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

Xue Bai
Brock University

Arpita Chatterjee
University of New South Wales

Kala Krishna
The Pennsylvania State University, CES-IFO, IGC and NBER

Hong Ma
Tsinghua University

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Abstract

This paper develops a new heterogeneous firm model under perfect competition in a Heckscher-Ohlin setting. It shows that a binding minimum wage raises product prices, encourages substitution away from labor, and creates unemployment. It reduces output and exports of the labor intensive good, despite the price increase and, less obviously, selection in the labor (capital) intensive sector becomes stricter (weaker). Exploiting rich regional variation in minimum wages across Chinese prefectures we find robust evidence in support of our theoretical predictions using Chinese Customs data matched with firm level production data.

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1 Introduction

Minimum wages are clearly highly relevant for policy and all their implications should be well understood, both in terms of theory and practice. Countries from Afghanistan to Zambia set a minimum wage. Australia is widely seen as having the highest minimum wage of about $\$9.54$ compared to $\$6.26$ in the U.S. in terms of 2013 U.S. prices.[1] 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.[2] 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.

Despite its clear policy relevance, the impact of minimum wage *on the economy as a whole* remains a largely open question. As discussed in more detail below, the extensive work in this area brings to mind the parable of the blind men and the elephant: each feels a different part of its body, and then describes the elephant in terms of his partial experience. As a result, they disagree fundamentally on the nature of the beast. In this paper we begin to address these lacunae.

Our contribution is twofold. First, we provide a 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 a number of intuitive and clean predictions about the effects of a minimum wage on selection, the structure of production and trade, factor intensity of production and survival patterns of heterogeneous firms. Second, we then use production and trade data from China, where different prefectures set and frequently change minimum wages, to test the predictions of the model.[3] We exploit the extremely rich regional variation and two plausible instruments to tease out the causal effect of minimum wages on a host of significant, yet hitherto unexplained, outcomes. We show that, as predicted by the model, a binding minimum wage raises product prices, encourages substitution away from labor, though less so for skill and capital intensive goods, and creates unemployment. Less obviously, it reduces output and exports, especially of the labor intensive good, despite the price increases. Least obvious is the prediction, also borne out in the data, that selection in the labor intensive sector becomes stricter, while that in the capital intensive sector becomes weaker. Thus, 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.

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

[1]See https://www.weforum.org/agenda/2016/04/where-are-the-world-s-highest-minimum-wages/

[2]"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." –Michael Reich and Jesse Rothstein, Econofact.org, April, 2017. For survey of the labor literature, see Neumark and Wascher (2008) who provide an in-depth, though slightly dated survey of the field, and Neumark, Salas and Wascher (2014).

[3]Note that in China the administrative division with the autonomy to set the minimum wage is the prefecture. We use the term city or location or prefecture interchangeably.

minimum wages in general equilibrium, to some work on the Chinese economy that documents the effects 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 wage on low-skill employment, in particular on fast food restaurants, with mixed results.[4] 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.[5] 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.[6] 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 for restaurants, Luca and Luca (2017) show that, as one might expect, higher minimum wage results in 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.[7]

In the context of the labor literature, our contribution is to provide a unifying 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

[4]See Neumark and Wascher (2008), Neumark et al. (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).

[5]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.

[6]In the District of Columbia, the hourly minimum wage will be \$12.50 (effective Jul.1, 2017) compared to a Federal one around \$8.00, and 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.

[7]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 (2015) 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 (2017) 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 (2016), and on the incidence of this increase in cost, for example Harasztosi, Lindner, Bank and Berkeley (2017).

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 costs, i.e., have 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 literature in International Trade, on the other hand, there are seminal papers such as Brecher (1974) and Davis (1998), that study the effects of a minimum wage in general equilibrium, though in a homogeneous firm model. 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.[8] 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 contribution here on the theoretical side is the addition of firm heterogeneity and the construction of a new model that allows us to lay out cleanly the array of predictions regarding the effects of minimum wages. Most novel are the predictions regarding firm selection and minimum wages. Moreover, despite the theoretical work in International Trade, there is very little empirical work on minimum wages and the structure of trade. 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.[9]

There is a recent 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. A recent paper, Huang, Loungani and Wang (2014), looks at the effects of minimum wages on firm employment exploiting the fact that cities in China set different minimum wages and these vary over time. They find that minimum wages do seem to reduce employment, particularly for low wage firms. Hau, Huang and Wang (2016) 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 Total Factor Productivity (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. In contrast to our paper, none of these papers have a general equilibrium model which can guide them in terms of the entire set of predictions to test and through which they can interpret the data.

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

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

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 relatively 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 modelling 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 the minimum wage operates 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.

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: by increasing competitive pressure, trade forces the exit of low productivity firms, the shrinkage of medium productivity firms and the expansion of high productivity firms since only low cost firms find exporting to be worthwhile as it involves fixed costs of accessing foreign markets. Bernard et al. (2007) extend the framework of Melitz (2003) to a simple Heckscher Ohlin setting. Among their new insights is 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.

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 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.

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.

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 lays out the key predictions of the model. This section 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 expalins our identification strategy. Section 6 looks for the predictions of the model in the data. Section 7 offers some directions for future work and concludes. Details of some proofs 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 goods are made up of the different varieties of x and y from the different prefectures.

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 prefecture has a capital endowment K^j and labor endowment L^j. These factors earn rental rate r and wage w. We will suppress j for simplicity till needed. Labor is of different productivity in its agricultural use but has the same productivity in manufactured goods. Firms can make one of two manufactured goods, x and y, in each prefecture. These goods differ in their factor intensities, and we assume that good x is labor intensive. Each location makes a homogeneous good, A, in its rural area. But different prefectures make different varieties of these manufactured goods. Within a city however, all manufacturing firms make the same variety of each manufactured good. Producers of manufactured goods do not know their costs ex-ante, but discover them ex-post, once they have paid their fixed entry costs. Each firm that chooses to enter can then produce a unit of the good at cost $c(w, r)\theta$ where $c(.)$ is the base unit cost and θ is the inverse of its realized productivity. We will first analyze what happens in a single location and then extend our model to many locations.

Good A has a price of unity. In agriculture, labor has differential productivity: type γ labor produces γ units of output as an effective unit of labor produces a unit of output. $g(.)$ is the distribution of labor productivity in agriculture. All workers are assumed to be equally productive in manufacturing so that workers with a high γ being are more productive in agriculture choose not to migrate from the rural to urban areas of a prefecture. 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 prefecture.

We assume that each prefecture produces its own variety of each of the two goods and all firms in a given prefecture 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 the different prefecture. Let p^{jx} and p^{jy} denote the *factory price* of the variety made in prefecture j. There is an integrated domestic market for each variety of each good so that each location 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 price of the variety manufactured in city j in city k. 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 location: well connected locations will tend to have lower aggregate prices than locations that are remote.

Demand for a typical variety comes from all the cities. The demand for variety $j \in J$ made by location j of good x for example comes from all cities $k = 1...J$

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

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 prefecture k which take the usual form:

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

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

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

Each firm in a prefecture is competitive and takes the price for the prefecture's variety as given. However, firms are ex-post heterogeneous. There is a distribution of efficiency, denoted by $f(\theta)$, which domestic firms in the heterogeneous firm sector draw from after paying an entry cost $f_e c^e(w, r)$. There are no financing frictions or credit constraints. A firm with draw θ has cost $\theta c(w, r)$ and can produce one unit of the good only. A higher θ denotes lower productivity or higher costs.

Take a representative location (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 $\theta \leq \tilde{\theta}(.) = \frac{p}{c(w,r)}$ will choose to produce the good. This defines the marginal firm as having $\theta = \tilde{\theta}(.)$. Supply of the location'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. Evidently, selection depends on the specification of entry costs.

