supply of labor at the wage relevant for workers exceeds the demand resulting in unemployment. Let $\hat{w}(\bar{w})$ be the expected wage in the manufacturing sector of a city when the minimum wage is binding at $\bar{w}$. The expected wage is the probability of finding a job in the manufacturing sector times the minimum wage, where the probability of finding a job is less than one due to equilibrium unemployment in presence of a binding minimum wage. If workers are risk neutral, this will be the relevant wage for workers choosing to migrate or not.[16]

As firms pay the minimum wage, their input decisions are dictated by it, and for this reason the $A's$ depend on the minimum wage and the rental rate. Demand for labor cannot exceed supply

[16] If they are not risk neutral, then the wage that equates their expected utility will be the relevant one for migration choices.

while capital markets clear so that:

$$N^x A_{Lx}(\bar{w}, r) + N^y A_{Ly}(\bar{w}, r) = L^D \leq G(\hat{w}(\bar{w}))L = L^s \quad (21)$$

$$N^x A_{Kx}(\bar{w}, r) + N^y A_{Ky}(\bar{w}, r) = K \quad (22)$$

where the expected wage $\hat{w}(\bar{w})$ is given by:

$$\hat{w}(\bar{w}) = \left(\frac{L^D}{L^S}\right)\bar{w} \quad (23)$$

and income, I, in the city is

$$I = \bar{\gamma}(\hat{w}(\bar{w}))L + \hat{w}(\bar{w})G(\hat{w}(\bar{w}))L + rK. \quad (24)$$

Goods market clearing will give product prices:

$$D^x(p^x, I) = N^x(p^x, p^y, \bar{w}, G(\hat{w}(\bar{w})L, K)\ F^x(\tilde{\theta}^x(\cdot)). \quad (25)$$

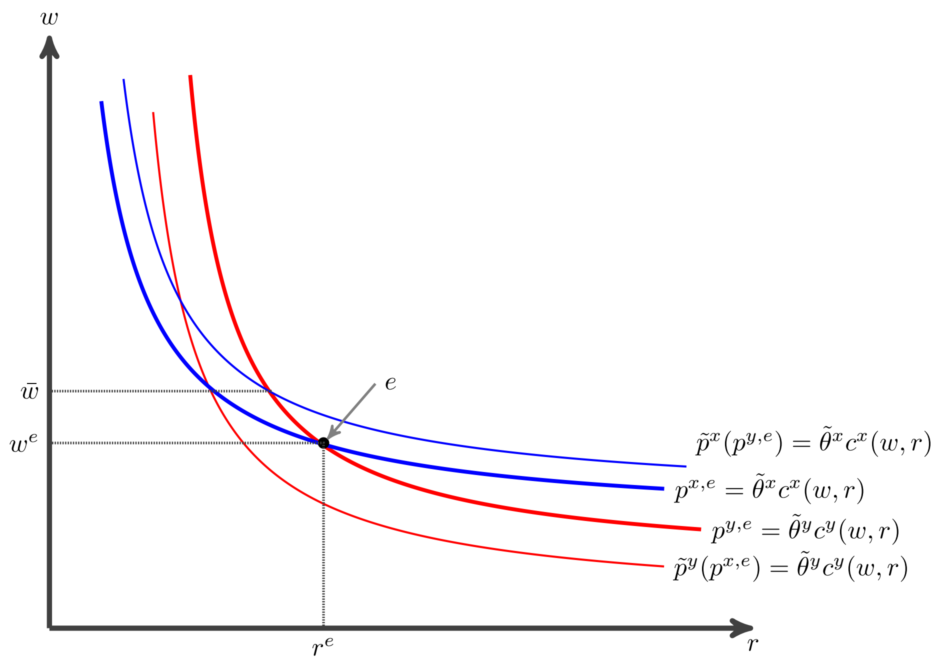
$$D^y(p^y, I) = N^y((p^x, p^y, \bar{w}, G(\hat{w}(\bar{w})L, K)\ F^y(\tilde{\theta}^y(\cdot)). \quad (26)$$

Consider the determination of factor prices at the equilibrium product prices $(p^{x,e}, p^{y,e})$ in the absence of a minimum wage in Figure 6. We depict the case where cutoffs are fixed. The curves represent $p^{x,e} = \tilde{\theta}^x c^x(w, r)$ and $p^{y,e} = \tilde{\theta}^y c^y(w, r)$ are depicted. As x is labor intensive, the former is flatter than the latter at any given $\frac{w}{r}$. At the given equilibrium product prices, and no minimum wage, factor prices are given by the intersection of the two thick curves depicting $p^{x,e} = \tilde{\theta}^x c^x(w, r)$ and $p^{y,e} = \tilde{\theta}^y c^y(w, r)$. This gives equilibrium factor prices, (w^e, r^e).

To understand the effects of a minimum wage consider the case where Assumption 1 holds so there are no selection effects and $\tilde{\theta}^x$ and $\tilde{\theta}^y$ are fixed. A minimum wage, $\bar{w}$, which is binding at the equilibrium prices in the absence of a minimum wage is depicted in Figure 6. At $(p^{x,e}, p^{y,e})$ the minimum wage is binding as $\bar{w}$ exceeds w^e. Since good y can afford to pay a higher r (along its price equal to cost curve) than x can, at these prices only the variety of good y is made. As a result, given $p^y = p^{y,e}$, the supply of x is zero until its price reaches $\tilde{p}^x(p^{y,e}, \bar{w})$ as depicted by the solid line in Figure 6. At this price, both goods can afford to pay the same r, given the minimum wage. This means that in Figure 4, supply of x is zero till the price rises to $\tilde{p}^x(p^{y,e}, \bar{w})$ which exceeds $p^{x,e}$. As a result, demand and supply for x intersect at a higher price and lower output. Consequently, the equilibrium price of x (for the given price of y) is actually $\tilde{p}^x(p^{y,e}, \bar{w})$. Note that $\tilde{p}^x(p^{y,e}, \bar{w})$ is the *lowest* prices of good x, given $p^y = p^{y,e}$, and $\bar{w}$, such that x is made.

What about good y? Let $\tilde{p}^y(p^{x,e}, \bar{w})$ be defined analogously as the highest prices of good y

Figure 6: Product Prices and Factor Prices with a Minimum Wage



such that x is made, given $p^x = p^{x,e}$. Recall that at $\tilde{p}^y(p^{x,e}, \bar{w})$, the two price equal to cost curves intersect at $\bar{w}$. If p^y rises beyond $\tilde{p}^y(p^{x,e}, \bar{w})$ in Figure 5, only y is made. As a result, there is a flat part for the supply function at $\tilde{p}^y(p^{x,e}, \bar{w})$ as depicted. All resources are used in y, but labor is in excess supply. As the price of y rises above this cutoff, r rises though w remains at $\bar{w}$. As a result, labor intensity rises and more of y can be made and supply is upward sloping. Supply with a minimum wage for good y is depicted by the solid line in Figure 5. As supply has shifted out, the equilibrium price of y, given the price of x, and the minimum wage $\bar{w}$, is lower with a binding minimum wage than without. The equilibrium price of good y, given $p^x = p^{xe}$ and the minimum wage $\bar{w}$ is denoted by $p^y(p^{xe}, \bar{w})$. Note that the minimum wage acts like a positive supply shock for y but a negative one for x.

Note that $\tilde{p}^x(p^y, \bar{w})$ and $\tilde{p}^y(p^x, \bar{w})$ represent the same thing, namely where the minimum wage is just binding in (p^x, p^y) space. This is drawn in Figure 7 and labeled as $\tilde{p}^x(p^y, \bar{w})$. $\tilde{p}^x(p^y, \bar{w})$ lies to the right of $p^x(p^y)$ at $p^y = p^{y,e}$ as drawn. The minimum wage is binding above the curve $\tilde{p}^x(p^y, \bar{w})$ and not binding below it. Below and to the right of it, x can be made as its price exceeds the cutoff price needed for it to be made, while above and to the left of this curve, the opposite is true. The *equilibrium* price for x, given a price of y, and the minimum wage $\bar{w}$, is denote by $p^x(p^y, \bar{w})$. It equals $p^x(p^y)$, the unconstrained equilibrium price when the minimum wage is not binding and $\tilde{p}^x(p^{y,e}, \bar{w})$ when it is binding as depicted by the solid blue line in Figure 7.

It is worth pointing out that the output of x is driven by demand, not supply (which is horizontal) when the minimum wage binds. Output is lower as shown in Figure 4, despite a higher equilibrium price. The higher the minimum wage, or the more labor intensive is x, the higher is the price ($\tilde{p}^x$) needed to elicit a positive supply of x, and the lower is the equilibrium output. That greater labor intensity of x raises $\tilde{p}^x$ is shown in Lemma 6 in the Appendix. This makes intuitive sense as the cost of x will rise by more when wage rises if x is more labor intensive. Consequently, price must also rise by more. Intuitively, the minimum wage acts like a negative supply shock in the labor intensive sector. This raises price and reduces quantity sold. In general equilibrium, the negative supply shock in the labor intensive sector implies a positive supply shock in the capital intensive one which reduces price and raises quantity, other things equal.

What about the equilibrium price of good y in the presence of a minimum wage denoted by $p^y(p^x, \bar{w})$? The same logic yields that in the region where the minimum wage is not binding, the equilibrium price of y, given a price of x, remains $p^y(p^x)$. In the region where it is binding, $p^y(p^x, \bar{w})$ lies below $p^y(p^x)$ as depicted in Figure 7. $p^y(p^x, \bar{w})$ is depicted by the solid red line in Figure 7. The intersection of $p^y(p^x, \bar{w})$ and $p^x(p^y, \bar{w})$ occurs where $\tilde{p}^x(p^y, \bar{w})$ intersects $p^y(p^x)$ which is labeled as the "New Equilibrium" in Figure 7.

Adding selection will make $\tilde{\theta}$ depend on the minimum wage and the rental rate. By limiting selection, the effects in the no selection case will dominate, so that the result will extend to limited selection as well. We look at the case even with strong selection effects at play in our simulations in the Appendix and find the same results.

Proposition 1. *A binding minimum wage in a city raises the price and reduces the output of the labor intensive good, for both the domestic market and for export, and this is more so, the higher the minimum wage and the more labor intensive the good.*

Note that both price are pushed up by the minimum wage and that the price increase is larger for x than y. This means that $\frac{w}{r}$ should rise so that the choice of technique becomes more capital intensive in both sectors. Moreover, though both prices rise, the output of x *falls* while that of y *rises*.

Proposition 2. *A binding minimum wage will raise the wage-rental ratio and raise the capital intensity in both sectors.*

A higher minimum wage raises the price of the labor intensive good by more than that of the capital intensive one. This in turn results in a higher equilibrium wage rental ratio. A higher minimum wage will thus tend to reduce the output of the labor intensive good and raise that of the capital intensive one while tending to making both goods more intensive in their use of capital. This is depicted in Figure 8 where $\frac{A_k}{A_L}$ is depicted as rising with the minimum wage in both sectors, with N^x falling and N^y rising. In Figure 8, migration is depicted as increasing with the minimum wage as the labor available in manufacturing is shown to be higher with the minimum wage.

Figure 7: Equilibrium Prices with and without a Minimum Wage

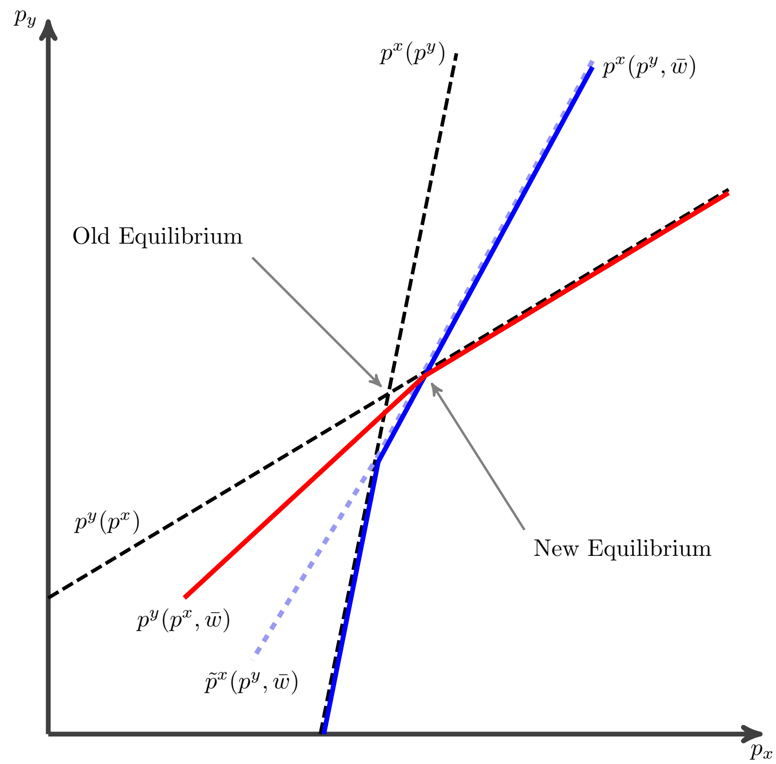
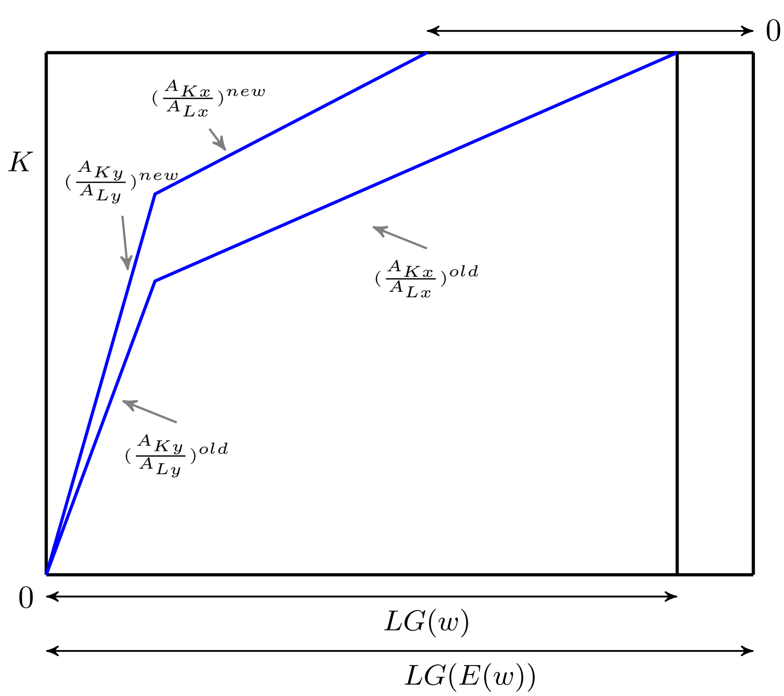


Figure 8: Factor Market Equilibrium with Minimum Wages



It is worth noting that while an increase in the wage always increases migration, an increase in the minimum wage could *raise* or *lower* migration. Note that the demand for labor is a derived demand from the final goods. As shown above migrants will equate their productivity in agriculture to their expected wage in manufacturing so that those with ability below $\tilde{\gamma}$ migrate where

$$\tilde{\gamma} = \hat{w}(\bar{w}) = \left(\frac{L^D}{G(\hat{w}(\bar{w}))L}\right)\bar{w}$$

or

$$\tilde{\gamma}G(\tilde{\gamma})L = L^D(\bar{w})\bar{w}.$$

The left hand side is increasing in $\tilde{\gamma}$. If the right hand side, which is the value of demand for labor at the minimum wage, rises (falls) with the minimum wage, then $\tilde{\gamma}$ will rise (fall) with an increase in the minimum wage and the total payment to labor will rise (fall) and there will be more (less) migration to the city. In other words, if labor demand is elastic, a higher minimum wage will actually reduce migration. Only if labor demand is inelastic will migration rise with the minimum wage. Thus, whether migration increases with minimum wage is ultimately an empirical question. Using state-level variation in minimum wage, Monras (2019) and Pérez (2018) provide evidence that low-skilled workers tend to leave US states that increase minimum wage.

Proposition 3. *An increase in the binding minimum wage will raise migration to the city if labor demand is inelastic and reduce it if labor demand is elastic.*

As the minimum wage raises the wage rental ratio in equilibrium, it causes selection effects as in Lemma 1. Moreover, the higher the minimum wage, the more prices and the wage rental ratio rise and the more the selection effects. In addition, the more labor intensive is sector X, the more costs and hence price rises in the sector due to a given minimum wage and hence the greater the selection effects. Higher exit in the labor intensive sectors lead to higher average productivity at both firm and industry level since only relatively more efficient (lower) cost draws survive the rise in minimum wage.

Proposition 4. *A binding minimum wage increases the wage rental ratio. If entry costs in an industry use both goods as inputs, then selection becomes stricter in the labor intensive industry, and weaker in the capital intensive one. Moreover, this is more so the higher the minimum wage and the more labor is used in making the labor intensive good. When selection gets stricter, productivity rises at the firm and industry level.*

4.1 Predictions of the Model

In this section we summarize the predictions regarding an increase in minimum wage for selection, production, exports, prices and factor intensity of production at the industry level on the basis of the model described above. Following this we turn to the implications of the model in terms of predictions at the firm level. We use firm level data to explore the predictions at the firm level, and city-industry data to test the predictions at the city level. We present firm level results in the body of the paper. Industry city results are available on request.

4.1.1 Predictions at the Industry - City Level

While the model we outline above has two goods and factors, the forces driving the results there should remain in more general settings. While we do not prove the results in a general setting, we use the intuition they are based on to lay out what we might expect to see in the real world based on the simple model presented.

What can we say about the extensive margin of firms and a binding minimum wage?

Prediction 1. (Exit): An increase in the minimum wage will make selection stricter in the the labor intensive sector and reduce the mass of firms in the sector. Consequently, we should see more exit in the labor intensive sector, and more so in more labor intensive sectors and where the minimum wage is more relevant.[17]

The more labor intensive a sector, the tighter becomes selection and the higher is average productivity at both the firm and industry level.

Prediction 2. (Productivity): Cities with high minimum wages should have a distribution of productivity that has a higher mean than that of low minimum wage cities, and this should be more pronounced in more labor intensive sectors and where the minimum wage is more relevant.

Next we turn to the effect on prices.

Prediction 3. (Prices): The price of the labor intensive good should rise with a binding minimum wage. The effects should be more pronounced for more labor intensive sectors, and when the minimum wage is more relevant.

Recall that as each city makes its own varieties, each labor intensive variety is not produced until its price rises by enough to cover the increase in cost, which creates the horizontal section of the supply curve.[18] Since this horizontal section is above the intersection of the two dashed lines

[17]Firms paying higher wages will find the minimum wage less *relevant* for them so it will have a smaller effect on them. For this reason, we will say that the minimum wage has less of an effect when it is less *relevant*.