Lemma 1 *(i) If entry costs use factors in the same proportion as the good being made, 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 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 $\theta c(.)$ makes 1 unit of output by hiring $a_L(w,r)\theta$ units of labor and $a_k(w,r)\theta$ 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.[10] Thus,

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

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

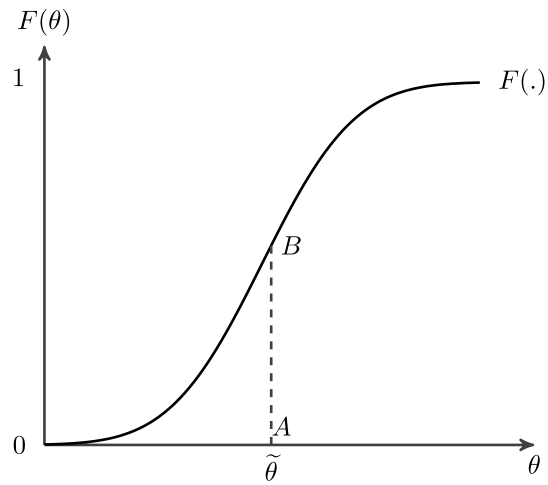

Figure 1. Cutoff Productivity

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 $c(.)$ 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 $c(.)$ rises so selection becomes stricter in both sectors.

It is worth noting that the free entry condition in equation (2) can be intuitively interpreted. With θ on the y axis and supply (of a unit mass of firms) at this θ on the x axis, expected profits are the area of the "quasi rent" OAB in Figure 1. Free entry requires that this area equals $\frac{c^e(w,r)}{c(w,r)} f_e$ which 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 type result goes through. The second twist is that both the price of x and y are endogenously determined, not just their ratio, so that we need to solve for the price of one good given the price of the other and then we solve for the equilibrium prices. 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 reduces the labor supply available to industry which raises y (the capital intensive good) and further reduces x a la Rybczynski. In other words, 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 wages raise the real cost of entry in the labor intensive sector and reduce it in the capital intensive sector. This in turn means that output and exports of the capital intensive sector expand and those of the labor intensive sector contract, along with selection becoming weaker in the former and stricter in the latter. We 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. In the Appendix we show using simulated examples that even when selection effects are relatively prominent, the key comparative 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 location. Note that as each location makes a different variety of the two manufactured goods, the equilibrium price of these goods can differ across locations: 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 locations. Trade is implicit in the model. The difference in demand from domestic locations and supply from a domestic location 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

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

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

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

$\left(\tilde{\theta}^x(w,r), \tilde{\theta}^y(w,r)\right)$.

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

$$\begin{aligned} p^x &= \tilde{\theta}^x(w,r)c^x(w,r) && (5)\\ p^y &= \tilde{\theta}^y(w,r)c^y(w,r) && (6)\\ 1 &= w^e. && (7) \end{aligned}$$

w^e 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 analogous to that in the simple Heckscher Ohlin setting.[11]

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 $p^{x'}$ keeping the selection cutoff fixed. As a result, w rises and r falls. This in turn reduces $\tilde{\theta}^x$ to $\tilde{\theta}^{x'}$ and raises $\tilde{\theta}^y$ to $\tilde{\theta}^{y\prime}$ which shifts the curve for x further out and for y in as shown in Figure 2. The selection effects further increase $\frac{p^x}{\tilde{\theta}^x}$ and reduce $\frac{p^y}{\tilde{\theta}^y}$. Note, both direct and indirect effects 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 ($\frac{c^{ey}(w,r)}{c^y(.)}$) in the capital intensive good, making selection tighter there, and as it raises the real cost of entry ($\frac{c^{ex}(w,r)}{c^x(.)}$) in the labor intensive good, making selection looser there. A more formal proof is in the Appendix.[12]

3.1.1 Migration and Income

Let $G(.)$ 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

[11] 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.

[12] An alternative way of understanding what is going on is to note that an increase in the price of the labor intensive good reduces the "real cost" of entry ($\frac{c^e(w,r)}{c^x(.)}$) in this sector which makes selection tighter in the labor intensive good while raising the real cost of entry in the capital intensive good thereby making selection looser there.

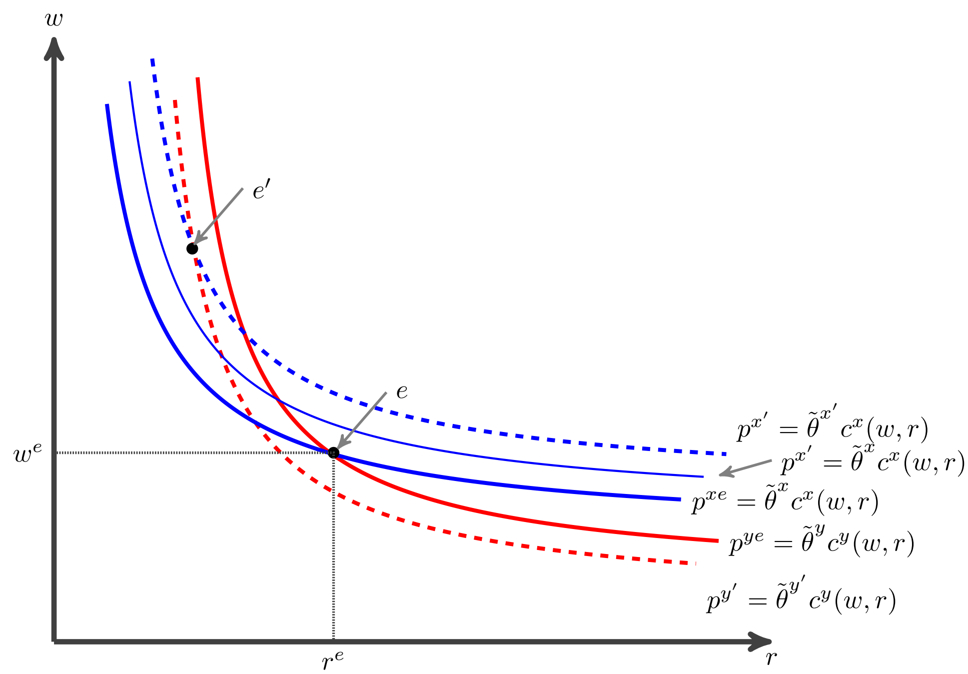

Figure 2. Product Prices and Factor Prices

which is used only in manufacturing.[13] 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:

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

where

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

is the number of effective units of labor in agriculture (with a unit mass of labor ($L = 1$)) 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

[13]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 location.

prefecture to its urban area for simplicity.[14]

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

In other words, the change in the labor income is just the change in wage times the number of 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 and a mass N of them are in the market. Hence, factor market clearing (FMC) gives:

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

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

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

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

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

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

[14]If we wanted to match migration patterns to the data, we could make locations differ in more than just wages. Adding utility that varied by source and destination of the agent as well as utility shocks for each location to migrant's preferences would allow migration to come from all locations. Making the usual parametric assumptions on shocks and matching patterns of migration in the data to those in the model would then allow preferences to be backed out.

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,* $\frac{A_{Lx}(.)}{A_{Kx}(.)} = \frac{a_{Lx}(.)}{a_{Kx}(.)} > \frac{A_{Ly}(.)}{A_{Ky}(.)} = \frac{a_{Ly}(.)}{a_{Ky}(.)}$.

Proof:

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

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 $\frac{c^{ex}(w,r)f_e}{c^x(w,r)} = f_e = \frac{f_e c^{ex}_w(.)}{c^x_w(.)}$ so that $A_{Lx} = c^x_w(.)\tilde{\theta}^x F(\tilde{\theta}^x)$ and as a result, $\frac{A_{Lx}(.)}{A_{Kx}(.)} = \frac{a_{Lx}(.)}{a_{Kx}(.)}$. 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 this pins down the $A_{ij}(.)$ 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 $\frac{A_{Lx}(.)}{A_{Ly}(.)} > \frac{A_{Kx}(.)}{A_{Ky}(.)}$, that is, $\frac{A_{Lx}(.)}{A_{Kx}(.)} > \frac{A_{Ly}(.)}{A_{Ky}(.)}$. With no selection effects, this is ensured by Lemma 3 since $\frac{a_{Lx}(.)}{a_{Kx}(.)} > \frac{a_{Ly}(.)}{a_{Ky}(.)}$ 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.

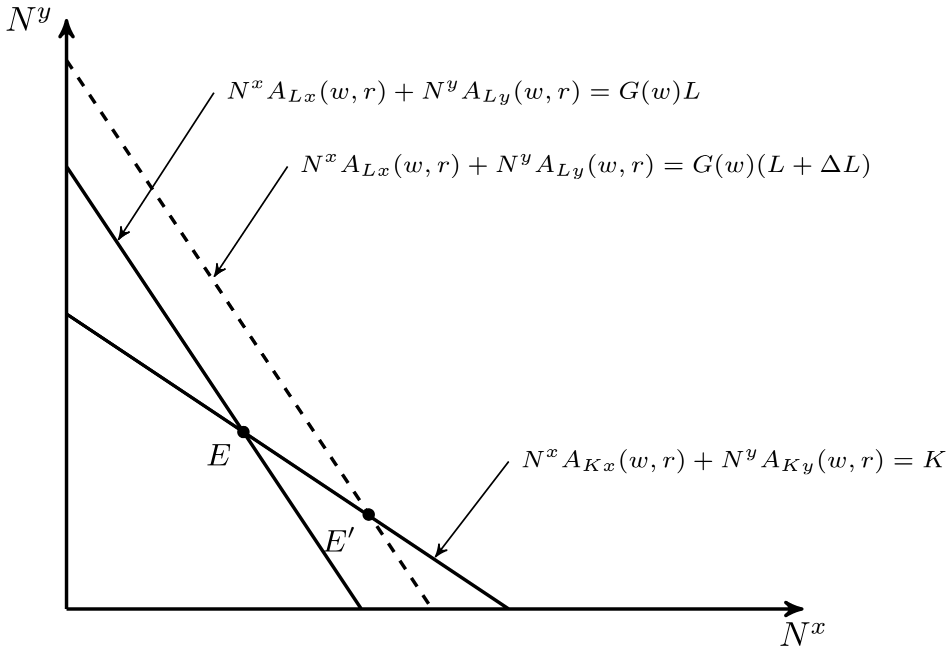

Figure 3. Entry and Endowments

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.

Even with selection effects, the same argument works as long as $\frac{A_{Lx}(.)}{A_{Kx}(.)} > \frac{A_{Ly}(.)}{A_{Ky}(.)}$. 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 $A_{ij}(.)$'s move exactly as the $a_{ij}(.)$'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, 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 $\bar{\theta}^x(\tilde{\theta}^x(w,r))$. For example, an increase in the price of x raises $c_w^x(w,r)$ and $c_w^e(w,r)$ but reduces $\bar{\theta}^x(\tilde{\theta}^x(w,r))$ as selection becomes stricter when the price of the good rises. As selection effects are constrained, so is the change in $\bar{\theta}^x(\tilde{\theta}^x(w,r))$ induced by them. Once again, by continuity, we can ensure that the $A_{ij}(.)$'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, it is easy to see that without selection effects these are 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. Since each firm makes one unit of output, supply is just $N(.)F(\tilde{\theta})$. 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. QED.

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

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

$$N^y(\overset{-}{p^x}, \overset{+}{p^y}; \overset{-}{L}, \overset{+}{K})F^y(\overset{-}{\tilde{\theta}^y(p^y)}) = D_j^y(p^y; P^X, P^Y, P, I). \quad (15)$$

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

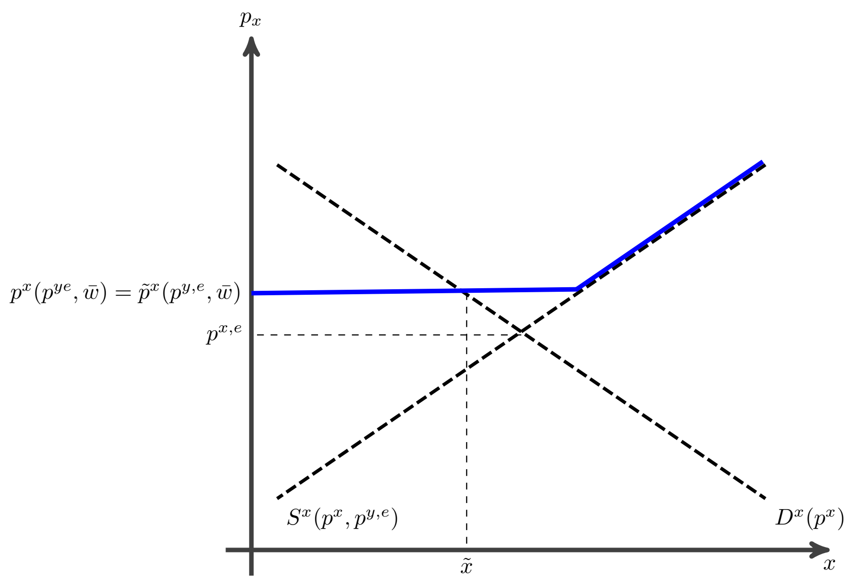

Figure 4. Supply, Demand and Minimum Wages in Good X

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) 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 in y for a given price in 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 y and the equilibrium price in 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, $p^x(p^y; L, K)$ is 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. First, in equilibrium, trade will make selection stricter in the comparative advantage sector as its price rises and weaker in the comparative disadvantage sector whose price falls. 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 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.

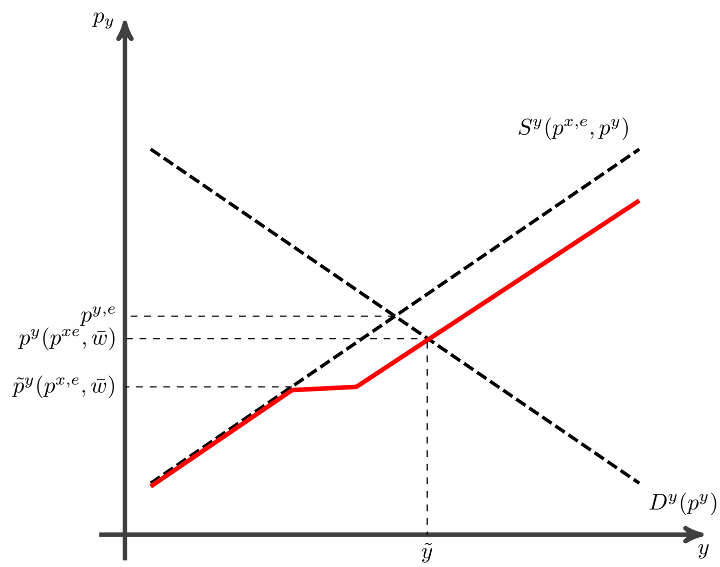

Figure 5. Supply, Demand and Minimum Wages in Good Y

4 Minimum Wages and Outcomes

How would a minimum wage affect equilibrium? Recall that there are three goods, A, x and y in each location 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 that price equals cost for each good. Consider a particular prefecture. Equilibrium will be given by the system of equations.