[18]This follows from Propositions 1. The price needed to cover the cost increase is $\tilde{p}^x$, the flat part of supply in Figure 4.

in Figure 4 (but below the intersection of the two dashed lines in Figure 5) only the output of x will be constrained by demand so that production *will fall of the labor intensive good despite the rise in price*. This would be accentuated for more labor intensive goods as these would require a higher price to be made,[19] and as a result, other things constant, demand would be lower. Price would rise while output would fall with the minimum wage, and more so the more labor intensive the good. This motivates using the minimum wage and the interaction of the minimum wage and factor intensity as an explanatory variable in both the price and output regressions. As we only have data on sales, i.e., revenues, at the firm and city level we cannot test any predictions on price or quantity for domestic variables. Moreover, since revenue can rise or fall (depending on demand elasticity) with a rise in price, there is nothing we can test as far as revenue goes. As we have both unit value and quantity of exports, we can test what happens with exports.

Prediction 4. (Exports): Exports of the labor intensive good should fall with a binding minimum wage. The effects should be more pronounced for more labor intensive sectors and when the minimum wage is more relevant.

Demand comes from all sources and a higher price results in lower demand from all sources for the labor intensive good i.e., lower exports. In an open economy, as the price of the labor intensive good rises with the minimum wage, demand from the rest of the world and hence, exports should fall. Whether the value of sales rise or fall depends on elasticity. If world demand has more than unitary elasticity, the rise in price will reduce the export value of the labor intensive good. If domestic demand has less than unitary elasticity, then value of domestic sales will rise, despite the value of export sales falling.

A rise in the minimum wage will also impact the input choice of firms, encouraging substitution towards more skill-intensive or capital-intensive mode of production. This prediction is captured below.[20] Given the substitution between factors, this should be more so where the minimum wage is more relevant, i.e., in sectors which are very labor intensive or where average wages are low so that firms are more likely to be impacted by the minimum wage.[21]

Prediction 5. (Capital intensity): A higher minimum wage should raise capital intensity. We would expect the increase in capital intensity to be higher the higher the minimum wage and the

[19]That is, $\tilde{p}^x$ would be higher in Figure 4.

[20]Note that in the data, in the presence of more than two factors of production, such as capital, unskilled and skilled labor, complementarity between capital and skilled labor will add more nuances to Prediction 5. We discuss this in more detail in the empirical section.

[21]A higher wage-rental ratio has selection effects on the cutoff in both x and y as shown in Lemma 1. A higher minimum wage increases the wage-rental ratio, given prices. Also, in equilibrium the price of x is likely to rise by more than that of y, which further raises equilibrium wage-rental ratio via Lemma 2. Consequently, from Lemma 1, selection in x will become stricter while that in y would become weaker. The more labor intensive the sector (or the higher or more relevant the minimum wage) the more costs rise with the minimum wage and the more the equilibrium price has to rise due to the minimum wage.

more relevant is the minimum wage in the sector. Labor use should fall, and more so where the minimum wage is more relevant.

4.1.2 From the Industry to the Firm

It is well understood that in the competitive model laid out above, the firm is not well defined. Is a firm one draw with unit capacity? Is it a collection of draws of unit capacity? If so, what defines the collection of draws that make up a firm? Clearly, the specification of a firm will depend on the facts that the researcher is interested in understanding. Since we are interested in understanding the effects of minimum wages on firm level variables in a tractable general equilibrium framework, we choose to think of firms as arising essentially from randomness along the lines of Armenter and Koren (2014).

Take a given mass of firms. Think of firms as bins and capacity draws as balls. A firm is the collection of draws of θ in a bin where each draw gives the ability to produce one unit of output at cost $\theta c(w, r)$. In this way each firm will have a weakly upward sloping supply function. Some firms will have many draws and some will have few. Some will have good draws of costs and some will have bad draws. Firms with many good cost draws will have elastic supply at low prices, while firms with only a few bad draws will be willing to supply a small quantity at relatively high prices.[22] Firms with no draws have no supply at any price.[23]

The cutoff, $\tilde{\theta}$, will determine which of its capacity draws a firm will choose to use in the given equilibrium. This will provide a model of firm level heterogeneity in supply functions that will allow us to go from industry level predictions to firm level ones. Of course, industry supply will just be the horizontal sum of the firm supply functions and will be exactly as in the model laid out above.[24] With this view of a firm, it follows that selection at the industry level will be mirrored in selection at the firm level. As a binding minimum wage makes selection stricter in the x sector and weaker in the y sector, firms will drop their high cost capacity in the x sector and do the opposite in the y sector. As a result, average (firm and industry) productivity will be rising in the former

[22]Note that even this simple model predicts many of the patterns seen in data. See, for example Bernard, Jensen, Redding and Schott (2012). Firms with many draws will have a better best draw and a worse worst draw. Thus, by the logic of order statistics, larger firms will tend to be willing to supply at prices smaller firms will not and larger firms will look like they are more productive - a common feature of the data. In addition, in the presence of transport costs, firms whose best θ draws put their costs above the transport cost adjusted price will not export. This will give rise to another feature often pointed out in the data - larger more productive firms tend to export. However, the model does not provide any predictions about selection into exporting. As there are no fixed costs of exporting, the most productive firms do not select into exporting. Rather, all firm produce what is profit maximizing at the given price and their output is as likely as that of any other firm's to be exported. Adding fixed cost of exporting to the model would give the patterns seen in the data. We choose not to do so for simplicity and as this is not the focus of our paper.

[23]Note that we need to back away from assuming a continuum of firms for our interpretation to work. With a continuum all bins would replicate the distribution of costs.

[24]Note that firms will differ from one another only when there are a finite number of draws. If we had a continuum of draws, firm demand would just be a scaled down versions of market demand.

and falling in the latter.

With this interpretation of a firm at hand, the predictions at the industry level will carry over to the firm level. Price will rise with the minimum wage at the firm level. Furthermore, as costs rise more than price in x (which is why selection becomes stricter) firms will produce and export less in the labor intensive sector and thus look more productive. Moreover, firms whose best draw of cost at the new factor prices exceeds the new price will exit. Thus, exit in x should rise in the wake of an increase in the minimum wage so that the average productivity of remaining firms will also rise. Furthermore, this will be more so for more labor intensive sectors, and where the minimum wage is more relevant.

5 The Data and Patterns

5.1 How is the Minimum Wage Set in China?

The Chinese Government published its first formal "*Minimum Wage Regulation*" in 1993, which was followed by the "*1994 Labor Law*". These initial regulations granted provincial governments authority and flexibility in adjusting their minimum wages. At its onset, only a limited number of cities adopted minimum wages. It is also widely believed that the growth in minimum wage was small until early 2000s and the enforcement had huge room for improvement.

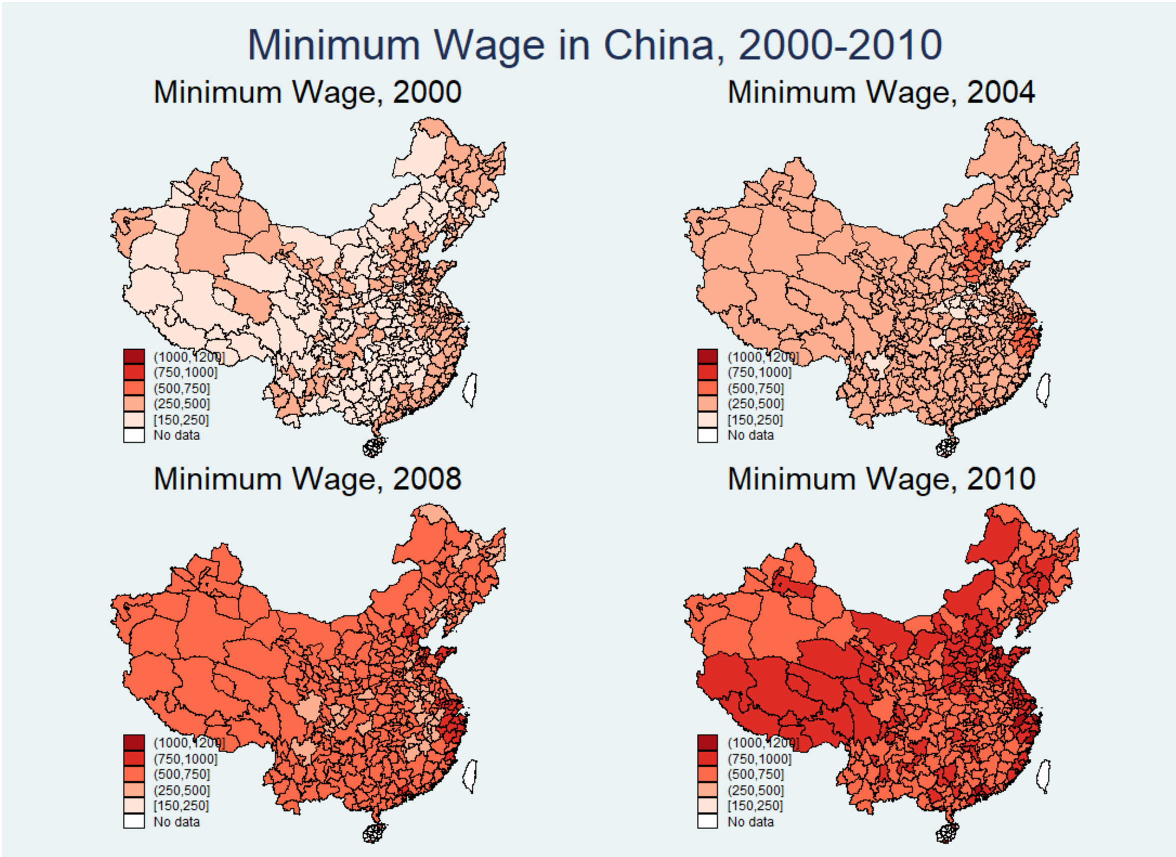
In March 2004, the Ministry of Human Resource and Social Security issued a new regulation, "*The 2004 Regulation on Minimum Wage*", which established a more comprehensive coverage of minimum wage standards. According to it, the minimum wage depends on the local living costs of workers and their dependents, urban residents' consumption price index, social insurance and housing insurance, average wage level of employees, economic development, local employment rate, etc. Notably, this policy reform also strengthened the enforcement by raising the non-compliance penalty[25] and requiring more frequent minimum-wage adjustments — at least once every two years (Hau et al., 2018; Mayneris et al., 2018).

Importantly, the regulation provides a guideline formula for minimum wage. To be concrete, there are two methods that the local governments can use to set their own level of minimum wages. *The proportion method* is based on the minimum income necessary to cover the standard living costs of an individual living in poor conditions. While *the Engel coefficient method* is based on the minimum food expenditure divided by the Engel coefficient, which results in a minimum living cost.[26] In practice, the adjustments of minimum wages are set by the provincial administration (Gan, Hernandez and Ma, 2016), while prefectural level cities negotiate with their provincial ad-

[25]The penalty for non-compliance was increased from 20-100% to 100-500% of the wage shortfall.

[26]Unfortunately, how different levels of local governments applied these two methods are not transparent to us.

Figure 9: Geography of Minimum Wages, 2000-2010

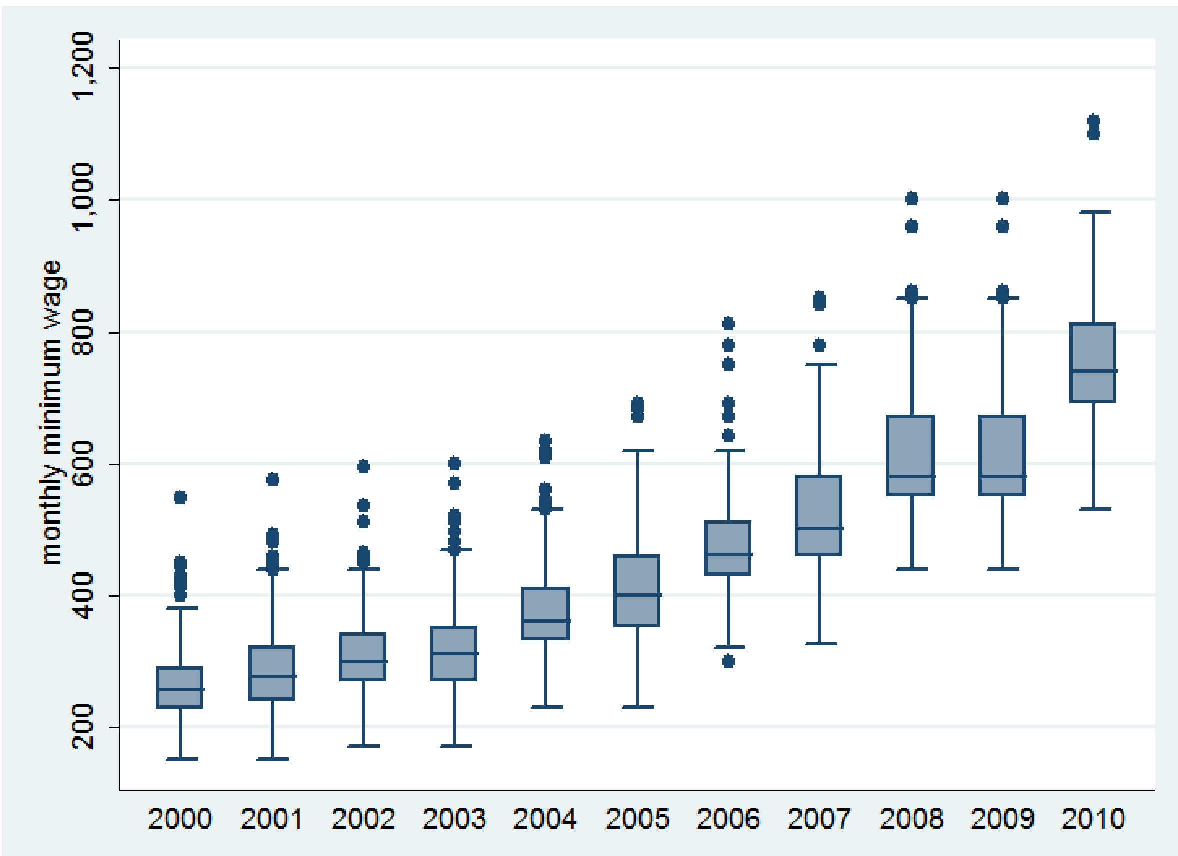


ministration to determine their actual level of minimum wage (Du and Wang, 2008; Casale and Zhu, 2013). In particular, cities in each province are divided into several groups according to their levels of economic development. Within each group, cities generally have the same minimum wage and follow the same adjustment. However, if a city is substantially less developed than other cities/counties in the group, it can be allowed to adopt the minimum wage of the next less-developed group (Gan et al., 2016).

The monthly minimum wage data used here was hand collected from local government's websites and statistical bulletins. Figure 9 illustrates the geographical difference in minimum wages across cities of mainland China. It also shows the evolution of minimum wage over time by presenting separately the geographical distribution in 2000, 2004, 2008, and 2010. Several interesting patterns emerge: First, there are large variations in minimum wages across regions: the coastal areas usually set higher minimum wages than the western regions. For example, in 2004, Shanghai had the highest minimum wage, at 635 Yuan per month (about 77 US dollars at the 2004 exchange rate), while most cities in Henan province in central China had the lowest level of minimum wage at 240 Yuan (29 US dollars). Second, there is significant, but unbalanced growth in minimum wages across regions over time, with the western regions catching up very quickly in later years. Thirdly, within each province, there are usually several groups of cities that adopt different levels of minimum wages — usually the capital city and other large cities adopt higher minimum wage levels than smaller cities. For example, in 2004, within Guangdong province, the highest monthly minimum wage was in Shenzhen at 610 Yuan (74 US dollars), while the lowest was set in Heyuan at 290 Yuan (35 US dollars).

Figure 10 illustrates the evolution of monthly minimum wages between 2000 and 2010. As shown in the figure, the median minimum wage rose from around 260 RMB in 2000 (i.e., around 31 US dollars at the 2000 exchange rate), to 750 RMB in 2010 (around 110 US dollar at the 2010 exchange rate).There is also an obvious acceleration of minimum wage growth after 2004.

Figure 10: Evolution of Minimum Wages, 2000-2010



Note: The box plot reports the 25, 50, and 75 percentile as the three horizontal lines of the box, the top and bottom line outside the box are the adjacent values (defined as the 75 percentile + 1.5 interquartile range, and 25 percentile − 1.5 interquartile range), the dots are deemed as outliers.

5.2 Firm and Transaction-Level Data

Besides city level minimum wage data, our main empirical results are drawn from transaction-level export and import data, collected by the China Customs General Administration. This dataset provides the universe of transactions by Chinese firms that participated in international trade over the 2000-2008 period. It reports for each transaction the value (in US dollars) and quantities at six-digit HS product level, the destination/origin country, and the firm's identification code, name and address. As we have value and quantity, we can calculate the unit value for each transaction.

The second dataset that we use is the Annual Surveys of Industrial Production (ASIP) from 2000 through 2007, collected by the China National Bureau of Statistics (CNBS). This survey includes all State-Owned Enterprises (henceforth SOEs) and non-SOEs with sales over 5 million Chinese Yuan (about $600,000$ US dollars with the exchange rate in 2000). This dataset contains information on the firms' industry of production, ownership type, age, employment, capital stocks, total material inputs, value of output and value-added, as well as the value of the firms' output that is exported. With additional information on output and input deflators (Brandt, Van Biesebroeck and Zhang, 2012), we estimate the total factor productivity (TFP) for each firm following Levinsohn and Petrin (2003).

The advantage of the survey data is we can get information on wages paid and can estimate TFP. The disadvantages are that it lacks complete coverage and it has no information on destination of exports or unit values or quantities. In contrast, the customs data is a census covering all firms that participate in trade. Moreover, product level information is very detailed since it includes not only quantity and value so that unit values can be calculated, but also the export destination (or import source) country for each 8-digit HS product exported or imported by a firm, as well as information on the firm's location. The disadvantage is that unless matched with the survey data, many firm level variables (e.g., the balance sheet information) are not available. To facilitate a thorough analysis, we also match the two datasets on the basis of firm name, region code, address, and so on.[27] The matched sample, though with fewer observations, enables us to look at the effect of minimum wage on firms with different TFPs.

The summary statistics for the data are given in Table 1. In the upper panel, variables are measured at different levels. The minimum wage is available at the city-year level and the average wage is available at the firm-year level. There are two $\ln(K/L)$ measures: at the firm-year level, which is used as a dependent variable, and at the industry-city level for 2004 which is used as a control. Note that while we use $\ln(K/L)$, we do not take the natural log of S/L since its natural

[27] It is sometimes claimed that the match in this data is not good. Since the customs data has information on all transactions, including those of intermediaries and small unsurveyed firms, we consider this in evaluating the matching rate. In 2004, intermediary firms accounted for 25.6% of the universe of the export values and matched producers (producing exporters) accounted for 62.9%. Unsurveyed firms' account for 2% of exports, which leaves 9.5% accounted for by unmatched surveyed producers. See Bai, Krishna and Ma (2017) for the details of this matching.