$$p^x = \tilde{\theta}^x(\bar{w}, r)c^x(\bar{w}, r) \tag{16}$$
$$p^y = \tilde{\theta}^y(\bar{w}, r)c^y(\bar{w}, r) \tag{17}$$
$$1 = w^e = p^A \tag{18}$$

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 prefecture 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.[15]

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 while capital markets clear so that:

$$
\begin{aligned}
N^x A_{Lx}(\bar{w}, r) + N^y A_{Ly}(\bar{w}, r) &= L^D \leq G(\hat{w}(\bar{w}))L = L^s && (21)\\
N^x A_{Kx}(\bar{w}, r) + N^y A_{Ky}(\bar{w}, r) &= K && (22)
\end{aligned}
$$

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

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

and

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

Goods market clearing will give product prices:

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

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

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. As $p^{x,e} = \tilde{\theta}^x c^x(w, r)$ and $p^{y,e} = \tilde{\theta}^y c^y(w, r)$ and 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

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

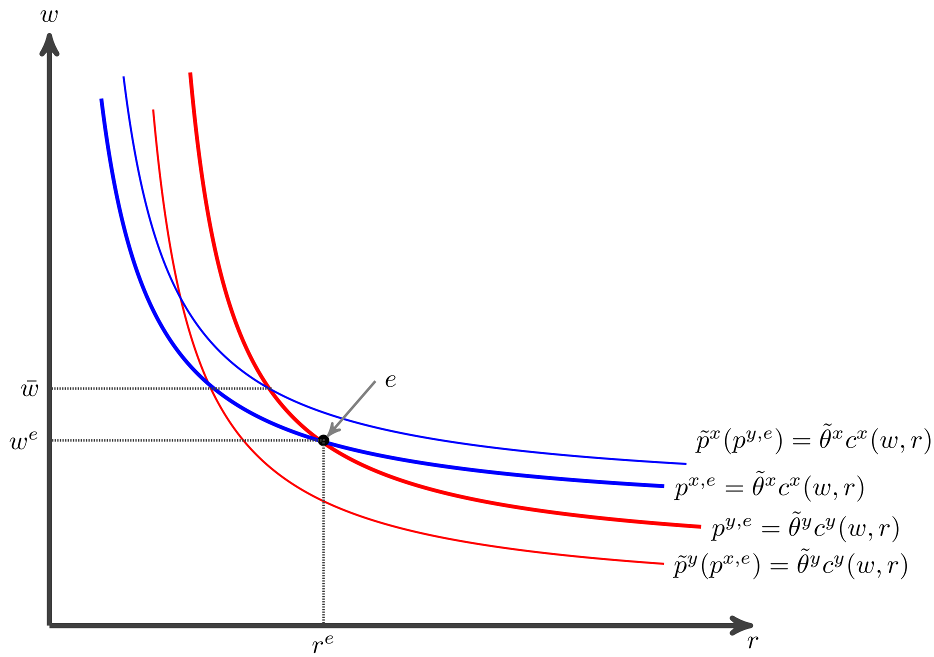

Figure 6. Product Prices and Factor Prices with a Minimum Wage

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 $\tilde{p}^y(p^{x,e}, \bar{w})$, 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 the curves $\tilde{p}^x(p^y, \bar{w})$ and $\tilde{p}^y(p^x, \bar{w})$ represent the same set of points and are 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 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,

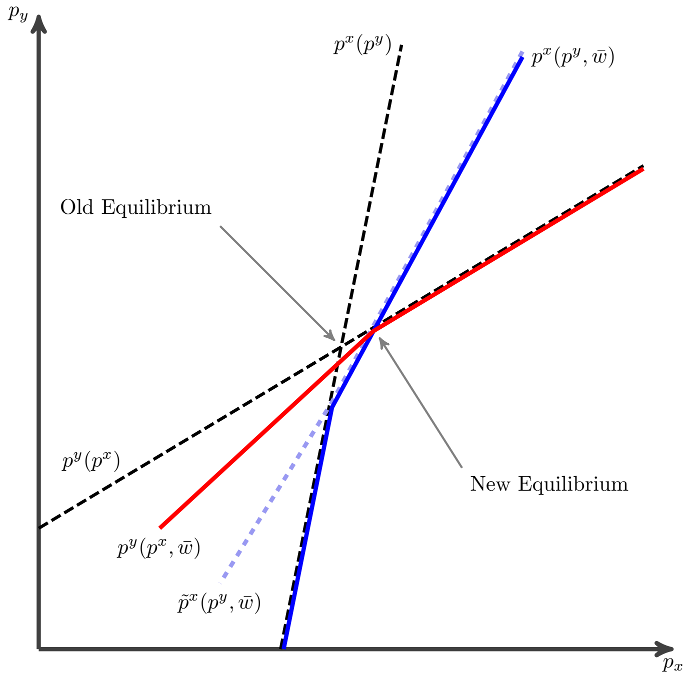

Figure 7. Equilibrium Prices with and without a Minimum Wage

price must also rise by more.

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 *For a given price of the capital intensive good, 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 price of the labor intensive good by more than that of the capital intensive one. This will raise the wage-rental ratio and raise the capital intensity in both sectors.*

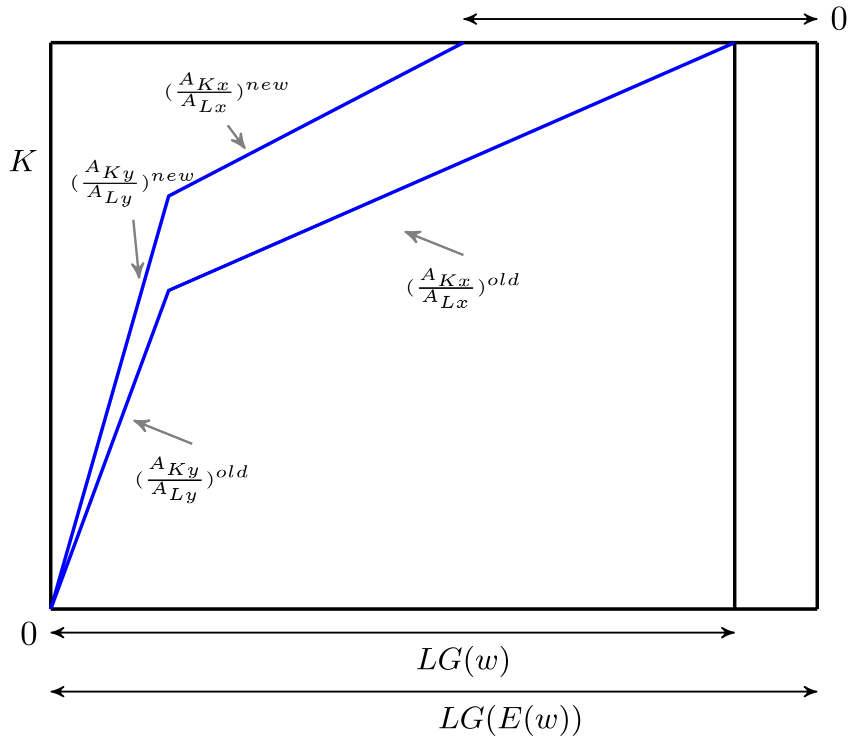

Figure 8. Factor Market Equilibrium with Minimum Wages

A higher minimum wage will thus tend 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.

In general, an increase in the minimum wage could raise or lower migration. 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 γ. If the right hand side, which is the value of demand for labor, rises (falls) with the minimum wage, then $\tilde{\gamma}$ will rise (fall) with an increase in the minimum wage 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 (2015) provides 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.*

4.1 Predictions of the Model

In this section we summarize the predictions regarding an increase in minimum wage for production, exports, prices, factor intensity of production and selection at the industry level on the basis on the model described above, before turning to the next big question of how we can extend the model to make predictions at the firm level. These are the predictions of the model that we take to the data in the empirical section of the paper.