Table 1: Summary Statistics

	Mean	Std. Dev.	5th Pctl	Median	95th Pctl	No. of Obs
ASIP Data						
Firm-Year Level						
ln (Average Wage)	2.5693	0.6312	1.6714	2.5603	3.6082	943951
Average firm wage / city minimum wage	2.5583	2.5024	1.0031	2.0555	5.5676	943951
ln (K/L)	3.5240	1.3426	1.2566	3.5984	5.5736	943951
Labor Share	0.0216	0.0323	0.0021	0.0133	0.0641	943951
Export Status	0.2983	0.4575	0	0	1	943951
Exit from Export	0.0298	0.1701	0	0	0	943951
Productivity	3.6615	2.5902	0.6414	2.8667	9.9711	928789
Industry-City Level						
S/L	0.1459	0.1381	0.0128	0.1046	0.4221	24802
ln (K/L)	3.8829	1.0284	2.1972	3.9194	5.4699	24802
City-Year Level						
ln (Min. Wage)	1.5493	0.2757	1.0578	1.5686	1.9906	1969
Customs Data						
Firm-Product-City-Destination-Year Level						
ln (Price)	1.1066	2.0881	-1.6094	0.8740	4.9668	6259797
ln (Quantity)	7.8068	2.9048	2.3026	8.0552	12.2061	6259797

Note: Monetary values in the ASIP data including the minimum wage, firm average wage, capital are measured in thousand Chinese yuan per year. Export price is in US dollars and quantity is measured in the product's corresponding recorded units of measurement (e.g. *kg* for food, *meter* for fabric, etc).

log would be negative which would make it harder to interpret the the coefficient of the interaction between it and the minimum wage. Also note that S/L is only available for 2004, which is a census year, which is why we take both $\ln(K/L)$ and S/L at the the industry city level from their 2004 values.[28] Export Status (Exit from Export) is 1 if the firm exports (exits from exporting) and 0 otherwise so that the average gives the probability of exporting (exiting from exporting) to be about .3 (.03). The mean, standard deviation and 5th, 50th and 95th percentile values are given for each variable to help interpret the size of the estimates below. Monetary values in the ASIP data including the minimum wage, firm average wage, capital are measured in thousand yuan per year. To see extent to which minimum wages were binding, we also look at the ratio of the firm's average wage to the city level minimum wage. Note that the mean of this ratio is 2.56. The lower this ratio for a firm, the more binding the minimum wage is likely to be.

[28]As part of the 2004 economic census, the 2004 ASIP records the number of workers by their education level for each surveyed firm, which we aggregate up to four-digit CIC industry level as a measure of skill intensity. Specifically, we use the share of workers with college or above education out of total firm employment in 2004 as S/L, and log of the deflated value of net fixed asset over firm employment in 2004 as $ln(K/L)$.

The lower panel gives the summary statistics for the Customs Data. Price in the customs data is measured in US dollars. Quantity is measured in the product's recorded units of measurement. An observation is at the firm-product-destination-year level. Transactions are aggregated to obtain, for example, the quantity of exports by a firm to a particular destination for a HS6 category in a particular year.

5.3 Endogeneity of Minimum Wage

Our main predictions focus on the consequence of higher minimum wages. However, a higher minimum wage might be set *because* the city is more productive and so has a higher *per capita* income. If cities that are more productive set higher minimum wages and also export more, then the correlation between higher exports and higher minimum wages would not be causal. Working with firm level data allows us to control for firm fixed effects (or even firm-product-destination fixed effects), which to a large extent alleviate concerns regarding such endogeneity bias. Nevertheless, endogeneity could be a major problem if more productive cities tend to set higher minimum wages.

To correct for endogeneity bias, we adopt an instrumental variable strategy. The minimum wages are set at the city level. Thus we expect that cities with similar income *per capita* tend to set similar minimum wages. To construct the instrumental variables, we group all cities based on their GDP *per capita* in each year into 20 groups. Cities in a particular group therefore have similar levels of income. Then we use the average minimum wage of all *other* cities in the group as the instrument for this city's minimum wage. Section 6 presents all key empirical predictions using both the OLS results and the 2SLS estimates using this instrument.[29]

As an alternative option, we also consider the initial minimum wage as an instrument for future changes in minimum wage, since synchronization of across-city minimum wage seems to be a clear policy initiative. Cities with low minimum wages at the start-of-period will have a strong motivation to raise it. Using this instrument would require changing our baseline empirical specification to a first-difference setup.[30] In the robustness checks section, we compare our benchmark IV results to those using the initial minimum wage as the instrument. To retain the time-varying nature of the instrument, we use five year lag level of minimum wage as the instrument for yearly change in minimum wage.

[29] It is worth noting that roughly half of the variation in minimum wage between cities in each year is within each GDP *per capita* group, with the rest being between groups.

[30] This IV is inspired by a similar IV strategy employed in international trade literature exploring the effect of tariff reductions by Amiti and Konings (2007). Their paper uses the start-of-period tariff rate to predict future tariff reductions.

6 Empirical Results

We present all the key empirical predictions using both OLS regressions and the IV estimates, while putting the first stage estimation results in the Appendix.

6.1 Minimum Wage and Selection of Firms

Our theoretical framework predicts that under reasonable conditions, a binding minimum wage should make selection stronger in the labor intensive sector and weaker in the capital intensive sector. This means each surviving firm drops its highest cost capacity, thereby becoming more productive on average and that high cost firms exit. Moreover, average productivity in labor intensive sectors rises. Hence, we expect to see more exit from exporting or from the industry with a higher minimum wage, and more so in labor intensive sectors (Prediction 1). Moreover, the average productivity of surviving firms in labor intensive sectors should rise with the minimum wage, after controlling for other city and industry specific factors (Prediction 2) as should average productivity in labor intensive industries. In order to test these predictions we use the ASIP survey data since the richness of production data on output and inputs allow us to estimate total factor productivity. We follow Bai et al. (2017) to construct the variables and estimate firm-level TFP following the control function method proposed in Levinsohn and Petrin (2003). As the survey data have a lower bound on size, a firm could be dropped from the survey data without exiting from the industry. For this reason we look at exit from exporting in the survey data.

The benchmark regression for testing the selection effect is specified as follows:

$$\begin{aligned} Selection_{ihct} &= \alpha_1 \cdot ln(mw)_{ct} + \beta_1 \cdot ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_2 \cdot ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ &+ \beta_3 \cdot (low\ wage)_{it} + \beta_4 \cdot (medium\ wage)_{it} + \beta_5 \cdot (high\ wage)_{it} \\ &+ \beta_6 \cdot ln(mw)_{ct} \cdot (low\ wage)_{it} + \beta_7 \cdot ln(mw)_{ct} \cdot (medium\ wage)_{it} \\ &+ \beta_8 \cdot ln(mw)_{ct} \cdot (high\ wage)_{it} \\ &+ \mu X_{ct} + \lambda_i + \lambda_t + \varepsilon_{it}, \end{aligned} \tag{27}$$

where the dependent variable is the relevant selection variable for firm i, in industry h, in city c at time t. The first selection variable of interest is the binary variable capturing firms' one-period forward exit decision. The second selection variable is firms' log total factor productivity (TFP). Independent variables of interest are the minimum wage and its interaction with industry capital and skill intensity. The theoretical prediction is that $\alpha_1 > 0$, $\beta_2 < 0$ and $\beta_1 < 0$. In other words, the minimum wage raises firm exit and TFP and less so in more capital or skilled labor intensive industries. We also control for the bin of wages paid, the dummy variables that indicate whether

Table 2: Minimum Wage and Export Exit

	OLS		IV	
	(1)	(2)	(3)	(4)
	Exit	Exit	Exit	Exit
ln (min. wage)	0.172***	0.131***	0.149***	0.091*
	[0.020]	[0.016]	[0.051]	[0.052]
ln (min. wage) × Industry-City (S/L)	-0.011	-0.005	0.004	0.009
	[0.012]	[0.012]	[0.008]	[0.008]
ln (min. wage) × Industry-City ln (K/L)	-0.005***	-0.005***	-0.004***	-0.004***
	[0.001]	[0.001]	[0.001]	[0.001]
ln (min. wage) × low wage		0.056***		0.059***
		[0.008]		[0.008]
ln (min. wage) × medium wage		0.034***		0.039***
		[0.005]		[0.005]
ln(min wage) × high wage		0.010***		0.013***
		[0.004]		[0.003]
low wage	0.003**	-0.096***	0.003**	-0.102***
	[0.001]	[0.014]	[0.001]	[0.014]
medium wage	0.009***	-0.056***	0.009***	-0.065***
	[0.001]	[0.010]	[0.001]	[0.009]
high wage	0.006***	-0.015**	0.006***	-0.021***
	[0.001]	[0.007]	[0.001]	[0.007]
city ln(GDP per capita)	0.035***	0.027***	0.036***	0.028***
	[0.008]	[0.007]	[0.007]	[0.007]
city ln(Population)	-0.017**	-0.011	-0.019***	-0.015**
	[0.008]	[0.008]	[0.007]	[0.007]
Observations	939,923	939,923	914,952	914,952

Note: Robust standard errors in parentheses, clustered at the sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 49.82 for Column (3) and 23.63 for Column (4).

the firm is the below 25th percentile of firm average wage (low wage firms), in the 25th to 50th percentile of average wage (medium wage firms) and the 50th to 75th percentile (high wage firms), with the excluded category being the highest quartile. We expect firms paying low wages to be more affected by the minimum wage. For this reason, we also include the interaction of minimum wage with the dummy variables for the wage bin. Exit and productivity rise with the minimum wage and we expect the effect to be greater for low wage firms. Thus we expect that the coefficients for the interactions between the wage bin and minimum wage to be positive and to decline as the wage bin rises.[31] Other independent variables used as controls (subsumed in X_{ct}) are city-year specific variables such as *per capita* GDP of a city and its population. In addition we add firm fixed effects (λ_i) and year dummies (λ_t). These city specific variables are controlled for in order

[31] Recall that the excluded category is the highest quantile of average wage firms.

to separate agglomeration from selection following Combes, Duranton, Gobillon, Puga and Roux (2012). The predictions for selection are shown to be borne out in Tables 2 and 3.

In Table 2, we use $Exit_{ihct}$, a dummy variable that indicates whether firm i exports in period $t-1$ but exits in the next period t, as the dependent variable. Columns (1) and (2) report the OLS results, and Columns (3) and (4) report the IV estimates. In Columns (2) and (4) we also include the wage bin dummy variables interacted with the minimum wage defined above. All results are consistent with the theoretical predictions. In Column (3) we see that an increase in the minimum wage raises the probability of exit, but less so for firms in capital intensive industries, though the interaction between the minimum wage and skill intensity is not significantly different from zero. Also note that the IV results are qualitatively similar to the OLS ones.[32] In Column (4) we see that the interaction of the minimum wage with the wage bin is positive and declines as the wage bin rises.[33]

In Table 3, we report the results for firm productivity. Here columns (1) and (2) report the OLS results, and Columns (3) and (4) report the corresponding IV results. The data supports the theoretical predictions. Productivity rises with the minimum wage in Columns (3) and (4), and less so for firms in more skill and capital intensive sectors. Column (4) shows that the impact of the minimum wage is the strongest for low average wage firms. The interaction with the medium bin is positve and smaller, but not significant. However, the interaction with the high bin is negative rather than positive. It is worth pointing out that in this regression, the IV estimates of the impact of the minimum wage are substantially larger than the OLS ones. This suggests that endogeniety of the minimum wage might be especially important for productivity.[34] In order to further check the robustness of our estimates, we also present the IV results using the alternative instrument in the first-difference specification in Section 6.4 below. Estimates at the city-industry level are available on request.

6.2 Minimum Wage and Inputs

As mentioned earlier, the main focus of the vast labor literature on minimum wage has been on the effect of the minimum wage on employment. Given our data we are able to look at both margins of labor demand - the extensive one coming from lower output (and exports) of the good

[32]The direction of the bias is not easy to predict as we also have interactions between the minimum wage and the factor intensities.

[33]The model strictly speaking has no implication for entry in the labor intensive sector: there is just exit both because of stricter selection and because of a lower mass of firms. For the sake of completeness, we look at the effects of a minimum wage on entry in Table 9 in Section 6.5 as a robustness check.

[34]If more productive cities set higher minimum wages, the OLS estimates of the effects of the minimum wage on the mean productivity would be biased upwards. With interactions between the minimum wage and the factor intensities, however, the direction of the bias becomes ambiguous as the direction of the bias depends on the entire set of correlations in the explanatory variables and the error term.

Table 3: Minimum Wage and Firm Productivity

	OLS		IV	
	(1)	(2)	(3)	(4)
	Productivity	Productivity	Productivity	Productivity
ln (min. wage)	0.101***	0.042	0.343***	0.285***
	[0.032]	[0.033]	[0.107]	[0.109]
ln (min. wage) × Industry-City (S/L)	-0.064*	-0.056*	-0.058**	-0.055*
	[0.033]	[0.033]	[0.029]	[0.028]
ln (min. wage) × Industry-City ln (K/L)	-0.007*	-0.007	-0.008**	-0.008**
	[0.004]	[0.004]	[0.004]	[0.004]
ln (min. wage) × low wage		0.096***		0.086***
		[0.022]		[0.023]
ln (min. wage) × medium wage		0.032*		0.012
		[0.017]		[0.016]
ln (min. wage) × high wage		-0.010		-0.038***
		[0.010]		[0.012]
low wage	-0.117***	-0.283***	-0.114***	-0.259***
	[0.005]	[0.040]	[0.004]	[0.040]
medium wage	-0.058***	-0.122***	-0.058***	-0.083***
	[0.004]	[0.031]	[0.004]	[0.030]
high wage	-0.035***	-0.017	-0.034***	0.036*
	[0.003]	[0.019]	[0.003]	[0.021]
city ln (GDP per capita)	0.143***	0.129***	0.136***	0.124***
	[0.027]	[0.027]	[0.023]	[0.022]
city ln (Population)	-0.093	-0.083	-0.070	-0.063
	[0.059]	[0.059]	[0.051]	[0.051]
Observations	924,805	924,805	900,710	900,710

Note: Robust standard errors in parentheses, clustered at the sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 48.98 for Column (3) and 23.23 for Column (4).

(despite the increase in price) due to the minimum wage acting like a negative supply shock, and the intensive one that comes from each firm adjusting its input mix as the minimum wage rises. As we do not have quantity data for output, only value data, and as the predictions on value depend on the elasticity of demand, we focus on exports (in the next subsection) for the extensive margin response. In the following exercise we test the intensive margin of labor demand.

Table 4: Minimum Wage and Factor Intensity

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln (K/L)	ln (K/L)	Labor share	Labor share	ln (K/L)	ln (K/L)	Labor share	Labor share
ln (min. wage)	0.205***	0.051	-0.006***	0.001	0.541***	0.256*	-0.024***	-0.011***
	[0.032]	[0.034]	[0.001]	[0.001]	[0.136]	[0.139]	[0.004]	[0.004]
ln (min. wage) × Industry-City (S/L)	0.061	0.084*	-0.003**	-0.004***	0.064*	0.093**	-0.003**	-0.004***
	[0.045]	[0.044]	[0.001]	[0.001]	[0.039]	[0.039]	[0.001]	[0.001]
ln (min. wage) × Industry-City ln(K/L)	-0.038***	-0.036***	0.001***	0.001***	-0.035***	-0.032***	0.001***	0.001***
	[0.005]	[0.005]	[0.000]	[0.000]	[0.005]	[0.005]	[0.000]	[0.000]
ln (min. wage) × low wage		0.202***		-0.012***		0.278***		-0.015***
		[0.021]		[0.001]		[0.022]		[0.001]
ln (min. wage) × medium wage		0.115***		-0.003***		0.180***		-0.004***
		[0.017]		[0.000]		[0.018]		[0.000]
ln (min. wage) × high wage		0.092***		-0.001**		0.132***		-0.001***
		[0.015]		[0.000]		[0.015]		[0.000]
low wage	-0.284***	-0.646***	0.010***	0.031***	-0.280***	-0.782***	0.010***	0.036***
	[0.006]	[0.039]	[0.000]	[0.001]	[0.006]	[0.040]	[0.000]	[0.001]
medium wage	-0.186***	-0.410***	0.004***	0.011***	-0.185***	-0.532***	0.004***	0.012***
	[0.005]	[0.033]	[0.000]	[0.001]	[0.004]	[0.035]	[0.000]	[0.001]
high wage	-0.112***	-0.294***	0.002***	0.004***	-0.112***	-0.372***	0.002***	0.005***
	[0.004]	[0.029]	[0.000]	[0.001]	[0.004]	[0.030]	[0.000]	[0.001]
city ln (GDP per capita)	0.282***	0.257***	-0.005***	-0.003***	0.273***	0.239***	-0.005***	-0.003***
	[0.019]	[0.019]	[0.001]	[0.001]	[0.018]	[0.018]	[0.001]	[0.001]
city ln (Population)	-0.250***	-0.230***	0.000	-0.001	-0.216***	-0.193***	-0.002	-0.003**
	[0.054]	[0.052]	[0.001]	[0.001]	[0.049]	[0.047]	[0.001]	[0.001]
Observations	939,923	939,923	939,923	939,923	914,952	914,952	914,952	914,952

Note: Robust standard errors in parentheses, clustered on sector-city pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 49.82 for Columns (5) and (7); 23.63 for Columns (6) and (8).

The regression equation is specified as follows:

$$\begin{aligned} ln(E_{ihct}) &= \alpha_1 \cdot ln(mw)_{ct} + \beta_1 \cdot ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_2 \cdot ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ &+ \beta_3 \cdot (low\ wage)_{it} + \beta_4 \cdot (medium\ wage)_{it} + \beta_5 \cdot (high\ wage)_{it} \\ &+ \beta_6 \cdot ln(mw)_{ct} \cdot (low\ wage)_{it} + \beta_7 \cdot ln(mw)_{ct} \cdot (medium\ wage)_{it} \\ &+ \beta_8 \cdot ln(mw)_{ct} \cdot (high\ wage)_{it} \\ &+ \mu X_{ct} + \lambda_i + \lambda_t + \varepsilon_{it}, \end{aligned} \tag{28}$$

where the dependent variable E_{ihct} refers to capital intensity or labor cost share for firm i in industry h, located in city c and time t.[35] The independent variables and controls are the same as in the previous regressions.

Table 4 reports the results from equation (28). Columns (1)-(4) report the OLS results, and columns (5)-(8) report the IV results. Again, the first stage results are in the Appendix. We start with firm level capital intensity. Columns (5) shows that after instrumenting for the minimum wage, firms choose to become significantly more capital-intensive ($\alpha_1 > 0$) as the minimum wage rises, but this is less so in more capital intensive sectors ($\beta_2 < 0$). However, the coefficient of S/L interacted with the minimum wage (β_1) is positive and significant.[36] In addition, K/L falls with average wages paid by the firm suggesting that firms that pay low wages tend to be less capital intensive. This is consistent with the marginal product of labor rising with capital. Column (6) shows that in addition, increases in the minimum wage raise K/L by more for lower wage bins. This makes sense as the minimum wage is less relevant for firms that pay higher wages.

Column (7) and (8) show labor cost share (measured at fixed wages) falls with the rise in minimum wage and that the labor share is higher for firms in low wage bins (both of which are consistent with elastic labor demand) and this is less pronounced in the more capital-intensive sectors and where the minimum wage is less relevant.[37]

6.3 Minimum Wage and Exports

Predictions 3 and 4 state that the output and exports of labor intensive goods should fall and their prices should rise with an increasing minimum wage. Furthermore, the effects should be stronger for more labor-intensive sectors. Due to the lack of price information for firm output in the survey data (which has firm revenue, not price or quantity), we investigate the impact of minimum wage

[35] We also obtain corresponding results for capital use and labor hired separately. Additional results are available upon request.

[36] This could be due to complementarity between inputs.