4.1.1 Predictions at the Industry - City Level

Prediction 1: The output of the labor intensive good should fall and its price should rise with a binding minimum wage. The effects should be more pronounced for more labor intensive sectors.

This follows from Propositions 1. Recall that as each location makes its own varieties, and as each variety is essential, the price of each variety is pinned down at $\tilde{p}^x$, the flat part of supply in Figure 4. 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, i.e., $\tilde{p}^x$ would be higher in Figure 4, and demand would be lower. As a result, 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.

A closely related prediction is about exports. 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.

Prediction 2: The exports should fall and their price rise with a binding minimum wage. The effects should be more pronounced for more labor intensive sectors.

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.[16] 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

Prediction 3: A higher minimum wage should raise capital intensity and encourage the use of capital while discouraging the use of labor. We would expect the increase in capital intensity to be

[16]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 nunances to Prediction 3. We discuss this in more detail in the empirical section.

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

Higher prices have selection effects on the cutoff in both x and y. A higher price of x makes selection stronger in x (while a higher price of y makes it weaker) as shown by Lemma 1 and Lemma 2 together. As the price of x is likely to rise by more than that of y, selection in x is likely to become stricter while that in y would become weaker. The more labor intensive the sector (or the higher or more binding 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 as well and the tighter becomes selection and the higher is average productivity. Our prediction regarding selection effects of minimum wage is below.

Prediction 4: Locations with high minimum wages should have a distribution of productivity that has a higher mean than that of low minimum wage locations, and this should be more pronounced in more labor intensive sectors.

Given the effects on output and selection, what can we say about the extensive margin of firms and a binding minimum wage? A higher minimum wage raises cost and price, but reduces output, while making selection stricter, especially in labor intensive sectors. Thus, we expect exit to rise in labor intensive sectors, and more so in more labor intensive sectors. In the capital intensive sector, existing firms are less likely to exit as selection becomes weaker. As entry falls, we will see less churning in this sector.

Prediction 5: Exit of existing firms should rise in labor intensive sectors with a binding minimum wage, and more so in more labor intensive sectors, other things constant.

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.

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).

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.[17] Firms with no draws

[17] 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, 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 worst θ draws

have no supply at any price.[18]

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. [19]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 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 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. Moreover, firms whose best draw of cost at the new factor prices exceeds the new price will exit. Thus, exit should rise in the wake of a minimum wage in x so that the average productivity of remaining firms will rise. Furthermore, this will be more so for more labor intensive sectors. The model does not provide any predictions into 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.[20]

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-

put their costs below the domestic price but above the transport cost adjusted price will not export. This will give riose to another feature often pointed out in the data - larger more productive firms tend to export.

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

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

[20]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.

compliance penalty[21] and requiring more frequent minimum-wage adjustments — at least once every two years (Hau et al., 2016; Mayneris, Poncet and Zhang, 2016).

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.[22] 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 administration 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 (or county) 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 wage across prefectural regions across 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 wage 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 (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 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 dollars), while the lowest was set in Heyuan at 290 Yuan (35 dollars).

Figure 10 illustrates the evolution of monthly minimum wages between 2000 and 2010. As shown in the figure, the median minimum wage keeps rising 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).[23] There is also an obvious acceleration of minimum wage growth after 2004.

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

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

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

[23] 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 inter-quarter range, and 25 percentile − 1.5 inter-quarter range), the dots are deemed as outliners.

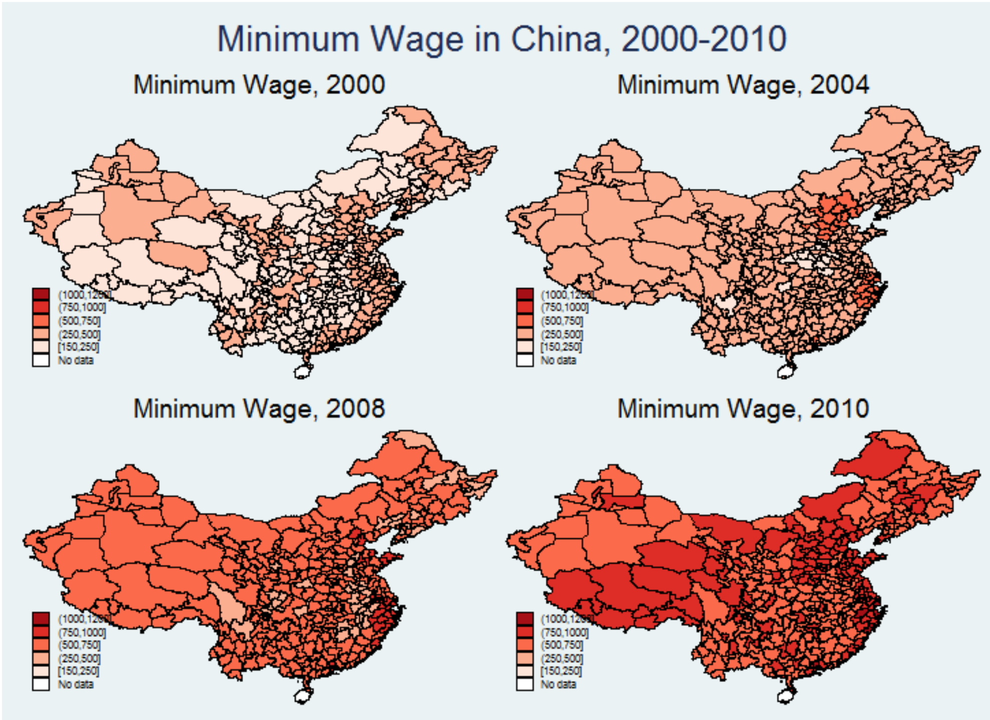

Figure 9. Geography of Minimum Wages, 2000-2010

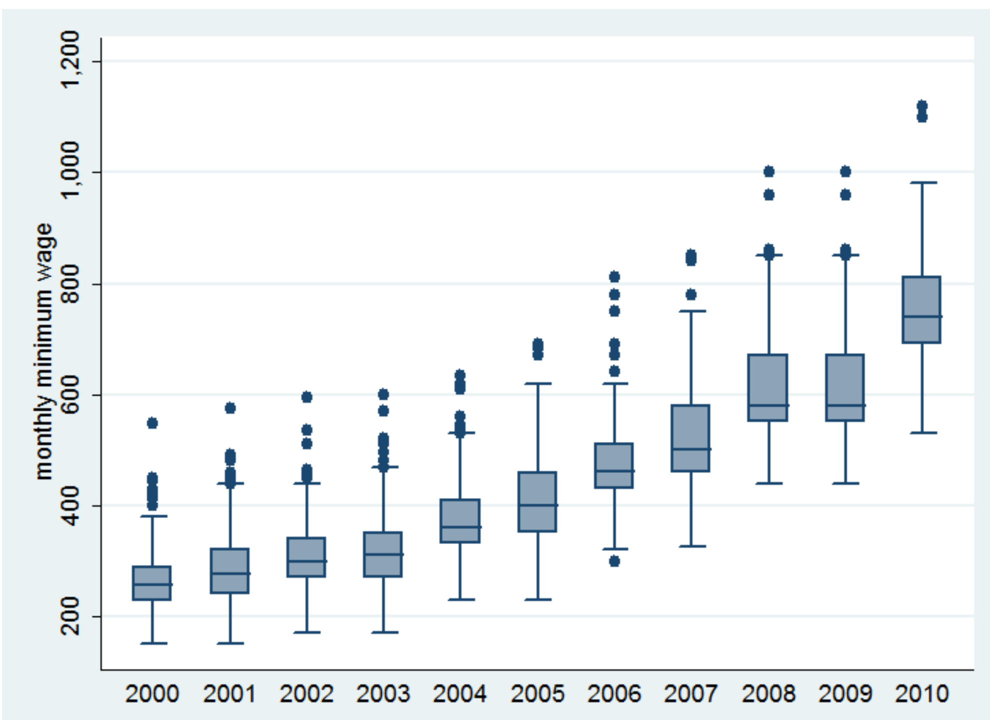

Figure 10. Evolution of Minimum Wages, 2000-2010

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 code and name. With value and quantity, we could conveniently 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 export values. With additional information on output and input deflators (Brandt, Van Biesebroeck and Zhang, 2012), we estimate the total factor productivity (TFP) for each firm using the Levinsohn & Petrin approach (Levinsohn and Petrin (2003)). For the year 2004 only, we have additional information on the number of the skilled and unskilled labor [24] employed by each firm. For this reason, we will on occasion reduce our sample to include only firms that were operating in 2004 as well as other periods (for example Table 2).

The advantage of the survey data is we can get information on wages paid as well as estimated TFP. The disadvantages are that it lacks complete coverage and it has no information on destination of export or unit values or quantities. The disadvantage of the customs data is that unless matched with the survey data, many firm level variables are not available. On the other hand, it is a census so there is no lack of coverage. Moreover, product level information is very detailed since it includes the export destination (or import source) country for each 8-digit HS product exported or imported by a firm, as well as the firms' location information. In addition, both quantity and value are reported. To facilitate a thorough analysis, we also match the two datasets on the basis of firm name, region code, address, and so on.[25] The matched sample, though with fewer observations, enables us to look at the effect of minimum wage on firms with different TFP, and also whether minimum wage changes firms' decision on importing inputs.

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 (in value or quantity) the correlation between higher exports and higher minimum wages for example 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, especially when we look at the relationship between the average productivity of firms in a city and the minimum wage (prediction 4) since in this case, our regressions are at the industry-city level instead of the firm

[24] Here we define skilled workers as workers who have obtained college education or above.

[25] It is worth noting that about 15.3% of exports are unmatched among producing exporters. For example, in 2004, intermediary firms accounted for 25.6% of the universe of the export values and matched producers (producing exporters) accounted for 62.9%. Among the unmatched and unsurveyed firms' share, small manufacturing firms (with sales below 5 million Chinese Yuan) account for only 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.

level.[26]

To correct for endogeneity bias, we adopt an instrumental variable strategy. The minimum wages are set at the prefecture level as discussed in previous sections. 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.

As an alternative option, we also consider the initial minimum wage as an instrument for future changes in minimum wage, since synchronization of across-prefecture 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. Because this instrument is not time varying, using it would require changing our baseline empirical specification to a first-difference setup.[27] In the robustness checks section, we compare our IV results here to those using the initial minimum wage as the instrument.

6 Empirical Results

We proceed by presenting all key empirical predictions using both OLS regressions and the IV estimates. [28]

6.1 Minimum Wage and Exports

Predictions 1and 2 state that the output and exports of labor intensive goods should fall and their prices should rise with a 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 start by investigating the impact of minimum wage on exports where we can calculate unit value since we have both export value and quantity. We use 2002-2008 Custom data. 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. We stop in 2008 to avoid the disturbance of the 2008-2009 global financial crisis, which had a huge negative impact on exports. More specifically, we use export information at the firm (i) - product (h) - prefecture/city (c) - destination (d) - time (t) level. The 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.

[26] 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 bias becomes ambiguous as the direction of the bias depends on the entire set of correlations in the explanatory variables and the error term

[27] 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.

[28] Please see the appendix for the first stage estimates.

The baseline regression is specified as follows.

$$\begin{aligned} ln(V_{ihcdt}) \quad = \quad & \alpha_1 \cdot ln(mw)_{ct} + \beta_1 \cdot ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_1 \cdot ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ & + \mu_1 X_{ct} + \gamma_1 Y_{dt} + \lambda_{ihd} + \lambda_t + \varepsilon_{ihdt}, \end{aligned} \tag{27}$$

where the dependent variable V_{ihcdt} refers to export value, price or quantity for firm i in city c, HS6 product h, destination d and time t. $ln(mw)_{ct}$ measures the log value of minimum wages in prefectural city c in year t. To examine the differential impact of minimum wages on firms across different industries, we include an interaction term between minimum wage and an industry-city measure of skill intensity $(S/L)_{hc}$ and capital intensity $ln(K/L)_{hc}$. The industry dimension is categorized at the 4-digit Chinese Industrial Classification (CIC) level , which is drawn from the 2004 ASIP data.[29] We also control for other concurrent economic factors at city-year level X_{ct}, in particular GDP *per capita* for income level, and population for city size. On the other hand, 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. Finally a year dummy is used to control for any macro shocks. All regressions are at exporter-hs6-destination-year level, using 2002-2008 Custom data, with standard error clustered on city-product pair.

Table 1: Minimum Wage and Firm Export

VARIABLES	(1) ln(export value)	(2) ln(unit value)	(3) ln(export quantity)	(4) ln(export value)	(5) ln(unit value)	(6) ln(export quantity)
ln(min wage)	-0.494***	0.178***	-0.672***	-0.565***	0.199**	-0.764***
	[0.0565]	[0.0338]	[0.0600]	[0.146]	[0.0880]	[0.151]
ln(min wage)× Industry-City (S/L)	1.157***	-0.265***	1.422***	1.323***	-0.306***	1.629***
	[0.120]	[0.0750]	[0.129]	[0.108]	[0.0672]	[0.115]
ln(min wage)× Industry-City ln(K/L)	0.122***	-0.0366***	0.159***	0.139***	-0.0384***	0.178***
	[0.0151]	[0.0101]	[0.0160]	[0.0139]	[0.00928]	[0.0148]
city ln(GDP/population)	0.0462***	-0.0259**	0.0721***	0.0438***	-0.0251***	0.0689***
	[0.0157]	[0.0115]	[0.0160]	[0.0133]	[0.00905]	[0.0134]
city ln(population)	0.00512	0.0495	-0.0444	0.00560	0.0517	-0.0461
	[0.0407]	[0.0511]	[0.0617]	[0.0379]	[0.0411]	[0.0529]
destination ln(GDP/population)	0.0643*	0.0104	0.0540	0.0581*	0.0121	0.0460
	[0.0361]	[0.0175]	[0.0396]	[0.0307]	[0.0149]	[0.0335]
Observations	12,885,836	12,885,836	12,885,836	12,881,448	12,881,448	12,881,448
R-squared	0.793	0.949	0.847	0.016	0.048	0.002

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.

Table 1 reports the baseline results using (log of) export *value*, export *price* and export *quantity*, as the dependent variable. The OLS results are reported in the first three columns and the results from IV regressions are reported in columns (4)-(6). All first stage regressions are reported in the Appendix in Section 8.3**.** Columns (1) and (4) show that increasing minimum wages discourages exports, but less so for more skill or capital intensive sectors. This result is consistent with our

[29] 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. Specially, we use the share of workers with college or above education out of total firm employment in 2004 as S/L, and the log value of net fixed asset over firm employment in 2004 as $ln(K/L)$.

theoretical framework as the higher price needed to elicit supply due to the minimum wage reduces demand, as well as the finding by Gan et al. (2016). A similar conclusion can be drawn when using capital intensity to measure industry heterogeneity. More capital intensive sectors are less discouraged by rising minimum wage. Columns (2) and (5) in Table 1 shows that export *prices* rise with increase in minimum wage, but less so for capital or skill-intensive industries. Columns (3) and (6) consider the impact of a rise in minimum wage on export *quantities*, with similar results. Again, a higher minimum wage reduces quantity exported and less so for skill or capital intensive industries. Note also that the levels of the coefficients of interest with and without the IV are not too different. This is the case in all the regressions below as well.