[37] Note that throughout the table, the OLS results have a similar pattern as the IV ones, only occasionally switching signs: for example, in column (4) the coefficient of minimum wage (α_1) is positive and but not significant while in column (8) is is negative and significant.

on exports where we can calculate unit value from export value and quantity. Our Customs data covers the universe of transactions of Chinese exporters during 2000-2006.[38] More specifically, we use export information at the firm (i) - product (h) - city (c) - destination (d) - time (t) level. The basic idea is after controlling for city- and product- specific characteristics, increasing the minimum wage $(ln(mw)_{ct})$ tends to discourage exports, but will discourage them less in more skilled labor-intensive and capital-intensive sectors.

The baseline regression is specified as follows.

$$\begin{aligned} ln(V_{ihcdt}) &= \alpha_1 \cdot ln(mw)_{ct} + \beta_1 \cdot ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_2 \cdot ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ &+ \mu X_{ct} + \gamma Y_{dt} + \lambda_{ihd} + \lambda_t + \varepsilon_{ihdt}, \end{aligned} \tag{29}$$

where the dependent variable V_{ihcdt} refers to export price (unit value) or quantity for HS6 product h exported by firm i located in city c to destination country d in time t. New to this regression, Y_{dt} controls for destination side characteristics, for which we use the GDP *per capita* of the destination country d. We use a firm-product-destination fixed effect λ_{ihd} to control for any characteristics that are specific to a firm-product-destination triplet, thus implying that our identification comes from within firm-product-destination changes over time. All other independent variables and controls are as in the previous regressions. All regressions are at exporter-hs6-destination-year level, using 2002-2006 Customs data, with standard error clustered on city-product pair. We only focus on non-intermediary exporters and also remove processing exports from the baseline set of regressions.[39]

Table 5 reports the baseline results using the customs data. We take the (log of) export *price* and export *quantity* as the dependent variables. Note that we do not add controls for the wage bin or the wage bin interacted with the minimum wage since this wage information is not available in the customs data. The OLS results are reported in the first two columns and the 2SLS results are reported in Columns (3)-(4). All first stage regressions are reported in the Appendix. Columns (1) and (3) confirm that export prices rise with minimum wage but less so for high capital or skill-intensive industries in line with the predictions of the model, whereas Columns (2) and (4) show that export quantity falls with a rise in the minimum wage (though the IV estimate is not significant) but this fall is muted the more skill or capital intensive the sector. These results are exactly in line with our theoretical framework as well as the finding by Gan et al. (2016). In our model the higher price needed to elicit supply due to the minimum wage reduces demand, and this price increase is lower in skill and capital intensive sectors, which makes the effect weaker in these sectors. The prediction for export value depends on the elasticity of demand for exports.

[38] We start from 2002 because this is the first year after China's WTO accession, and minimum wages began to increase more often after 2001.

[39] The results (available on request) are robust to including processing exports.

Table 5: Minimum Wage and Firm Exports

	OLS		IV	
	(1)	(2)	(3)	(4)
	ln (P)	ln (Q)	ln (P)	ln (Q)
ln (min. wage)	0.248***	-0.602***	0.199**	-0.128
	[0.059]	[0.152]	[0.090]	[0.234]
ln (min. wage) × Industry-City (S/L)	-0.522***	2.253***	-0.586***	2.908***
	[0.147]	[0.360]	[0.103]	[0.250]
ln (min. wage) × Industry-City ln (K/L)	-0.035**	0.113***	-0.042***	0.129***
	[0.017]	[0.042]	[0.011]	[0.028]
city ln(GDP per capita)	-0.035**	0.032	-0.036***	0.046*
	[0.016]	[0.042]	[0.009]	[0.024]
city ln(Population)	-0.068**	-0.213**	-0.076***	-0.160***
	[0.031]	[0.093]	[0.019]	[0.053]
destination ln(GDP per capita)	-0.116***	-0.223**	-0.116***	-0.222***
	[0.040]	[0.107]	[0.022]	[0.060]
Observations	6,252,280	6,252,280	3,003,363	3,003,363

Note: Robust standard errors in parentheses, clustered on city-product pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm-product-destination fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 58.56. Controls for the wage bin or the interaction of wage bin with minimum wage are not added here as the wage information is not available in the customs data.

Export value should rise (fall) with the minimum wage if export demand was inelastic (elastic) with respect to price. Since we do not have clean predictions for export value, we do not focus on it below.

Table 6 performs some robustness checks on the results in Table 5. We restrict our sample to the merged Survey and Customs data to add the firm level controls and to control for TFP to see if our results remain valid. All our theoretical predictions and the empirical patterns in Table 5 are confirmed using the merged sample while also controlling for productivity in Table 6. Columns (1)-(4) report OLS results while Columns (5)-(8) report IV results. Table 6 shows that export quantity falls with the minimum wage and less so for skilled labor and capital intensive goods as predicted in both the OLS (Columns 3-4) and IV regressions (Columns 7-8). Export unit value rises with the minimum wage in the OLS regressions (Columns 1-2) but is not significantly affected by the minimum wage in the IV regressions (Columns 5-6), but as expected, the effect is less positive for more skill or capital intensive sectors. We also see that unit value is higher for more productive firms which might be due to their producing higher quality. In addition, firms that pay low wages tend to be more affected by higher minimum wages.

Table 6: Minimum Wage and Firm Exports with Firm Level Controls

	OLS				IV			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	ln (P)	ln (P)	ln (Q)	ln (Q)	ln (P)	ln (P)	ln (Q)	ln (Q)
ln (min. wage)	0.282***	0.261***	-0.730***	-0.611**	0.042	-0.152	-1.349***	-1.112*
	[0.072]	[0.087]	[0.204]	[0.239]	[0.170]	[0.210]	[0.478]	[0.580]
ln (min. wage) × Industry-City (S/L)	-0.450**	-0.447**	2.781***	2.735***	-0.618***	-0.571***	3.361***	3.385***
	[0.193]	[0.193]	[0.479]	[0.474]	[0.153]	[0.149]	[0.365]	[0.348]
ln (min. wage) × Industry-City ln (K/L)	-0.050**	-0.047**	0.095*	0.082	-0.061***	-0.055***	0.087**	0.076*
	[0.020]	[0.020]	[0.053]	[0.054]	[0.015]	[0.015]	[0.039]	[0.039]
ln (min. wage) × low wage		0.029		-0.098		0.128***		-0.182
		[0.046]		[0.123]		[0.041]		[0.121]
ln (min. wage) × medium wage		0.014		-0.081		0.086**		-0.060
		[0.037]		[0.099]		[0.037]		[0.103]
ln (min. wage) × high wage		-0.008		-0.040		0.020		-0.043
		[0.034]		[0.083]		[0.027]		[0.071]
low wage		-0.059		0.191		-0.243***		0.310
		[0.085]		[0.220]		[0.076]		[0.221]
medium wage		-0.023		0.123		-0.170**		0.076
		[0.073]		[0.191]		[0.073]		[0.203]
high wage		0.016		0.060		-0.041		0.069
		[0.067]		[0.166]		[0.055]		[0.142]
ln (TFP)	0.017**	0.017**	0.307***	0.307***	0.016***	0.016***	0.306***	0.307***
	[0.008]	[0.008]	[0.030]	[0.030]	[0.005]	[0.005]	[0.018]	[0.018]
city ln(GDP per capita)	-0.026	-0.030	-0.093*	-0.084	-0.043***	-0.057***	-0.127***	-0.107**
	[0.020]	[0.020]	[0.054]	[0.055]	[0.016]	[0.017]	[0.044]	[0.047]
city ln(Population)	-0.042	-0.041	0.126	0.120	-0.038	-0.031	0.107*	0.098
	[0.042]	[0.042]	[0.109]	[0.109]	[0.025]	[0.025]	[0.065]	[0.064]
destintion ln(GDP per capita)	-0.073	-0.074	-0.263*	-0.257*	-0.058*	-0.057*	-0.262***	-0.258***
	[0.050]	[0.050]	[0.151]	[0.150]	[0.030]	[0.031]	[0.091]	[0.091]
Observations	1,765,797	1,765,797	1,765,797	1,765,797	1,006,983	1,006,983	1,006,983	1,006,983

Note: Robust standard errors in parentheses, clustered on city-product pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm-product-destination fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 12.82 for Columns (5) and (7); 4.91 for Columns (6) and (8).

Table 7: Effect of 500 RMB Increase in the Minimum Wages

Quartile of Average Wage	Exit from export	ln TFP	ln (K/L)	Labor share
1st (lowest wage)	0.0092	0.0323	0.0412	-0.0022
2nd	0.0077	0.0251	0.0317	-0.0011
3rd	0.0052	0.0202	0.0270	-0.0008
4th (highest wage)	0.0041	0.0239	0.0141	-0.0007

Note: This table reports the effects of 500 RMB increase in minimum wage on Chinese firms, evaluated at national averages of (S/L) and ln (K/L) as seen in Table 1. Estimates from the IV regressions (with full set of interactions) in Tables 2 - 4 are used.

6.4 Economic Interpretations

So far we have tested our theoretical predictions. Qualitatively the empirical results align with our theoretical predictions and the effects are, for the most part, statistically significant. In this section we try to quantify the magnitude of the estimates we obtain, both in order to see if the numbers are sensible and to understand what our estimates mean for different regions of China. We put the magnitudes of the impact in perspective by transforming the estimates into economically meanful numbers.

First we present in Table 7 the effects of an increase of 500 RMB from the average annual minimum wage of 4889.6 RMB (which is about a 9.7% increase).[40] In each regression we use the estimates from the IV regressions with the full set of interactions with factor intensities and average wage bin dummies. We evaluate the effects at the national mean skill and capital intensity as seen in Table 1. The results show that this 10% increase in the minimum wage has significant impacts. Consider the numbers for the effect on exit. This comes from Column (4) of Table 2. For firms in the low wage bin:

$$\begin{aligned}\frac{\partial Pr(exit)}{\partial ln(mw)_{ct}} &= \hat{\alpha_1} + \hat{\beta_1}\cdot(S/L)_{hc} + \hat{\beta_2}\cdot ln(K/L)_{hc} + \hat{\beta_6}(low\ wage)_{it} \\ &= 0.056 + 0.008(0.1459) - 0.004(3.8829) + 0.053 \\ &= 0.0946\end{aligned}$$

Thus a 9.7% increase in minimum wage increases the probability of exit by (0.097×0.0946) or 0.0092. In other words, a roughly 10% increase in minimum wage leads to a roughly 1 percentage point change in the probability of exit. This is the first number reported in Column (1) of Table 7. The impact falls as firms move into higher average wage quartiles, as shown in the remainder of Column (1). Using analogous procedures, we fill in the rest of the table.

Note that our estimates for the impact of a roughly 10% increase in the minimum wage are much smaller than those of Luca and Luca (2019) who suggest that a one dollar increase in the

[40]This is roughly comparable to a 1 USD increase in the hourly minimum wage as this is also about a 10% increase in the minimum wage.

minimum wage leads to a 10 percent increase in the likelihood of exit for a 3.5-star restaurant (which is the median rating on Yelp), but has no discernible impact for a 5-star restaurant (on a 1 to 5 star scale). This could be because in the period considered, China had few competitors in the products it exported. TFP increased for about 3% for firms in the lowest wage quartile, capital intensity rose for about 4% and labor cost share changed by little.[41]

While Table 7 gives an idea of the average impact of a 500 RMB increase in the minimum wage, we also calculate the predicted impact from observed minimum wage increases for different parts of the country at city level. In Figure 11, we illustrate the effects of minimum increase from 2002 to 2007 on firm exit (from exporting), ln (TFP), ln (K/L) and labor cost share across China. The effects are evaluated at city-level averaged skill intensity, capital intensity and accounting for the fraction of firms in each wage bin by city.[42] Darker colors indicate stronger effects. As can be seen, the patterns are roughly the same in all four maps, suggesting that some cities are uniformly more affected by changes in minimum wages than others. In addition, there are large variations across cities.

It is worth noting that cities that experienced large increases in minimum wage as depicted by darker shapes in Figure 9, do not necessarily have large effects in Figure 11. This comes from the observation that cities with high capital intensity experience smaller effects from higher minimum wages. Skill intensity tends to be less important, as capital intensity has a greater impact empirically. There are examples with large increases in minimum wages but smaller effects on firm outcomes, as with Hulunbuir (labelled "$\boxed{1}$" in the map), Guangzhou ($\boxed{2}$) and Wuhan ($\boxed{3}$). On the other hand, cities like Dandong ($\boxed{4}$) and Jiujiang ($\boxed{5}$) had strong effects on outcomes from relatively small increases in minimum wage. This was due to their having low skill- and capital-intensity. More common are cities that had strong effects from large increases in minimum wage - like Lianyungang ($\boxed{6}$) and Hangzhou ($\boxed{7}$).

Finally, to get a better sense of the magnitude of the impact of the minimum wage on exporters, we evaluate the elasticity of export price with repect to minimum wage based on the IV results (Column 5) of Table 5:

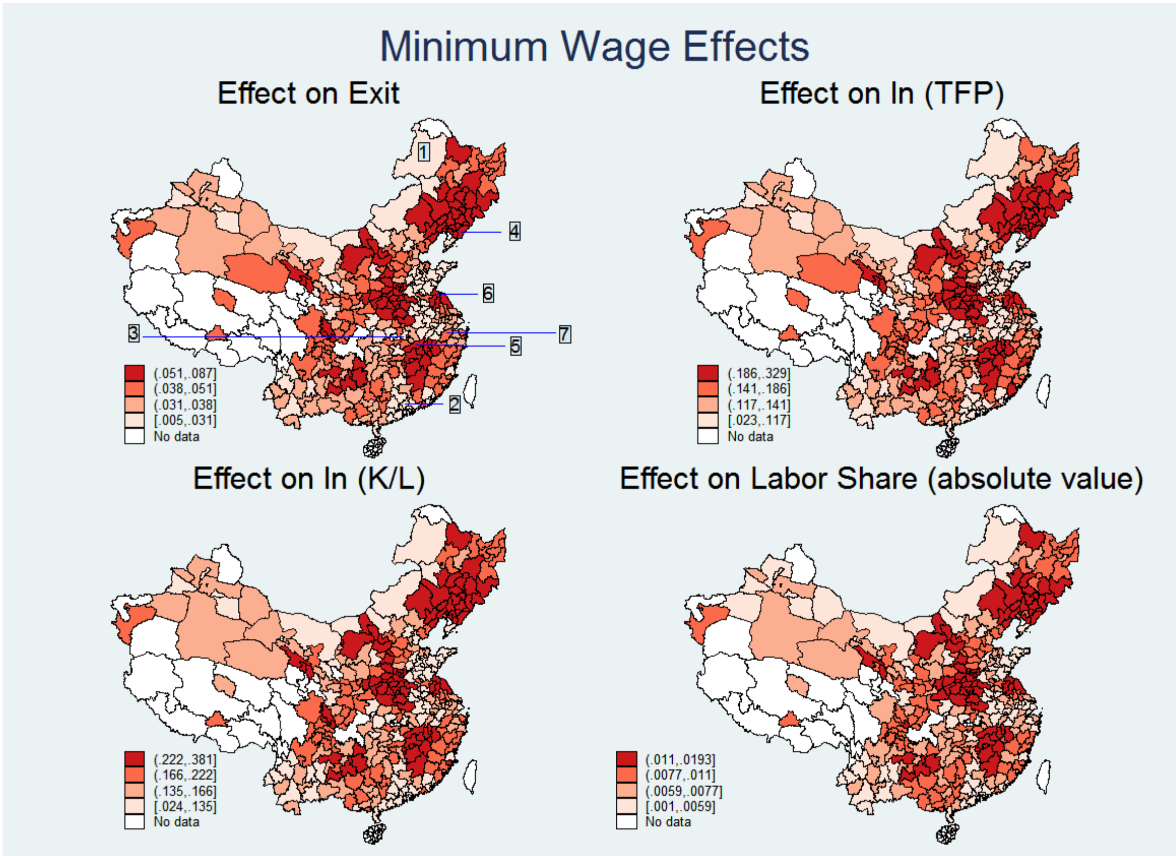
$$\frac{\partial ln(P_{ihcdt})}{\partial ln(mw)_{ct}} = \hat{\alpha}_1 + \hat{\beta}_1 \cdot (S/L)_{hc} + \hat{\beta}_2 \cdot ln(K/L)_{hc}$$

Because firm average wage information is not available in the customs data, we do not include the interaction of wage bin and minimum wage here. Table 8 presents the elasticity of export price

[41] In a different experiment, Amiti and Konings (2007) show that a 10 percentage point fall in input tariffs leads to a productivity gain of 12 percent for firms that import their inputs, at least twice as high as any gains from reducing output tariffs.

[42] Within each city, we take the weighted average of industry-city level skill and capital intensities with weights being the number share of firms in each industry.

Figure 11: Effects of Increasing Minimum Wages, 2002-2007



Note: Darker colors in the map indicate stronger effects. White color indicates cities that has either no data on minimum wage or has less than 10 annual observations in the ASIP data.

with respect to minimum wage.[43]

According to our estimates, export price elasticity would be negative for firms with high skill and capital intensities but positive for those with low skill and capital intensities. Evaluating this elasticity at the national unweighted averages of S/L and ln (K/L) tells us what happens to this average firm. The export price of this average firm falls with and increase in the minimum wage. However, note that such a firm would likely to be not exporting very much since China has comparative advantage in labor-intensive products. To account for this, we evaluate the weighted effect.[44] As expected, the (weighted) average firm tends to be less skill- and capital-intensive so that the price elasticity becomes less negative as seen in the second row of Table 8. The third and fourth row give the fraction of firms which have a positive price elasticity with respect to the minimum wage at firm and industry-city levels. Over half of firms and almost a third of industry-city-year

[43] We present the values evaluated at both the national average and weighted average skill and capital intensity levels.

[44] We take the weighted average of industry-city level skill and capital intensities with weights being the export value share of each industry-city pair.

Table 8: Effects of Minimum Wage Increase on Export Price

Elasticity	ln (P)
Simple Average	-0.0496
Weighted Average	-0.0292
Predicted Ratio of Positive Elasticities (Firm Level - 2004 Census)	0.5457
Predicted Ratio of Positive Elasticities (Industry-City-Year)	0.3196

Note: Values in the first row are evaluated at national averages of (S/L) and ln (K/L) as seen in Table 1. Values in the second row are evaluated at the weighted average of industry-city level (S/L) and ln (K/L) with weights being the export value share of each industry-city pair. Estimates from Columns (5) of Table 5 are used.

pairs have a positive price elasticity. What might be behind the presence of negative price elasticities? A simple reason might be that higher minimum wage reallocate resources away from labor-intensive firms towards the rest of the economy, which can reduce prices there.

6.5 Robustness Checks

In this section we extend our regressions to incorporate entry into export as well as three new checks. First, it is well understood that firms with different ownership types might be behaving differently. For example, State owned enterprises may respond to minimum wages differently from private firms as part of their mandate is to provide employment and foreign firms may comply with minimum wages to a greater extent than domestic private firms if they have more to lose if they are caught. For this reason we extend the regressions to allow for this. Second, it is usually believed as discussed in Section 5.1, that enforcement of the minimum wage was stricter after 2004 than before. For this reason we include interactions with the post 2004 period in the regressions. Third, we use an alternative instrument and check if the results remain.