6.2 Minimum Wage and Inputs

As mentioned earlier, the main focus of the labor literature 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 firms exiting due to the increase in minimum wage, and the intensive one that comes from each firm using less labor and more capital as the minimum wage rises. In the following exercise we test the intensive margin of labor demand. The regression equation is specified as follows.

$$\begin{aligned} ln(E_{it}) =& \alpha_1 \cdot ln(mw)_{ct} + \beta_1 \cdot ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_1 \cdot ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ &+ \mu_1 X_{ct} + \lambda_i + \lambda_t + \varepsilon_{it}, \end{aligned} \tag{28}$$

where the dependent variable E_{it} refers to capital intensity, labor, capital or labor cost share for firm i and time t. $ln(mw)_{ct}$ measures the log of minimum wages in prefectural city c in year t. To examine the differential impact of minimum wages on firms across different industries, we include an interaction term between minimum wage and an industry-city measure of skill intensity $(S/L)_{hc}$ and capital intensity $ln(K/L)_{hc}$, at the 4-digit CIC level.

Table 2: Minimum Wage and Factor Intensity:

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	ln(K/L)	ln(L)	ln(K)	Labor cost share	ln(K/L)	ln(L)	ln(K)	Labor cost share
ln(min wage)	0.823***	-0.119***	0.704***	-0.0236***	1.370***	-0.0281	1.342***	-0.0453***
	[0.0586]	[0.0451]	[0.0628]	[0.00172]	[0.158]	[0.114]	[0.144]	[0.00542]
ln(min wage) × Industry-City (S/L)	0.193**	0.123**	0.316***	-0.00970***	0.176*	0.181***	0.358***	-0.0109***
	[0.0941]	[0.0626]	[0.0942]	[0.00306]	[0.0912]	[0.0598]	[0.0940]	[0.00297]
ln(min wage) × Industry-City ln(K/L)	-0.198***	0.0419***	-0.156***	0.00546***	-0.205***	0.0423***	-0.162***	0.00616***
	[0.0135]	[0.0111]	[0.0142]	[0.000419]	[0.0135]	[0.0107]	[0.0142]	[0.000419]
city ln(GDP/population)	0.295***	-0.0770***	0.218***	-0.00560***	0.285***	-0.0791***	0.206***	-0.00522***
	[0.0187]	[0.0157]	[0.0208]	[0.000699]	[0.0181]	[0.0136]	[0.0207]	[0.000557]
city ln(population)	-0.247***	0.0469	-0.200***	0.000260	-0.192***	0.0545	-0.137**	-0.00177
	[0.0566]	[0.0401]	[0.0591]	[0.00108]	[0.0558]	[0.0361]	[0.0601]	[0.00129]
Observations	810,177	810,177	810,177	760,269	784,870	784,870	784,870	735,816
R-squared	0.841	0.921	0.910	0.724	0.048	0.017	0.084	0.059

Note: Robust standard errors in parentheses, clustered on industry-city pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions include firm fixed effects and year dummies.

In Table 2 we test whether firms respond to a rise in minimum wage by substituting away from low skilled labor by adjusting factor intensity. We use the ASIP survey data for the sample period 2002-2007 for this analysis. Labor cost share is at fixed wages. Here columns (1)-(4) report the

OLS results, and columns (5)-(8) the corresponding IV results. Again, first stage results are in the Appendix.

Column (2) and (6) show that labor falls as the minimum rises, but less so in skill and capital intensive sectors where the minimum wage is less relevant. In column (3) and (7), capital rise with the minimum wage, less so in the capital intensive sector as the minimum wage is less relevant there, but more so in the skill intensive sector, possibly because skilled labor also rises and due to capital and skilled labor complementarity.

Column (1) and (5) show that the firm-level capital intensity rises with the minimum wage and less so for capital intensive sectors (as the minimum wage is less relevant) but more so for skill intensive sectors, again possibly due to capital skilled labor complementarity. Column (4) and (8) show labor cost share (at fixed wages) falls with the rise in minimum wage, and this is less pronounced in the more capital-intensive sectors where the minimum wage is less relevant and more pronounced in skill intensive ones, again possibly due to capital skill complementarity. The same results are validated using the instrument for minimum wage.

6.3 Minimum Wage, Average Productivity and Firm Exit

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. Thus, average productivity of surviving firms in a more labor intensive sector is higher with higher minimum wage, after controlling for other city and industry specific factors. Related to this, we expect to see more exit from exporting or from producing with a higher minimum wage, and more so in labor intensive sectors. 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 estimate firm-level TFP following the method proposed in Levinsohn and Petrin (2003). We followBai et al. (2017) to construct the variables.

The benchmark regression for testing selection is specified as follows:

$$\begin{aligned} TFP_{hct} =& \alpha_1 \cdot ln(mw_{ct}) + \beta_1 \cdot ln(mw)_{ct} \cdot (Bindingness)_{hc} + \mu_1 X_{ct} \\ &+ \lambda_{hc} + \lambda_t + \varepsilon_{cht}, \end{aligned} \tag{29}$$

The dependent variable is the mean productivity of each 4-digit industry in each city. Independent variables of interest are the minimum wage and its interaction with a measure of how binding the minimum wage is in a city- industry, $(Bindingness)_{hc}$. The two options we use for this are industry-city measures of skill intensity $(S/L)_{hc}$ and capital intensity $ln(K/L)_{hc}$, and share of surveyed firms with wage lower than minimum wage of each 4-digit industry in each city. If firms use little labor, the effect on their costs of a minimum wage will be smaller, as will be the price increase needed to cover the cost increase due to the minimum wage. Similarly, if the wage paid is already above the minimum wage, it will raise costs by less. The theoretical prediction is that $\alpha_1 > 0$,and $\beta_1 < 0$ if skill or capital intensity is used as cost and price increases and hence selection effects will be muted in this case. In the same vein, β_1 is expected to be positive if share of firms with wage less than minimum wage is used as the measure of bindingness, since these industries are more likely find the minimum wage binding so that surviving firms in such industries are more productive. Other independent variables used as controls are city specific variables such as average wage in a city, population and population density, industry-city fixed effects and year dummies.

The city specific variables are controlled for to separate agglomeration from selection following Combes, Duranton, Gobillon, Puga and Roux (2012).[30]

Table 3: Minimum Wage and Mean Productivity

	(1)	(2)	(3)	(4)
VARIABLES	Avg TFP	Avg TFP	Avg TFP	Avg TFP
ln(min wage)	0.161***	0.150***	0.590***	0.576***
	[0.0247]	[0.0288]	[0.0880]	[0.0912]
ln(min wage) ×Industry-City S/L	-0.0443	-0.0604	-0.0318	-0.0499
	[0.0410]	[0.0479]	[0.0464]	[0.0536]
ln(min wage) ×Industry-City ln(K/L)	-0.0141**	-0.0163**	-0.0200***	-0.0167**
	[0.00554]	[0.00639]	[0.00624]	[0.00712]
ln(min wage) ×(shr of firms $<$ min wage in 2001)		0.208***		0.268***
		[0.0269]		[0.0307]
city ln(avg wage)	0.0918***	0.0998***	0.0862***	0.0914***
	[0.00984]	[0.0112]	[0.00994]	[0.0113]
city ln(population)	-0.176***	-0.182***	-0.144***	-0.147***
	[0.0364]	[0.0383]	[0.0372]	[0.0392]
city population density	0.0351***	0.0412***	0.0408***	0.0470***
	[0.0103]	[0.0108]	[0.0104]	[0.0109]
Observations	160,711	117,231	159,752	117,051
R-squared	0.973	0.975	0.042	0.043

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions include industry-city fixed effects and year dummies.