6.5.1 Entry into Export

Although the model strictly speaking has no implication for entry in the labor intensive sector: there is just exit both because of stricter selection and because of a lower mass of firms. If one thinks of some churning always occurring because of exogenous death of firms, the lower mass of firms in the labor intensive sector will also imply fewer firms dying and being replaced by new entrants. With this interpretation we can say that we also expect less entry in the labor intensive sector when the minimum wage rises. In the capital intensive sector, selection becomes weaker and the mass of firms rises. So we actually expect entry to rise here. Thus, our formulation remains valid: entry falls and less so in the capital intensive industry. In Columns (3) and (4) of Table 9, we see entry falling,[45] but not significantly less so in skill or labor intensive sectors.

[45] Note that sign of the coefficient on the minimum wage flips from being positive to negative from the OLS to the IV regressions.

Table 9: Minimum Wage and Export Entry

	OLS		IV	
	(1)	(2)	(3)	(4)
	Entry	Entry	Entry	Entry
ln (min. wage)	0.097***	0.099***	-0.236***	-0.229***
	[0.013]	[0.014]	[0.073]	[0.078]
ln (min. wage) × Industry-City (S/L)	0.008	0.008	0.011	0.010
	[0.010]	[0.010]	[0.008]	[0.008]
ln (min. wage) × Industry-City ln (K/L)	-0.001	-0.001	-0.001	-0.001
	[0.001]	[0.001]	[0.001]	[0.001]
ln (min. wage) × low wage		0.012**		0.005
		[0.005]		[0.007]
ln (min. wage) × medium wage		-0.022***		-0.022***
		[0.005]		[0.005]
ln (min. wage) × high wage		-0.012***		-0.010**
		[0.004]		[0.004]
low wage	-0.008***	-0.025***	-0.012***	-0.018
	[0.001]	[0.008]	[0.001]	[0.013]
medium wage	-0.005***	0.036***	-0.006***	0.033***
	[0.001]	[0.008]	[0.001]	[0.010]
high wage	-0.003***	0.021***	-0.003***	0.017**
	[0.001]	[0.007]	[0.001]	[0.008]
city ln(GDP per capita)	0.020***	0.019***	0.029***	0.029***
	[0.006]	[0.006]	[0.008]	[0.008]
city ln(Population)	0.041**	0.041***	0.007	0.008
	[0.016]	[0.016]	[0.015]	[0.014]
Observations	939,923	939,923	914,952	914,952

Note: Robust standard errors in parentheses, clustered at the sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 49.82 for Column (3) and 23.63 for Column (4).

6.5.2 Firm Ownership and Post 2004

In Table 10 we present the IV results. Consider for example the results in Column (1). Exit is not significantly affected by the minimum wage for foreign firms or state owned enterprises (SOEs). However, private domestic firms exit rises with the minimum wage. This is less so for foreign firms or domestic firms that are capital intensive. The minimum wage also raises exit by more for low wage firms than for medium wage firms and even less for high wage firms. The only coefficient that is significant and different from what we expected is that foreign skill intensive firms seem more likely to exit when the minimum wage rises. All the coefficients in all the other columns are either insignificant or of the expected sign with two exceptions. First, productivity rises by less with increases in the minimum wage after 2004. Second, in Column (7), export quantity falls with the minimum wage (mostly coming from the effect on SOEs) but this is less so after 2004. It is

Table 10: Minimum Wage Effects by Ownership and Post 2004

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Exit	Entry	Productivity	ln (K/L)	Labor share	ln (P)	ln (Q)
ln (min. wage)	-0.011	-0.091	0.527***	-0.191	-0.014***	0.260**	0.028
	[0.047]	[0.071]	[0.129]	[0.152]	[0.004]	[0.105]	[0.261]
ln (min. wage) × SOE	0.011	-0.021***	-0.120***	0.337***	-0.009***	-0.261***	-0.855***
	[0.008]	[0.008]	[0.027]	[0.039]	[0.001]	[0.069]	[0.178]
ln (min. wage) × domestic	0.018**	-0.003	-0.007	0.437***	0.002	-0.154**	-0.183
	[0.008]	[0.007]	[0.024]	[0.036]	[0.001]	[0.076]	[0.187]
ln (min. wage) × Industry-City (S/L)	0.024**	-0.005	-0.012	0.070	-0.002	-0.690***	3.209***
	[0.010]	[0.013]	[0.032]	[0.055]	[0.001]	[0.128]	[0.307]
ln (min. wage) × Industry-City (S/L) × SOE	-0.011	0.028**	-0.032	0.102*	-0.002	0.355*	-1.286***
	[0.011]	[0.013]	[0.027]	[0.054]	[0.001]	[0.206]	[0.442]
ln (min. wage) × Industry-City (S/L) × domestic	-0.014	0.013	-0.059**	0.050	-0.001	0.063	0.699
	[0.010]	[0.013]	[0.026]	[0.055]	[0.001]	[0.228]	[0.519]
ln (min. wage) × Industry-City ln (K/L)	-0.002**	-0.000	-0.005	-0.032***	0.002***	-0.054***	0.084***
	[0.001]	[0.001]	[0.004]	[0.006]	[0.000]	[0.012]	[0.032]
ln (min. wage) × Industry-City ln(K/L) × SOE	-0.002	-0.001	-0.001	-0.005	-0.000	0.050**	0.071
	[0.001]	[0.002]	[0.004]	[0.007]	[0.000]	[0.020]	[0.049]
ln (min. wage) × Industry-City ln(K/L) × domestic	-0.002*	0.000	-0.004	-0.004	-0.000	0.019	0.040
	[0.001]	[0.002]	[0.004]	[0.007]	[0.000]	[0.023]	[0.055]
ln (min. wage) × low wage	0.091***	-0.041***	0.025	0.227***	-0.013***	0.074***	0.028
	[0.009]	[0.008]	[0.019]	[0.023]	[0.001]	[0.028]	[0.069]
ln(min wage) × medium wage	0.055***	-0.045***	-0.017	0.135***	-0.003***	0.052**	-0.107*
	[0.006]	[0.006]	[0.013]	[0.018]	[0.000]	[0.023]	[0.057]
ln (min. wage) × high wage	0.017***	-0.018***	-0.045***	0.092***	-0.001**	0.028*	-0.114***
	[0.004]	[0.004]	[0.011]	[0.015]	[0.000]	[0.016]	[0.043]
ln (min. wage) × post 2004	0.053***	-0.075***	-0.108***	0.041*	0.003***	-0.008	0.089**
	[0.008]	[0.011]	[0.022]	[0.022]	[0.001]	[0.014]	[0.040]
low wage	-0.159***	0.066***	-0.148***	-0.687***	0.033***	-0.140***	-0.008
	[0.016]	[0.014]	[0.033]	[0.041]	[0.001]	[0.051]	[0.125]
medium wage	-0.095***	0.078***	-0.028	-0.446***	0.010***	-0.101**	0.204*
	[0.010]	[0.012]	[0.024]	[0.034]	[0.001]	[0.045]	[0.110]
high wage	-0.030***	0.031***	0.050**	-0.296***	0.004***	-0.058*	0.211**
	[0.007]	[0.008]	[0.020]	[0.029]	[0.001]	[0.033]	[0.085]
city ln(GDP per capita)	0.036***	0.018***	0.115***	0.189***	-0.002***	-0.036***	0.065***
	[0.007]	[0.007]	[0.022]	[0.017]	[0.001]	[0.009]	[0.024]
city ln(Population)	-0.035***	0.039***	-0.015	-0.193***	-0.004***	-0.059***	-0.209***
	[0.008]	[0.014]	[0.052]	[0.045]	[0.001]	[0.017]	[0.052]
SOE	-0.001	0.030***	0.201***	-0.642***	0.017***	(omitted)	(omitted)
	[0.010]	[0.010]	[0.038]	[0.048]	[0.001]		
domestic	-0.010	-0.010	0.031	-0.803***	-0.000	(omitted)	(omitted)
	[0.010]	[0.008]	[0.035]	[0.046]	[0.001]		
Observations	914,952	914,952	900,710	914,952	914,952	3,003,363	3,003,363

Note: Robust standard errors in parentheses, clustered on sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Weak identification test (Kleibergen-Paap rk Wald F statistic): 11.65 in Columns (1), (2), (4) and (5); 11.42 in Column (3); 18.10 in Columns (6) and (7).

clear that it is not the case that all our results are being driven by one type of firms or another. For example, the effect of the minimum wage on exit seems to be driven mostly by domestic firms, but that on entry by SOEs. Effects are more pronounced after 2004 except for productivity (Column 3) and output (Column 7) where the effects of a minimum wage are greater before 2004.

6.5.3 An Alternative Instrument

Is there another instrument we can use to check on the robustness of our estimates? Figure 9 demonstrates that initially low-minimum wage areas experienced a high growth in minimum wage in later years, confirming a clear policy initiative of bringing minimum wages closer together. We use this insight to instrument the annual change in minimum wage by the 5-year lagged minimum wage, following Amiti and Konings (2007). This involves changing our specification to a first-difference setup and restricting our sample to 2005-2007, since the earliest minimum wage in our sample is the year 2000.

We are also able to check whether our key empirical predictions hold if we allow for different growth rates over time and across industries. This can be easily incorporated within the first-difference setup by allowing for time fixed effects and 4-digit industry fixed effects. To check robustness of the firm productivity result, we estimate the following equation:

$$\begin{aligned} \Delta Selection_{ihct} &= \alpha_1 \cdot \Delta ln(mw)_{ct} + \beta_1 \cdot \Delta ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_2 \cdot \Delta ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ &+ \mu_1 \Delta X_{ict} + \lambda_h + \lambda_t + \varepsilon_{it}, \end{aligned} \tag{30}$$

Here λ_h and λ_t refer to the industry- and time- fixed effects meant to capture the different trend growth rates. Note that $(S/L)_{hc}$ and $ln(K/L)_{hc}$ are time invariant. In Table 11, we report the firm productivity results in first-difference setup. Here we only report the IV results. Column (2) in Table 11 is the analogue of our baseline result (Column 3 in Table 3). Column (3) in Table 11 includes both year dummies and industry fixed effects, while Column (1) has neither fixed effects. Compared to the baseline results, we see the same sign patterns and the coefficients are of the same order of magnitude. Note that we cannot estimate an analogue of the exit regression at the firm level by definition, which is why we do not include it here.

Table 12 is the analogue of Table 4. Columns (1) and (2) give the capital intensity and labor share results respectively without any additional controls, Columns (3) and (4) report the same set of results including year dummies only, while Columns (5)-(6), in addition, control for industry dummies to allow for industry specific trend growth rates. These results confirm our theoretical predictions and baseline empirical results. Comparing Columns (5) and (7) of Table 4 to Columns (3) and (4) of Table 12 shows again that the patterns are the same in most cases.[46]

[46] However, in the labor share regression, the interaction effects for skill-intensity are statistically not different from zero in contrast to being significantly negative in our baseline result.

Table 11: Minimum Wage and Firm Productivity: First Difference

	(1)	(2)	(3)
	Δ Productivity	Δ Productivity	Δ Productivity
Δ ln (min. wage)	1.188***	1.326***	1.194***
	[0.120]	[0.144]	[0.122]
Δ ln (min. wage)× Industry-City (S/L)	-0.469***	-0.476***	-0.382***
	[0.119]	[0.125]	[0.100]
Δ ln (min. wage)× Industry-City ln (K/L)	-0.016	-0.013	0.016
	[0.016]	[0.016]	[0.014]
Δ city ln (GDP per capita)	0.155***	0.157***	0.163***
	[0.019]	[0.020]	[0.018]
Δ city ln (Population)	-0.142***	-0.180***	-0.177***
	[0.033]	[0.036]	[0.031]
Year FE		Y	Y
Industry FE			Y
Observations	488,809	488,809	488,809

Note: Robust standard errors in parentheses, clustered on sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Weak identification test (Kleibergen-Paap rk Wald F statistic): 96.38.

Table 12: Minimum Wage and Factor Intensity: First Difference

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ ln (K/L)	ΔLabor share	Δ ln (K/L)	ΔLabor share	Δ ln (K/L)	Δ Labor share
Δln (min. wage)	1.698***	-0.059***	1.600***	-0.063***	1.516***	-0.051***
	[0.105]	[0.004]	[0.120]	[0.004]	[0.113]	[0.004]
Δln (min. wage) × Industry-City (S/L)	0.099	0.005	0.114	0.005	0.059	0.001
	[0.122]	[0.003]	[0.120]	[0.003]	[0.132]	[0.004]
Δln (min. wage) × Industry-City ln (K/L)	-0.285***	0.006***	-0.288***	0.005***	-0.331***	0.003***
	[0.018]	[0.001]	[0.017]	[0.001]	[0.018]	[0.000]
Δ city ln (GDP per capita)	0.125***	-0.004***	0.139***	-0.004***	0.120***	-0.004***
	[0.014]	[0.000]	[0.014]	[0.000]	[0.014]	[0.000]
Δ ln (Population)	-0.148***	0.002**	-0.163***	0.004***	-0.140***	0.004***
	[0.039]	[0.001]	[0.040]	[0.001]	[0.037]	[0.001]
Year FE			Y	Y	Y	Y
Industry FE					Y	Y
Observations	495,170	495,170	495,170	495,170	495,170	495,170

Note: Robust standard errors in parentheses, clustered on sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Weak identification test (Kleibergen-Paap rk Wald F statistic): 97.97.

Table 13: Minimum Wage and Firm Exports: First Difference

	(1)	(2)	(3)	(4)	(5)	(6)
	Δ ln (P)	Δ ln (Q)	Δ ln (P)	Δ ln (Q)	Δ ln (P)	Δ ln (Q)
Δln (min. wage)	0.405***	0.040	0.324***	-0.181	0.255***	0.510***
	[0.079]	[0.204]	[0.079]	[0.195]	[0.060]	[0.169]
Δln (min. wage) × Industry-City (S/L)	-0.663***	2.813***	-0.673***	2.786***	-0.217*	0.060
	[0.111]	[0.275]	[0.112]	[0.277]	[0.113]	[0.281]
Δln (min. wage) × Industry-City ln (K/L)	-0.070***	0.177***	-0.075***	0.161***	-0.033***	0.056*
	[0.013]	[0.034]	[0.013]	[0.034]	[0.011]	[0.030]
Δ city ln (GDP per capita)	0.058***	-0.102***	0.076***	-0.054***	0.071***	-0.034*
	[0.008]	[0.021]	[0.008]	[0.021]	[0.008]	[0.020]
Δ city ln (Population)	0.021	-0.227***	0.027	-0.210***	0.004	-0.223***
	[0.026]	[0.063]	[0.026]	[0.062]	[0.020]	[0.049]
Δ destination ln (Population)	0.422***	-1.104***	0.511***	-0.858***	0.428***	-0.889***
	[0.071]	[0.181]	[0.071]	[0.178]	[0.058]	[0.154]
Year FE			Y	Y	Y	Y
Industry FE					Y	Y
Observations	1,203,258	1,203,258	1,203,258	1,203,258	1,203,258	1,203,258

Note: Robust standard errors in parentheses, clustered on sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Weak identification test (Kleibergen-Paap rk Wald F statistic): 139.03.

Table 13 is the analogue of Table 5, which reports the first-difference version of equation (29). Given the first-difference setup, we no longer use the firm-product-destination specific fixed effects so that our baseline (Columns 3-4 in Table 5) and first difference results (Columns 3-4 in Table 13) should be compared. Doing so, we see that the estimates are remarkably close in sign, magnitude and significance. In the extended specification in Table 13, we also include 4-digit industry fixed effects in Columns (5)-(6) to check whether our results are robust to industry specific trends. In Columns (1)-(2) we do not include any fixed effects. The patterns are roughly the same, though it is clear that adding industry fixed effects is asking a lot of the data.

7 Conclusion

This paper has three components. First, it develops a new perfectly competitive heterogeneous firm model of supply in general equilibrium in a Heckscher-Ohlin setting. Firm heterogeneity coexists with competition because firms are capacity constrained which prevents the more productive firms from taking over. Entry is free and firms enter in search of quasi rents that accrue to more productive firms. Second, the model is used to predict how minimum wages affect selection of firms into entry/exit and productivity, production and export, prices, and technique of production. In other words, unlike much of the work in the area, it highlights the rich set of predictions in general equilibrium rather than focusing on a single one or a small subset of them. Third, we test these predictions using firm level Chinese customs and survey data. Using two IV strategies, we provide robust empirical evidence for causal effects of minimum wages in line with the entire range of theoretical predictions. In future work we plan to incorporate migration and agglomeration patterns in this rich research agenda to further explore the role of minimum wages in impacting geography of inequality.

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8 Appendix

8.1 Proofs of the Propositions

Lemma 1. From equation (2) it is straightforward to show that (i) If entry costs in a sector are paid solely in terms of the good being made in that sector, the identity of the marginal firm, $\tilde{\theta}$, is fixed and there are no selection effects of a change in factor price. (ii) If entry requires the use of both goods x and y, then an increase in the price of a factor makes selection stricter in the good that uses the factor intensively. Below is the proof of (iii) If entry costs are in terms of the numeraire good, then an increase in costs of production makes selection stricter in both sectors, i.e. if entry costs are in terms of the numeraire good, then $\mathbf{0} < \frac{dp}{dc}\frac{c}{p} < 1$.

Proof. Totally differentiating the above with respect to $c(\cdot)$ and p gives

$$F(\frac{p}{c(w.r)})\frac{[cdp - pdc]}{c^2} = -\frac{f_e}{c^2}dc$$

so that

$$\frac{dp}{dc}\frac{c}{p} = \frac{-\frac{f_e}{p} + F(\frac{p}{c(\cdot)})}{F(\frac{p}{c(\cdot)})} < 1$$

Also, as

$$F(\frac{p}{c(w,r)})\frac{p}{c(w.r)} > \int_0^{\frac{p}{c(w.r)}} F(\theta)d\theta = \frac{f_e}{c(w,r)},$$

we know that

$$F(\frac{p}{c(w.r)})p > f_e$$

so $-\frac{f_e}{p} + F(\frac{p}{c(\cdot)}) > 0$. □

Lemma 2. An increase in the price of the labor intensive good raises w and reduces r and makes selection stricter in the labor intensive good and weaker in the capital intensive one. Analogously, an increase in the price of the capital intensive good reduces w and raises r and makes selections stricter in the capital intensive good and weaker in the labor intensive one.

Proof. We know that

$$p^x = \tilde{\theta}^x(w,r)c^x(w,r) \tag{31}$$
$$p^y = \tilde{\theta}^y(w,r)c^y(w,r) \tag{32}$$

Generically,

$$\begin{aligned} p &= \tilde{\theta}(w,r)c(w,r) \\ \ln p &= \ln \tilde{\theta}(w,r) + \ln c(w,r) \end{aligned}$$

Using hat notation and totally differentiating gives:

$$\hat{p}^x = \theta_{Lx}\hat{w} + \theta_{Kx}\hat{r} + \widehat{\left(\tilde{\theta}^x\right)} \tag{33}$$
$$\hat{p}^y = \theta_{Ly}\hat{w} + \theta_{Ky}\hat{r} + \widehat{\left(\tilde{\theta}^y\right)} \tag{34}$$
$$\hat{p}^e = \theta_{Le}\hat{w} + \theta_{Ke}\hat{r}, \tag{35}$$

where θ_{ij} is the cost share of i in j for $i = L, K$ and $j = x, y, e$ while $\hat{p}^{ei} = \frac{dc^{ei}(w,r)}{c^{ei}(w,r)}$ as "hats" denote percentage changes. For ease of notation we will not differentiate entry costs by industry but it is easy to check the same proofs go through if we do.

As

$$\left[\int_0^{\tilde{\theta}^j} F(\theta)d\theta\right] = \frac{c^e(w,r)f_e}{c^j(w,r)}$$

differentiating this gives

$$\begin{aligned} \tilde{\theta}^j F(\tilde{\theta}^j)\frac{d\tilde{\theta}^j}{\tilde{\theta}^j} = \frac{f_e\left[c^e_w(w,r)dw + c^e_r(w,r)dr\right]}{c^j(w,r)} \\ -\frac{c^e(w,r)f_e}{[c^j(w,r)]}\left[\frac{wc^j_w(w,r)}{c^j(w,r)}\frac{dw}{w} + \frac{rc^j_r(w,r)}{c^j(w,r)}\frac{dr}{r}\right] \\ \tilde{\theta}^j F(\tilde{\theta}^j)\frac{d\tilde{\theta}^j}{\tilde{\theta}^j} &= \frac{c^e(w,r)f_e}{c^j(w,r)}\left[\left[\theta_{Le}\hat{w} + \theta_{Ke}\hat{r}\right] - \left[\theta_{Lj}\hat{w} + \theta_{Kj}\hat{r}\right]\right]. \end{aligned}$$

Using the fact that $\left[\int_0^{\tilde{\theta}} F(\theta)d\theta\right] = \frac{c^e(w,r)f_e}{c(w,r)}$,

$$\frac{d\tilde{\theta}^j}{\tilde{\theta}^j} = \frac{\left[\int_0^{\tilde{\theta}^j} F(\theta)d\theta\right]}{\tilde{\theta}^j F(\tilde{\theta}^j)} \left[(\theta_{Le} - \theta_{Lj})\,\hat{w} + (\theta_{ke} - \theta_{kj})\,\hat{r}\right]$$

Consequently:

$$\widehat{\left(\tilde{\theta}^x\right)} = \upsilon^x \left[(\theta_{Le} - \theta_{Lx})\hat{w} + (\theta_{Ke} - \theta_{Kx})\hat{r}\right] \tag{36}$$

$$\widehat{\left(\tilde{\theta}^y\right)} = \upsilon^y \left[(\theta_{Le} - \theta_{Ly})\hat{w} + (\theta_{Ke} - \theta_{Ky})\hat{r}\right] \tag{37}$$

where $\left[\frac{\int_0^{\tilde{\theta}^x} F(\theta)d\theta}{F(\tilde{\theta}^x)\tilde{\theta}^x}\right] = \upsilon^x$, $\left[\frac{\int_0^{\tilde{\theta}^x} F(\theta)d\theta}{F(\tilde{\theta}^y)\tilde{\theta}^y}\right] = \upsilon^y$. Note that $\upsilon^x, \upsilon^y \in (0,1)$.

Substituting (36) and (37) into (33) and (34) gives:

$$\begin{aligned}
\hat{p}^x &= \theta_{Lx}\hat{w} + \theta_{Kx}\hat{r} + \upsilon^x \left[(\theta_{Le} - \theta_{Lx})\hat{w} + (\theta_{Ke} - \theta_{Kx})\hat{r}\right] \\
\hat{p}^y &= \theta_{Ly}\hat{w} + \theta_{Ky}\hat{r} + \upsilon^y \left[(\theta_{Le} - \theta_{Ly})\hat{w} + (\theta_{Ke} - \theta_{Ky})\hat{r}\right]
\end{aligned}$$

$$\begin{aligned}
\hat{p}^x &= \left[\theta_{Lx}(1-\upsilon^x) + \upsilon^x(\theta_{Le})\right]\hat{w} + \left[\theta_{Kx}(1-\upsilon^x) + \upsilon^x(\theta_{Ke})\right]\hat{r} \\
\hat{p}^y &= \left[\theta_{Ly}(1-\upsilon^y) + \upsilon^y(\theta_{Le})\right]\hat{w} + \left[\theta_{Ky}(1-\upsilon^y) + \upsilon^y(\theta_{Ke})\right]\hat{r}
\end{aligned}$$

or

$$\begin{aligned}
\hat{p}^x &= \left[\breve{\theta}_{Lx}\right]\hat{w} + \left[\breve{\theta}_{Kx}\right]\hat{r} \\
\hat{p}^y &= \left[\breve{\theta}_{Ly}\right]\hat{w} + \left[\breve{\theta}_{Ky}\right]\hat{r}
\end{aligned}$$

where

$$\begin{aligned}
\left[\theta_{Lx}(1-\upsilon^x) + \upsilon^x(\theta_{Le})\right] &= \breve{\theta}_{Lx} \\
\left[\theta_{Kx}(1-\upsilon^x) + \upsilon^x(\theta_{Ke})\right] &= \breve{\theta}_{Kx} \\
\left[\theta_{Ly}(1-\upsilon^y) + \upsilon^y(\theta_{Le})\right] &= \breve{\theta}_{Ly} \\
\left[\theta_{Ky}(1-\upsilon^y) + \upsilon^y(\theta_{Ke})\right] &= \breve{\theta}_{Ky}
\end{aligned}$$

Since $\theta_{Lx} > \theta_{Le}$ and $\theta_{Ly} < \theta_{Le}$ and $\breve{\theta}'_L s$ are convex combinations of θ_L and θ_L^e we know that $\breve{\theta}_{Ly} < \breve{\theta}_{Lx}$. This is depicted below.

$$\theta_{Ly} < \breve{\theta}_{Ly} < \theta_{Le} < \breve{\theta}_{Lx} < \theta_{Lx}$$

Similarly, $\breve{\theta}_{Ky} > \breve{\theta}_{Kx}$.

As

$$\begin{bmatrix} \hat{p}^x \\ \hat{p}^y \end{bmatrix} = \begin{bmatrix} \breve{\theta}_{Lx} & \breve{\theta}_{Kx} \\ \breve{\theta}_{Ly} & \breve{\theta}_{Ky} \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix}$$

$$\begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix} = \begin{bmatrix} \breve{\theta}_{Lx} & \breve{\theta}_{Kx} \\ \breve{\theta}_{Ly} & \breve{\theta}_{Ky} \end{bmatrix}^{-1} \begin{bmatrix} \hat{p}^x \\ \hat{p}^y \end{bmatrix}$$

so that

$$\begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix} = \frac{1}{DetA} \begin{bmatrix} \breve{\theta}_{Ky} & -\breve{\theta}_{Kx} \\ -\breve{\theta}_{Ly} & \breve{\theta}_{Lx} \end{bmatrix} \begin{bmatrix} \hat{p}^x \\ \hat{p}^y \end{bmatrix}.$$

Solving gives

$$\begin{aligned} \hat{w} &= \frac{1}{\left(\breve{\theta}_{Lx}\breve{\theta}_{Ky} - \breve{\theta}_{Ly}\breve{\theta}_{Kx}\right)} \left[\breve{\theta}_{Ky}\hat{p}^x - \breve{\theta}_{Kx}\hat{p}^y\right] \\ \hat{r} &= \frac{1}{\left(\breve{\theta}_{Lx}\breve{\theta}_{Ky} - \breve{\theta}_{Ly}\breve{\theta}_{Kx}\right)} \left[-\breve{\theta}_{Ly}\hat{p}^x + \breve{\theta}_{Lx}\hat{p}^y\right] \end{aligned}$$

$DetA = \breve{\theta}_{Lx}\breve{\theta}_{Ky} - \breve{\theta}_{Ly}\breve{\theta}_{Kx} > 0$ as $\breve{\theta}_{Ly} < \breve{\theta}_{Lx}$ and $\breve{\theta}_{Ky} > \breve{\theta}_{Kx}$.

So if $\hat{p}^x = 0,\ \hat{p}^y > 0$

$$\begin{aligned} \hat{w} &= \frac{1}{\breve{\theta}_{Lx}\breve{\theta}_{Ky} - \breve{\theta}_{Ly}\breve{\theta}_{Kx}} \left[-\ \breve{\theta}_{Kx}\hat{p}^y\right] < 0 \\ \hat{r} &= \frac{1}{\breve{\theta}_{Lx}\breve{\theta}_{Ky} - \breve{\theta}_{Ly}\breve{\theta}_{Kx}} \left[\ \breve{\theta}_{Lx}\hat{p}^y\right] > 0 \end{aligned}$$

In other words, an increase in the price of the capital intensive good reduces w and raises r. Analogously, an increase in the price of the labor intensive good reduces r and raises w.

Moreover

$$
\begin{aligned}
\widehat{\left(\tilde{\theta}^{x}\right)} &= v^{x}\left[(\theta_{Le}-\theta_{Lx})\hat{w}+(\theta_{Ke}-\theta_{Kx})\hat{r}\right] \\
\widehat{\left(\tilde{\theta}^{y}\right)} &= v^{y}\left[(\theta_{Le}-\theta_{Ly})\hat{w}+(\theta_{Ke}-\theta_{Ky})\hat{r}\right]
\end{aligned}
$$

as $\theta_{Lx} > \theta_{Le}$, $\theta_{Kx} < \theta_{Ke}$, $\theta_{Le} > \theta_{Ly},\ \theta_{Ke} > \theta_{Ky}$ and $\breve{\theta}_{Ky} > \breve{\theta}_{Kx},\ \breve{\theta}_{Ly} < \breve{\theta}_{Lx}$. So if w rises and r falls, then $\widehat{\left(\tilde{\theta}^{x}\right)} < 0,\ \widehat{\left(\tilde{\theta}^{y}\right)} > 0$.

This proves that a rise in the price of the labor intensive good also makes selection tighter in the labor intensive good and weaker in the capital intensive one. Analogously, a rise in the price of the capital intensive good makes selection tighter in the capital intensive good and weaker in the labor intensive one. $\square$

Lemma 3-A. $\frac{A_{Kx}}{A_{Lx}} < \frac{A_{Ky}}{A_{Ly}}$ if f_e is small enough or $c^{j}(\cdot) \approx c^{je}(\cdot)$.

Proof. We know

$$
\begin{aligned}
\bar{\theta}(\tilde{\theta}) &= \int_{0}^{\tilde{\theta}} \theta f(\theta) d\theta \\
&= \tilde{\theta}F(\tilde{\theta}) - \int_{0}^{\tilde{\theta}} F(\theta) d\theta \qquad (38)
\end{aligned}
$$

Hence

$$
\begin{aligned}
A_L &= c_w(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \int_{0}^{\tilde{\theta}} F(\theta)d\theta\right] + f_e c^{e}_{w}(\cdot) \\
&= c_w(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \int_{0}^{\tilde{\theta}} F(\theta)d\theta + \frac{f_e c^{e}_{w}(\cdot)}{c_w(\cdot)}\right] \\
&= c_w(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \frac{c^{e}(w,r)f_e}{c(w,r)} + \frac{f_e c^{e}_{w}(\cdot)}{c_w(\cdot)}\right]
\end{aligned}
$$

where we use equation (38) and the free entry condition

$$
\int_{0}^{\tilde{\theta}} F(\theta)d\theta = \frac{c^{e}(w,r)f_e}{c(w,r)}
$$

in the second and last lines respectively. Similarly

$$
\begin{aligned}
A_K &= c_r(\cdot)\bar{\theta}(\tilde{\theta}(w,r)) + f_e c_r^e(\cdot) \\
&= c_r(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \frac{c^e(\cdot)f_e}{c(\cdot)} + \frac{f_e c_r^e(\cdot)}{c_r(\cdot)}\right]
\end{aligned}
$$

Thus,

$$
\begin{aligned}
\frac{A_L}{A_K} &= \frac{c_w(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \frac{c^e(w,r)f_e}{c(w,r)} + \frac{f_e c_w^e(\cdot)}{c_w(\cdot)}\right]}{c_r(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \frac{c^e(\cdot)f_e}{c(\cdot)} + \frac{f_e c_r^e(\cdot)}{c_r(\cdot)}\right]} \\
&= \frac{c_w(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \frac{\theta_L}{\theta_L^e}\frac{c_w^e(w,r)f_e}{c_w(w,r)} + \frac{f_e c_w^e(\cdot)}{c_w(\cdot)}\right]}{c_r(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) - \frac{\theta_K}{\theta_K^e}\frac{f_e c_r^e(\cdot)}{c_r(\cdot)} + \frac{f_e c_r^e(\cdot)}{c_r(\cdot)}\right]} \\
&= \frac{c_w(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) + \frac{c_w^e(\cdot)f_e}{c_w(\cdot)}(1 - \frac{\theta_L}{\theta_L^e})\right]}{c_r(\cdot)\left[\tilde{\theta}F(\tilde{\theta}) + \frac{c_r^e(\cdot)f_e}{c_r(\cdot)}(1 - \frac{\theta_K}{\theta_K^e})\right]}
\end{aligned}
$$

If entry costs are made up of x and y, then $(1 - \frac{\theta_{Lx}}{\theta_{Lx}^e}) < 0$ and $(1 - \frac{\theta_{Ly}}{\theta_{Ly}^e}) > 0$,

$$
\frac{\left[\tilde{\theta}^x F(\tilde{\theta}^x) + \frac{c_w^{ex}(w,r)f_e}{c_w^x(w,r)}(1 - \frac{\theta_{Lx}}{\theta_{Lx}^e})\right]}{\left[\tilde{\theta}^x F(\tilde{\theta}^x) + \frac{f_e c_r^{ex}(\cdot)}{c_r^x(\cdot)}(1 - \frac{\theta_{Kx}}{\theta_{Kx}^e})\right]} < \frac{\tilde{\theta}^x F(\tilde{\theta}^x)}{\tilde{\theta}^x F(\tilde{\theta}^x)} = 1
$$

so

$$
\frac{A_{Lx}}{A_{Kx}} < \frac{a_{Lx}}{a_{Kx}}
$$

By the same argument,

$$
\left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{c_w^{ey}(w,r)f_e}{c_w^y(w,r)}(1 - \frac{\theta_{Ly}}{\theta_{Ly}^e})\right] > \left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{f_e c_r^{ey}(\cdot)}{c_r^y(\cdot)}(1 - \frac{\theta_{Ky}}{\theta_{Ky}^e})\right]
$$

as $(1 - \frac{\theta_{Ly}}{\theta_{Ly}^e}) > 0$ and $(1 - \frac{\theta_{Ky}}{\theta_{Ky}^e}) < 0$ so that

$$
\begin{aligned}
\frac{A_{Ly}}{A_{Ky}} &= \frac{a_{Ly}}{a_{Ky}} \frac{\left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{f_e c_w^{ey}(w,r)}{c_w^y(w,r)}(1 - \frac{\theta_{Ly}}{\theta_{Ly}^e})\right]}{\left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{f_e c_r^{ey}(\cdot)}{c_r^y(\cdot)}(1 - \frac{\theta_{Ky}}{\theta_{Ky}^e})\right]} \\
&> \frac{a_{Ly}}{a_{Ky}}.
\end{aligned}
$$

Thus, in general, even if $\frac{a_{Lx}}{a_{Kx}} > \frac{a_{Ly}}{a_{Ky}}$, we cannot in general say $\frac{A_{Lx}}{A_{Kx}} > \frac{A_{Ly}}{A_{Ky}}$ as selection raises the total labor intensity in y and reduces it in x bringing them closer together. However, if entry costs are similar enough to production costs, or f_e is small enough, then $\frac{A_L}{A_K}$ approaches $\frac{a_L}{a_K}$. Thus, $\frac{A_{Lx}}{A_{Kx}} > \frac{A_{Ly}}{A_{Ky}}$ will hold even with selection and the Rybczynski theorem will hold. □

Lemma 4. When Assumption 1 holds, $N^x(.; \overset{+}{L}, \overset{-}{K})$, $N^y(.; \overset{-}{L}, \overset{+}{K})$.

Proof. Using Lemma 3 in equation (13) and (12) gives:

$$\begin{aligned} N^x c_w^x(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) + N^y c_w^y(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= G(w)L && (39) \\ N^x c_r^x(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) + N^y c_r^y(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= K && (40) \end{aligned}$$

Product prices pin down factor prices so at given product prices, entry mass changes satisfy

$$\begin{aligned} a_{Lx}(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x) dN^x + a_{Ly}(\cdot)\tilde{\theta}^y F(\tilde{\theta}^y) dN^y &= G(w)dL && (41) \\ a_{Kx}(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x) dN^x + a_{Ky}(\cdot)\tilde{\theta}^y F(\tilde{\theta}^y) dN^y &= dK && (42) \end{aligned}$$

so that

$$\begin{aligned} \lambda_{Lx}\hat{N}^x + \lambda_{Ly}\hat{N}^y &= \hat{L} && (43) \\ \lambda_{Kx}\hat{N}^x + \lambda_{Ky}\hat{N}^y &= \hat{K} && (44) \end{aligned}$$

where $\frac{a_{Lx}(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x) N^x}{G(w)L} = \lambda_{Lx}$, $\frac{a_{Ly}(\cdot)\tilde{\theta}^y F(\tilde{\theta}^y) N^y}{G(w)L} = \lambda_{Ly}$, $\frac{a_{Kx}(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x) N^x}{K} = \lambda_{Kx}$, $\frac{a_{Ky}(\cdot)\tilde{\theta}^y F(\tilde{\theta}^y) N^y}{K} = \lambda_{Ky}$.

Solving gives

$$\begin{bmatrix} \hat{N}^x \\ \hat{N}^y \end{bmatrix} = \begin{bmatrix} \lambda_{Lx} & \lambda_{Ly} \\ \lambda_{Kx} & \lambda_{Ky} \end{bmatrix}^{-1} \begin{bmatrix} \hat{L} \\ \hat{K} \end{bmatrix}$$

$$\begin{bmatrix} \hat{N}^x \\ \hat{N}^y \end{bmatrix} = \frac{1}{(\lambda_{Lx}\lambda_{Ky} - \lambda_{Kx}\lambda_{Ly})} \begin{bmatrix} \lambda_{Ky} & -\lambda_{Ly} \\ -\lambda_{Kx} & \lambda_{Lx} \end{bmatrix} \begin{bmatrix} \hat{L} \\ \hat{K} \end{bmatrix}$$

so that

$$\left\{ \left[\hat{N}^x = \frac{\hat{K}\lambda_{Ly} - \hat{L}\lambda_{Ky}}{\lambda_{Kx}\lambda_{Ly} - \lambda_{Ky}\lambda_{Lx}}, \hat{N}^y = -\frac{\hat{K}\lambda_{Lx} - \hat{L}\lambda_{Kx}}{\lambda_{Kx}\lambda_{Ly} - \lambda_{Ky}\lambda_{Lx}} \right] \right\}$$

Since

$$\begin{aligned}
\lambda_{Kx}\lambda_{Ly} - \lambda_{Ky}\lambda_{Lx} &= \lambda_{Kx}\lambda_{Ky}(\frac{\lambda_{Ly}}{\lambda_{Ky}} - \frac{\lambda_{Lx}}{\lambda_{Kx}}) \\
&= \lambda_{Kx}\lambda_{Ky}(\frac{\frac{a_{Ly}(\cdot)\tilde{\theta}^y F(\tilde{\theta}^y)N^y}{G(w)L}}{\frac{a_{Ky}(\cdot)\tilde{\theta}^y F(\tilde{\theta}^y)N^y}{K}} - \frac{\frac{a_{Lx}(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x)N^x}{G(w)L}}{\frac{a_{Kx}(\cdot)\tilde{\theta}^x F(\tilde{\theta}^x)N^x}{K}}) \\
&= \lambda_{Kx}\lambda_{Ky}\frac{K}{G(w)L}(\frac{A_{Ly}}{A_{Ky}} - \frac{A_{Lx}}{A_{Kx}}) < 0
\end{aligned}$$

it follows that

$$\begin{aligned}
\frac{\hat{N}^x}{\hat{K}} &= \frac{\lambda_{Ly}}{\lambda_{Kx}\lambda_{Ly} - \lambda_{Ky}\lambda_{Lx}} < 0, \frac{\hat{N}^x}{\hat{L}} = \frac{-\lambda_{Ky}}{\lambda_{Kx}\lambda_{Ly} - \lambda_{Ky}\lambda_{Lx}} > 0 \\
\frac{\hat{N}^y}{\hat{K}} &= \frac{-\lambda_{Lx}}{\lambda_{Kx}\lambda_{Ly} - \lambda_{Ky}\lambda_{Lx}} > 0, \frac{\hat{N}^y}{\hat{L}} = \frac{\lambda_{Kx}}{\lambda_{Kx}\lambda_{Ly} - \lambda_{Ky}\lambda_{Lx}} < 0
\end{aligned}$$

This proves that $N^x(.;\overset{+}{L},\overset{-}{K})$, $N^y(.;\overset{-}{L},\overset{+}{K})$. □

Lemma 5. When Assumption 1 holds, $N^x(\overset{+}{p^x},\overset{-}{p^y};.)$, $N^y(\overset{-}{p^x},\overset{+}{p^y};.)$.

Proof. Recall that

$$\begin{aligned}
c^x_w(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) &= A_{Lx}(w,r) \\
c^y_w(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= A_{Ly}(w,r) \\
c^x_r(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) &= A_{Kx}(w,r) \\
c^y_r(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= A_{Ky}(w,r).
\end{aligned}$$

$$\frac{A_{Lx}}{A_{Kx}} = \frac{c^x_w(w,r)\tilde{\theta}F(\tilde{\theta})}{c^x_w(w,r)\tilde{\theta}F(\tilde{\theta})} = \frac{a_{Lx}(\cdot)}{a_{Kx}(\cdot)}$$

which is decreasing in w and increasing in r.

$$N^x A_{Lx}(w,r) + N^y A_{Ly}(w,r) = G(w)L \tag{45}$$

$$N^x A_{Kx}(w,r) + N^y A_{Ky}(w,r) = K \tag{46}$$

Differentiating

$$\begin{aligned} \lambda_{Lx}\hat{N}^x + \lambda_{Ly}\hat{N}^y + \lambda_{Lx}\hat{A}_{Lx}(\cdot) + \lambda_{Ly}\hat{A}_{Ly}(\cdot) &= \hat{L} + \frac{wG'(w)}{G(w)}\hat{w} & (47) \\ \lambda_{Kx}\hat{N}^x + \lambda_{Ky}\hat{N}^y + \lambda_{Kx}\hat{A}_{Kx}(\cdot) + \lambda_{Ky}\hat{A}_{Ky}(\cdot) &= \hat{K} & (48) \end{aligned}$$

where $\lambda_{Lx} = \frac{N^x A_{Lx}(w,r)}{G(w)L}, \lambda_{Ly} = \frac{N^y A_{Ly}(w,r)}{G(w)L}, \lambda_{Kx} = \frac{N^x A_{Kx}(w,r)}{K}, \lambda_{Ky} = \frac{N^y A_{Ky}(w,r)}{K}$ are usage shares.

Since

$$\hat{A}_{ij} = \frac{dc_i^j(w,r)}{c_i^j(w,r)} = \hat{a}_{ij}$$

$$\begin{aligned} \lambda_{Lx}\hat{N}^x + \lambda_{Ly}\hat{N}^y + \lambda_{Lx}\hat{a}_{Lx}(\cdot) + \lambda_{Ly}\hat{a}_{Ly}(\cdot) &= \hat{L} + \frac{wG'(w)}{G(w)}\hat{w} & (49) \\ \lambda_{Kx}\hat{N}^x + \lambda_{Ky}\hat{N}^y + \lambda_{Kx}\hat{a}_{Kx}(\cdot) + \lambda_{Ky}\hat{a}_{Ky}(\cdot) &= \hat{K} & (50) \end{aligned}$$

Setting $\hat{L} = \hat{K} = 0$

$$\begin{aligned} \hat{a}_{Lj}(\cdot) &= \frac{da_{Lj}}{a_{Lj}} = \frac{\partial a_{Lj}}{\partial w}\frac{w}{a_{Lj}}\frac{dw}{w} + \frac{\partial a_{Lj}}{\partial r}\frac{r}{a_{Lj}}\frac{dr}{r} \\ &= \eta_w^{Lj}\hat{w} + \eta_r^{Lj}\hat{r} \\ &= \eta_w^{Lj}\left(\hat{w} - \hat{r}\right) \end{aligned}$$

as a_{Lj} is homogeneous of degree 0 in (w,r) so that $\eta_w^{Lj} + \eta_r^{Lj} = 0$. Also note that $\eta_w^{Lj} < 0,\ \eta_w^{Kj} > 0$. Hence,

$$\begin{aligned} \hat{a}_{Lx} &= \eta_w^{Lx}\left(\hat{w} - \hat{r}\right) \\ \hat{a}_{Ly} &= \eta_w^{Ly}\left(\hat{w} - \hat{r}\right) \\ \hat{a}_{Kx} &= \eta_w^{Kx}\left(\hat{w} - \hat{r}\right) \\ \hat{a}_{Ky} &= \eta_w^{Ky}\left(\hat{w} - \hat{r}\right). \end{aligned}$$

So

$$\begin{aligned} \lambda_{Lx}\hat{N}^x + \lambda_{Ly}\hat{N}^y &= \frac{wG'(w)}{G(w)}\hat{w} - \left[\lambda_{Lx}\eta_w^{Lx} + \lambda_{Ly}\eta_w^{Ly}\right]\left(\hat{w} - \hat{r}\right) & (51) \\ \lambda_{Kx}\hat{N}^x + \lambda_{Ky}\hat{N}^y &= -\left[\lambda_{Kx}\eta_w^{Kx} + \lambda_{Ky}\eta_w^{Ky}\right]\left(\hat{w} - \hat{r}\right) & (52) \end{aligned}$$

Recall that

$$\begin{aligned}
\hat{w} &= \frac{1}{\left(\breve{\theta}_{Lx}\breve{\theta}_{Ky} - \breve{\theta}_{Ly}\breve{\theta}_{Kx}\right)} \left[\breve{\theta}_{Kx}\hat{p}^{x} - \breve{\theta}_{Kx}\hat{p}^{y}\right] \\
\hat{r} &= \frac{1}{\left(\breve{\theta}_{Lx}\breve{\theta}_{Ky} - \breve{\theta}_{Ly}\breve{\theta}_{Kx}\right)} \left[-\breve{\theta}_{Ly}\hat{p}^{x} + \breve{\theta}_{Lx}\hat{p}^{y}\right]
\end{aligned}$$

and if there is no selection $\breve{\theta}_{ij} = \theta_{ij}$ so that

$$\begin{aligned}
\lambda_{Lx}\hat{N}^{x} + \lambda_{Ly}\hat{N}^{y} &= -\left[\lambda_{Lx}\eta_{w}^{Lx} + \lambda_{Ly}\eta_{w}^{Ly} - \frac{wG'(w)}{G(w)}\right]\hat{w} + \left[\lambda_{Lx}\eta_{w}^{Lx} + \lambda_{Ly}\eta_{w}^{Ly}\right]\hat{r} \\
&= B_{11}\hat{w} + B_{12}\hat{r} \\
\lambda_{Kx}\hat{N}^{x} + \lambda_{Ky}\hat{N}^{y} &= -\left[\lambda_{Kx}\eta_{w}^{Kx} + \lambda_{Ky}\eta_{w}^{Ky}\right](\hat{w} - \hat{r}) = B_{21}(\hat{w} - \hat{r})
\end{aligned}$$

Denote by

$$\begin{aligned}
B_{11} &= -\left[\lambda_{Lx}\eta_{w}^{Lx} + \lambda_{Ly}\eta_{w}^{Ly} - \frac{wG'(w)}{G(w)}\right] \\
&= -B_{12} + \frac{wG'(w)}{G(w)} > 0 \qquad (53) \\
B_{12} &= \left[\lambda_{Lx}\eta_{w}^{Lx} + \lambda_{Ly}\eta_{w}^{Ly}\right] < 0 \\
B_{21} &= -\left[\lambda_{Kx}\eta_{w}^{Kx} + \lambda_{Ky}\eta_{w}^{Ky}\right] = -B_{22} < 0.
\end{aligned}$$

Therefore

$$\begin{bmatrix} \lambda_{Lx} & \lambda_{Ly} \\ \lambda_{Kx} & \lambda_{Ky} \end{bmatrix} \begin{bmatrix} \hat{N}^{x} \\ \hat{N}^{y} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & -B_{21} \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix}$$

so

$$\begin{bmatrix} \hat{N}^{x} \\ \hat{N}^{y} \end{bmatrix} = \begin{bmatrix} \lambda_{Lx} & \lambda_{Ly} \\ \lambda_{Kx} & \lambda_{Ky} \end{bmatrix}^{-1} \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & -B_{21} \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix}$$

so using equation (53) we get

$$
\begin{aligned}
\begin{bmatrix} \hat{N}^x \\ \hat{N}^y \end{bmatrix} &= \frac{1}{Det\Lambda} \begin{bmatrix} \lambda_{Ky} & -\lambda_{Ly} \\ -\lambda_{Kx} & \lambda_{Lx} \end{bmatrix} \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix} \\
&= \frac{1}{Det\Lambda} \begin{bmatrix} -\left(\lambda_{Ky}B_{12} - \lambda_{Ly}B_{22}\right) + \lambda_{Ky}\frac{wG'(w)}{G(w)} & \lambda_{Ky}B_{12} - \lambda_{Ly}B_{22} \\ \lambda_{Kx}B_{12} - \lambda_{Lx}B_{22} - \frac{wG'(w)}{G(w)}\lambda_{Kx} & -\lambda_{Kx}B_{12} + \lambda_{Lx}B_{22} \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix} \\
&= \frac{1}{+} \begin{bmatrix} + & - \\ - & + \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix}
\end{aligned}
$$

where

$$
\begin{aligned}
Det\Lambda &= \lambda_{Lx}\lambda_{Ky} - \lambda_{Ly}\lambda_{Kx} \\
&= \frac{N^x A_{Lx}(w,r)}{G(w)L}\frac{N^y A_{Ky}(w,r)}{K} - \frac{N^y A_{Ly}(w,r)}{G(w)L}\frac{N^x A_{Kx}(w,r)}{K} \\
&= \frac{N^x N^y (A_{Lx}(w,r)A_{Ky}(w,r) - A_{Ly}(w,r)A_{Kx}(w,r))}{G(w)LK} \\
&= \frac{N^x N^y A_{Lx}(w,r)A_{Ly}(w,r)(\frac{A_{Ky}(w,r)}{A_{Ly}(w,r)} - \frac{A_{Kx}(w,r)}{A_{Lx}(w,r)})}{G(w)LK} > 0.
\end{aligned}
$$

.

As an increase in p_x raises w and reduces r as shown in Lemma 2, so $\hat{w} > 0,\ \hat{r}\ < 0$ in

$$
\begin{bmatrix} \hat{N}^x \\ \hat{N}^y \end{bmatrix} = \frac{1}{+} \begin{bmatrix} + & - \\ - & + \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix}.
$$

Thus

$$
\begin{aligned}
\begin{bmatrix} \hat{N}^x \\ \hat{N}^y \end{bmatrix} &= \frac{1}{+} \begin{bmatrix} + & - \\ - & + \end{bmatrix} \begin{bmatrix} + \\ - \end{bmatrix} \\
&= \frac{1}{+} \begin{bmatrix} + \\ - \end{bmatrix}
\end{aligned}
$$

so $\frac{\hat{N}^x}{\hat{p}^x} > 0$ and $\frac{\hat{N}^y}{\hat{p}^x} < 0$. Analogously, $\frac{\hat{N}^x}{\hat{p}^y} < 0$ and $\frac{\hat{N}^y}{\hat{p}^y} > 0$. □

Lemma 6. An increase in the minimum wage raises the price needed for good x to be made, and more so, the more labor intensive is good x.

Proof. As

$$\begin{aligned} p^x &= \tilde{\theta}^x c^x(w,r) \\ p^y &= \tilde{\theta}^y c^y(w,r) \end{aligned}$$

differentiating gives

$$\begin{aligned} \hat{p}^x &= \tilde{\theta}^x \left(\lambda_{Lx}\hat{w} + \lambda_{Kx}\hat{r}\right) \\ \hat{p}^y &= \tilde{\theta}^y \left(\lambda_{Ly}\hat{w} + \lambda_{Ky}\hat{r}\right) \end{aligned}$$

With a minimum wage, we want to know how $\tilde{p}^x(\bar{w}, r, p^y)$ changes with the minimum wage. Recall that we get $\tilde{p}^x(\bar{w}, r, p^y)$ as the price of x needed to make price equal to cost when the price of y is fixed in the presence of a minimum wage. Thus, we know that $\hat{p}^y = 0$. So $0 = \lambda_{Ly}\hat{w} + \lambda_{Ky}\hat{r}$ and

$$\begin{aligned} \hat{r} &= -\frac{\lambda_{Ly}}{\lambda_{Ky}}\hat{w} \\ &= -\frac{\lambda_{Ly}}{(1-\lambda_{Ly})}\hat{w}. \end{aligned}$$

Substituting this back into $\hat{p}^x = \tilde{\theta}^x \left(\lambda_{Lx}\hat{w} + \lambda_{Kx}\hat{r}\right)$ and some rearranging we get

$$\begin{aligned} \hat{p}^x &= \tilde{\theta}^x \left(\lambda_{Lx}\hat{w} - \lambda_{Kx}\frac{\lambda_{Ly}}{(1-\lambda_{Ly})}\hat{w}\right) \\ &= \tilde{\theta}^x \left(\frac{(\lambda_{Lx}-\lambda_{Ly})}{(1-\lambda_{Ly})}\right)\hat{w} \\ &= \tilde{\theta}^x \frac{(k_y - k_x)}{k_y\left(1+\frac{r}{w}k_x\right)}\hat{w}. \end{aligned}$$

as

$$\begin{aligned} \frac{(\lambda_{Lx}-\lambda_{Ly})}{(1-\lambda_{Ly})} &= \frac{\frac{wa_{Lx}}{c^x(\cdot)} - \frac{wa_{Ly}}{c^y(\cdot)}}{1-\frac{wa_{Ly}}{c^y(\cdot)}} \\ &= \frac{\frac{\frac{r}{w}(k_y-k_x)}{c^x(\cdot)c^y(\cdot)}}{\frac{ra_{ky}}{c^y(\cdot)}} \\ &= \frac{(k_y-k_x)}{k_y\left(1+\frac{r}{w}k_x\right)}. \end{aligned}$$

As k_x rises the numerator falls and the denominator rises. Thus, given w/r and k_y, the higher is

k_x, the lower the price increase needed to compensate for a wage increase. Thus, the price of the labor intensive good should rise with a minimum wage and more so the more labor intensive the good. $\square$

8.2 Simulations

In this section we construct numerical examples given simple functional forms and distributional assumptions to demonstrate that our key comparative static results of change in minimum wage, summarized as predictions in Section 4.1, continue to hold in presence of selection effects.

8.2.1 Solving the Model

In the model without minimum wage, we solve 8 equations (3)-(4), the free entry conditions, (5)-(6), the price equals cost of the marginal firm (12)-(13) the factor market clearing conditions, and (14)-(15) the product market clearing conditions. This gives eight equations in 8 unknowns for w, r, $\tilde{\theta}_x$, $\tilde{\theta}_y$, N^x, N^y, and p^x and p^y. Once we know w and r, we know income from equation (8). Once we know w, we also know which workers migrate which pins down labor availability. We can solve for the problem block recursively. Given prices, the block of equations (3)-(6) can be solved for w, r, $\tilde{\theta}_x$, $\tilde{\theta}_y$. Given these solutions, we can solve for N^x, N^y from factor market clearing conditions (12)-(13), which then give supply and demand at these prices. Equilibrium prices then come from equating demand and supply as in (14)-(15).

In the model with a minimum wage, we solve 8 equations (19)-(20), the free entry conditions, (16)-(17), the price equals cost of the marginal firm along with the complementary slackness conditions, so if the marginal firm cannot afford to produce, there is zero supply, (21)-(22) the factor market clearing conditions, where the equality in (12) is replaced by an inequality so that demand can fall short of supply for labor, and (25)-(26) the product market clearing conditions. There are two main changes in the solution procedure. First, as we are fixing the minimum wage, $\bar{w}$, we are solving for unemployment and through it, for the expected wage $\hat{w}(\bar{w})$. How can one solve the system with a minimum wage?

Set prices. If the minimum wage is not binding then solve as above. If the minimum wage is binding at these prices, only good y will be made unless price is $\tilde{p}^x(p^y)$ or more. If both goods are essential in demand as assumed, both need to be made so that we know that $p^x = \tilde{p}^x(p^y)$. Thus, we solve for $\tilde{p}^x(p^y)$, and r and the two cutoff productivity levels from (18)-(19) and (15)-(16).

Second, to solve for entry, we need to know income and from it demand at the given prices $\tilde{p}^x(p^y), p^y, \bar{w}, r, \tilde{\theta}_x, \tilde{\theta}_y$. Income in equation (8) needs to be adjusted as now

$$I = \bar{\gamma}(\hat{w}(\bar{w}))L + \hat{w}(\bar{w})G(\hat{w}(\bar{w}))L + rK$$

which has expected wage in manufacturing for rural migrants as an unknown. Expected wage is defined by probability of finding a job in manufacturing times the minimum wage, and this probability depends on labor demand in manufacturing which in turn depends on number of firms in operation in each sector. Expected income affects demand. Hence, now we need to solve factor market and goods market clearing conditions simultaneously. Given a set of values for N^x and N^y, we can obtain labor demand from (20) as the A's are known once we have factor prices and cutoffs. Then

$$\hat{w}(\bar{w}) = \frac{L^D}{G(\hat{w}(\bar{w}))}\bar{w}$$

gives the expected wage and hence income, and hence, demand for both goods.[47] Setting

$$\begin{aligned} D^x(\tilde{p}^x(p^y), p^y, I(N^x, N^y)) &= N^x F(\tilde{\theta}_x) \\ D^y(\tilde{p}^x(p^y), p^y, I(N^x, N^y)) &= N^y F(\tilde{\theta}_x) \end{aligned}$$

allows us to solve for N^x and N^y for the given p^y.

Finally, for the given p^y, we have demand for capital equal to supply of capital.

$$N^x A_{Kx}(\cdot) + N^y A_{Ky}(\cdot) = K$$

If at this p^y, demand is more than supply, reduce p^y,else increase it. Note that labor markets will not clear, and at these prices, we will get unemployment in equilibrium.

8.2.2 Examples

In the numerical examples, we consider following functional forms for unit production costs:

$$\begin{aligned} c^x(w,r) &= w^{\eta_x} r^{1-\eta_x} \\ c^y(w,r) &= w^{\eta_y} r^{1-\eta_y} \end{aligned}$$

and following functional forms for unit entry costs:

$$\begin{aligned} c_e^x(w,r) &= w^{\eta_{e,x}} r^{1-\eta_{e,x}} \\ c_e^y(w,r) &= w^{\eta_{e,y}} r^{1-\eta_{e,y}} \end{aligned}$$

As x is more labor-intensive than y, we set $\eta_x > \eta_y$. No selection effect for change in minimum

[47] Note that as $G(\cdot)$ is increasing in the expected wage, the RHS is decreasing in expected wage so that there is a unique intersection of the 45 degree line and the RHS.

wage requires $\eta_x = \eta_{e,x}$ and $\eta_y = \eta_{e,y}$ which implies that in each sector, production and entry costs employ labor and capital using same factor intensity. Selection effects would occur when we set parameters such that $\eta_x > \eta_{e,x}, \eta_{e,y} > \eta_y$.

Consumers have a utility function

$$U = A^{\alpha} S^{1-\alpha}$$

and

$$S = (X^{\rho} + Y^{\rho})^{\frac{1}{\rho}}$$

where $\sigma = \frac{1}{1-\rho}$ is the constant elasticity of substitution between X and Y. For now, we are considering the case of no trade–thus there is only one variety of x and y in the consumption bundle of city j. For the distributional assumption, we make the simplest possible assumption that agricultural productivity γ is distributed Uniform $(0, b]$ and firm efficiency θ is distributed Pareto with scale parameter a and shape α^*.

In the first numerical example, we consider the case with no selection effects of a change in the minimum wage. The parameter values used in this example are in Table 14:

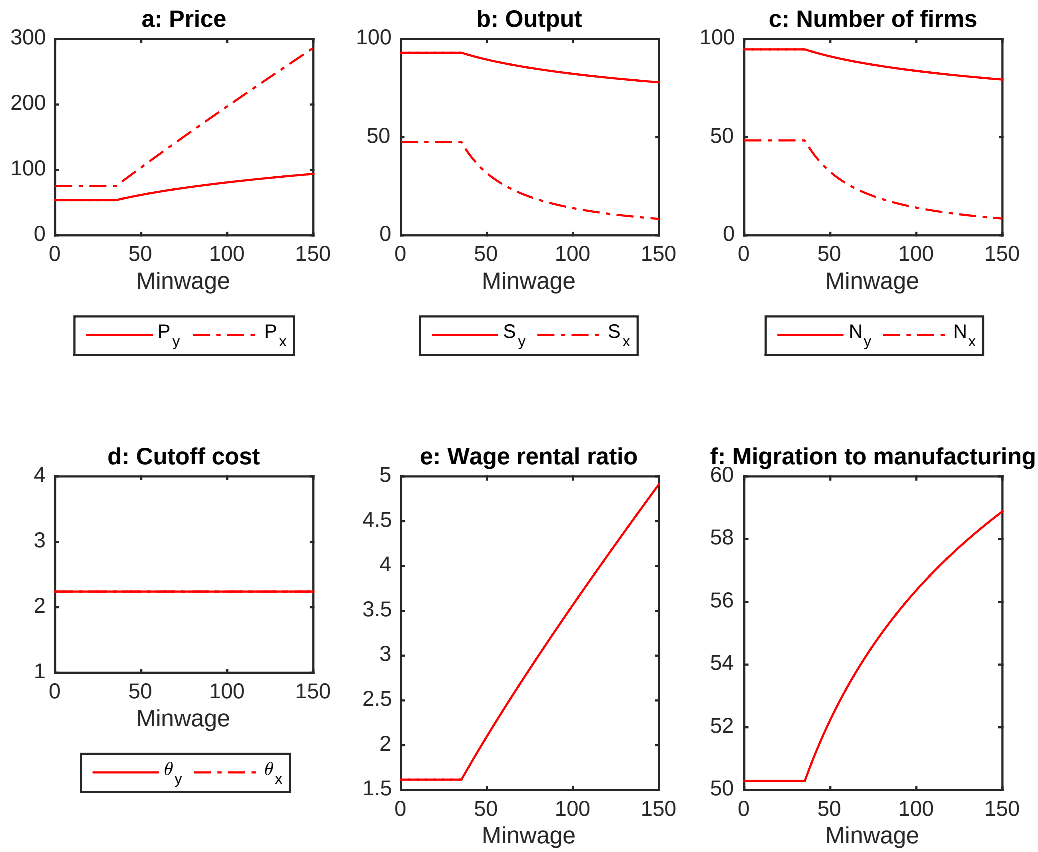
Table 14: Numerical Example: No Selection

Parameters	η_x	η_y	$\eta_{e,x}$	$\eta_{e,y}$	α	σ	b	L	K	a	α^*
Values	.8	.1	.8	.1	0.5	2	50	170	200	1	5

Figure 12 demonstrates the key comparative static effects of change in minimum wage, closely paralleling the predictions outlined in Section 4.1. The flat parts in all the figures occur for values of minimum wage for which minimum wage is not binding. Naturally, when the minimum wage is not binding, none of the comparative statics are influenced by change in minimum wage. For high values of minimum wage, it starts to bind. For this range of values, an increase in minimum wage raises the price of both goods but more so for the labor intensive x good as shown in panel (a), and reduces equilibrium production of both goods, but more so for the labor intensive good in panel (b). In this case, there is no selection effect as panel (d) shows and the change in the number of firms in panel (c) parallels the change in output in panel (b). Corresponding to this, panel (e) shows the rise in equilibrium wage rental ratio. Finally, panel (f) shows that for the parameters selected, there is an increase in migration with a rise in the minimum wage. This is not unexpected - substitutability between x and y is low enough for the derived demand for labor to be inelastic which ensures migration will increase with a higher minimum wage.

In the next numerical example, we consider the case of presence of some selection effect of change in minimum wage. Compared to Table 14, in order to allow for selection, we let $\eta_{e,x}$ to

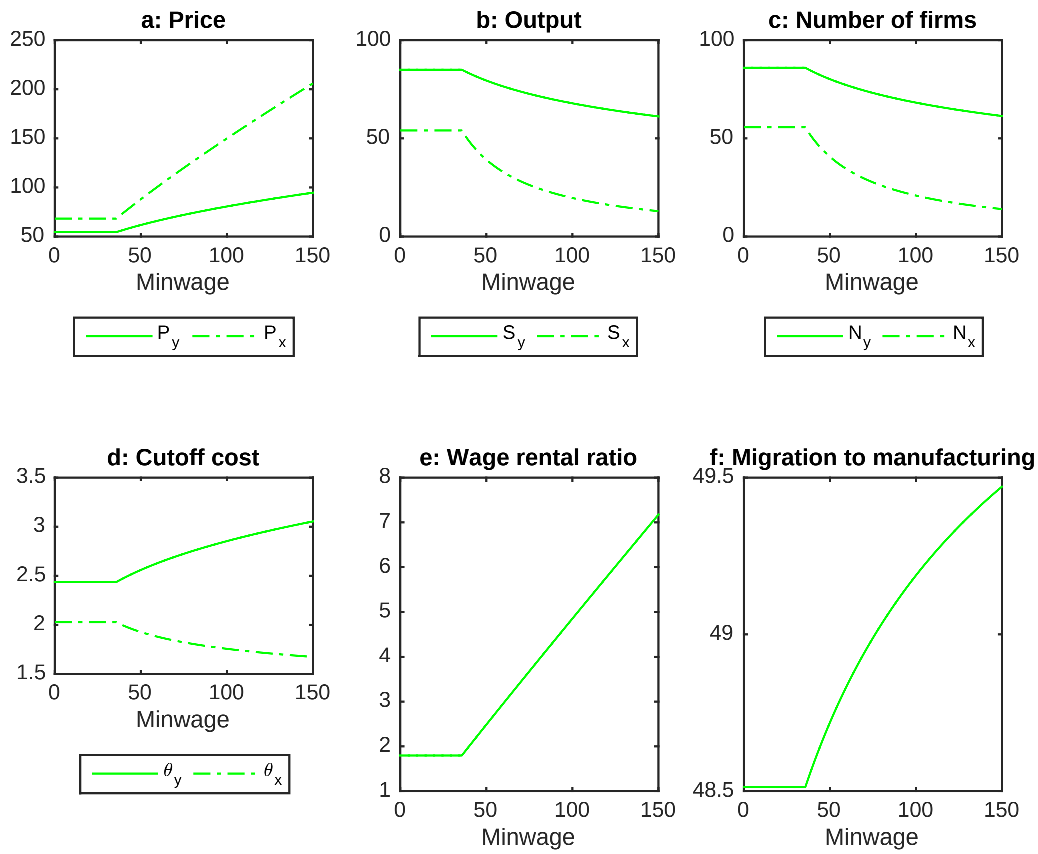
Figure 12: Comparative Statics of Minimum Wage without Selection



differ from η_x and also let $\eta_{e,y}$ to differ from η_y. In particular, in this example we set $\eta_{e,x}$ to .7 and $\eta_{e,y}$ to .2, and leave η_x and η_y at .8 and .1 respectively. This difference in skill intensities between entry cost and production in each sector reflects the possibility that entry in each sector requires some combination of both manufacturing goods. We leave the rest of the parameters unchanged from Table 14.

In this case, as documented in panel (d) of Figure 13, selection gets stricter in the labor intensive x sector and weaker in the capital intensive y sector with an increase in the minimum wage. As shown in Figure 13, all the key comparative static effects of minimum wage are unchanged in the neighborhood of the no selection case. Even where the selection effects are stronger as when entry cost in both sectors use factors in the same intensity ($\eta_{e,x} = \eta_{e,y} = .5$) while their skill intensities in production continue to be very different, all the comparative static results continue to hold. Results are available upon request.

Figure 13: Comparative Statics of Minimum Wage with Selection



8.3 First Stage Estimates

In Tables 15 to 21, we present the first stage regression results of the baseline and the first-difference IV regressions corresponding to Tables 2 to 5 and Tables 11 to 13. We do not have weak identification problems as the values for the Kleibergen-Paap rk Wald F statistics are above the critical levels.[48]

[48] We use the Kleibergen-Paap rk Wald F statistics as the standard errors are clustered.

Table 15: Minimum Wage and Exit from Export: IV Regression First Stage

	(1) ln (min. wage)	(2) ln (min. wage) × Industry-City (S/L)	(3) ln (min. wage) × Industry-City ln (K/L)
IV ln (min. wage)	0.236 ***	-0.098***	-3.081***
	(0.019)	(0.005)	(0.080)
IV ln (min. wage) × Industry-City (S/L)	-0.004**	1.005***	-0.017*
	(0.002)	(0.001)	(0.010)
IV ln (min. wage) × Industry-City ln (K/L)	0.000	0.000	1.010***
	(0.000)	(0.000)	(0.001)
low wage	-0.010***	-0.002***	-0.041***
	(0.001)	(0.000)	(0.005)
medium wage	-0.004***	-0.001***	-0.016***
	(0.001)	(0.000)	(0.005)
high wage	-0.002**	-0.000*	-0.009***
	(0.001)	(0.000)	(0.003)
city ln (GDP per capita)	-0.008	0.001	-0.001
	(0.013)	(0.002)	(0.051)
city ln (Population)	-0.097***	-0.016***	-0.374***
	(0.022)	(0.003)	(0.083)
Observations	914952	914952	914952

Note: Robust standard errors in parentheses, clustered at the sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 49.82.

Table 16: Minimum Wage and Firm Productivity: IV Regression First Stage

	(1) ln (min. wage)	(2) ln (min. wage) × Industry-City (S/L)	(3) ln (min. wage) × Industry-City ln (K/L)
IV ln (min wage)	0.236***	-0.099***	-3.092***
	(0.019)	(0.005)	(0.080)
IV ln (min wage)× Industry-City (S/L)	-0.004**	1.005***	-0.017*
	(0.002)	(0.001)	(0.010)
IV ln (min wage)× Industry-City ln (K/L)	0.000	0.000	1.010***
	(0.000)	(0.000)	(0.001)
low wage	-0.010***	-0.002***	-0.041***
	(0.001)	(0.000)	(0.005)
medium wage	-0.004***	-0.001***	-0.016***
	(0.001)	(0.000)	(0.005)
high wage	-0.002**	-0.000*	-0.009***
	(0.001)	(0.000)	(0.003)
city ln (GDP per capita)	-0.008	0.001	-0.003
	(0.013)	(0.002)	(0.052)
city ln (Population)	-0.096***	-0.016***	-0.371***
	(0.022)	(0.003)	(0.084)
Observations	900710	900710	900710

Note: Robust standard errors in parentheses, clustered at the sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 48.98.

Table 17: Minimum Wage and Factor Intensity: IV Regression First Stage

	(1) ln (min. wage)	(2) ln (min. wage) × Industry-City (S/L)	(3) ln (min. wage) × Industry-City ln (K/L)
IV ln (min. wage)	0.266***	-0.084***	-2.941***
	(0.021)	(0.003)	(0.087)
IV ln (min. wage)× Industry-City (S/L)	-0.001	1.004***	-0.000
	(0.002)	(0.001)	(0.011)
IV ln (min. wage)× Industry-City ln (K/L)	0.000	0.000**	1.009***
	(0.000)	(0.000)	(0.002)
low wage	-0.008***	-0.001***	-0.033***
	(0.001)	(0.000)	(0.005)
medium wage	-0.004***	-0.000***	-0.015***
	(0.001)	(0.000)	(0.005)
high wage	-0.003***	-0.000***	-0.011***
	(0.001)	(0.000)	(0.004)
city ln (GDP per capita)	-0.008	0.003*	0.010
	(0.014)	(0.002)	(0.057)
city ln (Population)	-0.076**	-0.004	-0.259**
	(0.032)	(0.003)	(0.118)
Observations	824817	824817	824817

Note: Robust standard errors in parentheses, clustered on sector-city pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 49.82.

Table 18: Minimum Wage and Firm Exports: IV Regression First Stage

	(1) ln (min. wage)	(2) ln (min. wage) × Industry-City (S/L)	(3) ln (min. wage) × Industry-City ln (K/L)
IV ln (min. wage)	0.192***	-0.077***	-2.567***
	(0.018)	(0.002)	(0.058)
IV ln (min. wage)× Industry-City (S/L)	-0.185***	0.793***	-0.847***
	(0.022)	(0.012)	(0.097)
IV ln (min. wage)× Industry-City ln (K/L)	-0.002	0.001	0.883***
	(0.003)	(0.001)	(0.012)
city ln (GDP per capita)	-0.040***	-0.006***	-0.135***
	(0.004)	(0.001)	(0.015)
city ln (Population)	-0.092***	-0.010***	-0.361***
	(0.009)	(0.001)	(0.035)
destination ln (GDP per capita)	-0.028***	-0.001	-0.078***
	(0.004)	(0.001)	(0.016)
Observations	3012586	3012586	3012586

Note: Robust standard errors in parentheses, clustered on city-product pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. All regressions include firm-product-destination fixed effects and year dummies. Weak identification test (Kleibergen-Paap rk Wald F statistic): 58.56. Controls for the wage bin or the interaction of wage bin with minimum wage are not added here as the wage information is not available in the customs data.

Table 19: Minimum Wage and Firm Productivity (First Difference): IV Regression First Stage

	(1) ln (min. wage)	(2) ln (min. wage) × Industry-City (S/L)	(3) ln (min. wage) × Industry-City ln (K/L)
5yr-lag ln (min. wage)	-0.065***	-0.011***	-0.382***
	(0.005)	(0.001)	(0.021)
5yr-lag ln (min. wage) × Industry-City (S/L)	0.002*	0.028***	0.002
	(0.001)	(0.001)	(0.006)
5yr-lag ln (min. wage)× Industry-City ln (K/L)	-0.000**	-0.000	0.029***
	(0.000)	(0.000)	(0.001)
Δ city ln (GDP per capita)	-0.045***	-0.003	-0.151***
	(0.012)	(0.002)	(0.053)
Δ city ln (Population)	0.095***	0.012**	0.407***
	(0.024)	(0.005)	(0.101)
Constant	0.498***	0.060***	1.993***
	(0.028)	(0.006)	(0.126)
Observations	488809	488809	488809

Note: Robust standard errors in parentheses, clustered on sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Weak identification test (Kleibergen-Paap rk Wald F statistic): 96.38.

Table 20: Minimum Wage and Factor Intensity (First Difference): IV Regression First Stage

	(1) ln (min. wage)	(2) ln (min. wage) × Industry-City (S/L)	(3) ln (min. wage) × Industry-City ln (K/L)
5yr-lag ln (min. wage)	-0.065***	-0.011***	-0.383***
	(0.005)	(0.001)	(0.021)
5yr-lag ln (min. wage) × Industry-City (S/L)	0.002*	0.029***	0.002
	(0.001)	(0.001)	(0.006)
5yr-lag ln (min. wage)× Industry-City ln(K/L)	-0.000**	-0.000	0.029***
	(0.000)	(0.000)	(0.001)
Δ city ln (GDP per capita)	-0.044***	-0.003	-0.150***
	(0.012)	(0.002)	(0.053)
Δ city ln (Population)	0.096***	0.011**	0.408***
	(0.024)	(0.005)	(0.101)
Observations	495170	495170	495170

Note: Robust standard errors in parentheses, clustered on sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Weak identification test (Kleibergen-Paap rk Wald F statistic): 97.97.

Table 21: Minimum Wage and Firm Exports (First Difference): IV Regression First Stage

	(1) ln (min. wage)	(2) ln (min. wage) $\times$ Industry-City (S/L)	(3) ln (min. wage) $\times$ Industry-City ln (K/L)
5yr-lag ln (min. wage)	-0.060***	-0.009***	-0.327***
	(0.003)	(0.000)	(0.012)
5yr-lag ln (min. wage) $\times$ Industry-City (S/L)	-0.003***	0.022***	-0.013***
	(0.001)	(0.000)	(0.004)
5yr-lag ln (min. wage)$\times$ Industry-City ln(K/L)	-0.001***	-0.000***	0.020***
	(0.000)	(0.000)	(0.001)
Δ city ln (GDP per capita)	0.053***	0.005***	0.204***
	(0.004)	(0.000)	(0.014)
Δ city ln (Population)	0.198***	0.022***	0.700***
	(0.008)	(0.001)	(0.028)
Δ destination ln (GDP per capita)	0.800***	0.086***	3.018***
	(0.009)	(0.001)	(0.033)
Constant	0.492***	0.055***	1.889***
	(0.020)	(0.002)	(0.070)
Observations	1207218	1207218	1207218

Note: Robust standard errors in parentheses, clustered on sector-city level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Weak identification test (Kleibergen-Paap rk Wald F statistic): 139.03.