The results are reported in Table 3. Here columns (1) and (2) report the OLS results, and columns (3)-(4) report the corresponding IV results. The estimated β_1 is negative if capital intensity is used as a measure of bindingness (see Column (1)) while the interaction of $\ln(S/L)$ and $\ln(min\ wage)$ is not significantly different from zero at 10 percent level. When the share of firms with wage less than the minimum wage is used as the measure of bindingness, a higher minimum wage indeed has stronger selection effects when a greater share of firms that pays less than the minimum wage, though productivity is lower for such sectors.

To test the theoretical predictions regarding extensive margins of firm survival, we examine a linear regression equation specified as follows:

$$\begin{aligned} EXIT_{hct} =& \alpha_1 \cdot ln(mw_{ct}) + \beta_1 \cdot ln(mw)_{ct} \cdot (Bindingness)_{hc} + \mu_1 X_{ct} \\ & + \lambda_{hc} + \lambda_t + \varepsilon_{cht}, \end{aligned} \tag{30}$$

where $EXIT_{cht}$ is the share of firms in the 4-digit industry - city h that export this period t but exit next period". i.e. we use the one-period forward exit pattern. Again, we interact minimum wage with a measure of how binding the minimum wage is in an industry-city, $(Bindingness)_{hc}$. Like in equation 29, we use industry-city measures of skill intensity $(S/L)_{hc}$ and capital intensity

[30]Richer cities may have higher minimum wage and higher density both of which may affect average TFP. Thus, we control for agglomeration effects following Combes et al. (2012).

$ln(K/L)_{hc}$, and share of surveyed firms with wage lower than minimum wage of each 4-digit industry in each city. As usual, we control for individual fixed effects (industry-city) and use a year dummy λ_t to control for any macro shocks or time trends.

Table 4: Minimum Wage and Exit from Export

VARIABLES	(1) Exit Share	(2) Exit Share	(3) Exit Share	(4) Exit Share
ln(min wage)	0.0362***	0.0377***	0.0528**	0.0478*
	[0.00689]	[0.00774]	[0.0245]	[0.0245]
ln(min wage) ×Industry-City S/L	-0.0385***	-0.0249*	-0.0264**	-0.0158
	[0.0114]	[0.0129]	[0.0129]	[0.0143]
ln(min wage) ×Industry-City ln(K/L)	-0.00271*	-0.00486***	-0.00353**	-0.00604***
	[0.00154]	[0.00172]	[0.00173]	[0.00191]
ln(min wage) ×(shr of firms < min wage in 2001)		0.0357***		0.0339***
		[0.00723]		[0.00823]
Avg TFP	0.00535***	0.00636***	0.00528***	0.00633***
	[0.000776]	[0.000868]	[0.000783]	[0.000875]
city ln(avg wage)	0.0206***	0.0185***	0.0203***	0.0185***
	[0.00274]	[0.00301]	[0.00276]	[0.00303]
city ln(population)	-0.0118	-0.0126	-0.0113	-0.0126
	[0.0101]	[0.0103]	[0.0103]	[0.0105]
city population density	0.000421	0.000264	0.000615	0.000307
	[0.00286]	[0.00291]	[0.00288]	[0.00292]
Observations	160,711	117,231	159,752	117,051
R-squared	0.225	0.205	0.020	0.022

Note: Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

The theoretical prediction is that an increase in the minimum wage will lead to more exit from exporting, but the effect is should be less so in more skill or capital intensive industries. The results are reported in Table 4. Columns (1) and (2) report the OLS results, and columns (3) and (4) report the IV estimates. The results confirm the theoretical predictions. In Columns (2) and (4) we use the share of firms with wage less than minimum wage in 2001 as an additional measure of bindingness at the 2-digit industry level.

6.4 Robustness Checks

Selection not only happen along the dimension of the extensive margin (i.e., enter or exit), but also on firms' choices of export destinations and export regimes. For example, when an exporter exports the same product to two destination markets, an increase in minimum wage is more likely to induce the firm to exit from the market with lower income. This is because richer countries tend to demand more skill or capital intensive products, therefore exports to them are less affected by increasing minimum wages. To this end, the odd columns of Table 5 shows that higher minimum wage increases exporters' share of exports to the OECD countries, and this effect is weakened in more skill-intensive or/and capital-intensive sectors, possibly because the minimum wage has less of an effect in these sectors.

Table 5: Minimum Wage and Export Selection Patterns

VARIABLES	(1) share to OECD	(2) processing share	(3) share to OECD	(4) processing share
ln(min wage)	0.0901***	-0.0229***	0.0840***	-0.0200***
	[0.0168]	[0.00666]	[0.0156]	[0.00676]
ln(min wage)$\times$ Industry-City (S/L)	-0.254***	0.0138	-0.236***	0.0163
	[0.0258]	[0.00983]	[0.0255]	[0.0101]
ln(min wage)$\times$ Industry-City ln(K/L)	-0.0170***	0.00738***	-0.0173***	0.00701***
	[0.00465]	[0.00175]	[0.00433]	[0.00178]
lag ln(firm total export value)			0.00163***	0.00235***
			[0.000312]	[0.000135]
city ln(GDP/population)	-0.0197***	0.0155***	-0.0241***	0.0124***
	[0.00613]	[0.00233]	[0.00575]	[0.00221]
city ln(population)	0.118***	0.0158***	0.0628***	0.0108***
	[0.0138]	[0.00270]	[0.0101]	[0.00266]
Observations	10,191,176	10,191,176	8,191,565	8,191,565
R-squared	0.868	0.935	0.873	0.937

Note: Robust standard errors in parentheses, clustered on product. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
All regressions include year dummies and firm-HS6 specific fixed effects.

The even columns of Table 5 examine the share of processing exports by each firm. It is well known that firms that do export processing in China are more labor intensive and less productive compared with firms that do normal trade. As shown in these columns, a higher minimum wage leads to a lower share of processing exports, while this effect is weakened in more skill or capital intensive sectors, possibly because the minimum wage has less of an impact there.

We can further control for productivity as done in columns 3 and 4. Estimation of productivity requires merged survey-customs data which reduces the sample size.

Tables 6 to 8 perform some robustness checks on export value, quantity and unit value respectively. Here we report empirical results from regressions at exporter-hs6-year level, using 2002-2007 Custom-survey merged data, with firm-hs6-destination fixed effects and year dummies. All our theoretical predictions and empirical patterns in Table 1 are confirmed using the merged sample while controlling for productivity in Tables 6-8. Table 6 and 8 show that export value (and in Table 8 export quantity) falls with the minimum wage and less so for skilled labor and capital intensive goods. It is also reasonable that higher productivity firms export more and seem less affected by higher minimum wages. In Table 7 we see that unit value is higher for more productive firms suggesting they produce higher quality.

Table 6: Minimum Wage and Export Value

VARIABLES	(1) ln(export value)	(2) ln(export value)	(3) ln(export value)
TFP	0.275***	0.270***	0.263***
	[0.0225]	[0.0243]	[0.0221]
ln(min wage)	-0.795***	-0.230***	0.108***
	[0.0732]	[0.0742]	[0.0340]
ln(min wage)× Industry-City (S/L)	1.508***		
	[0.185]		
ln(min wage)× Industry-City ln(K/L)	0.197***		
	[0.0191]		
destination ln(GDP/population)	-0.130**	0.0125	0.0236
	[0.0611]	[0.0676]	[0.0681]
city ln(GDP/population)	0.0475**	0.0871***	0.0852***
	[0.0218]	[0.0260]	[0.0260]
city ln(population)	-0.146***	-0.0543	-0.0272
	[0.0556]	[0.0677]	[0.0706]
lagged firm wage		-0.843***	
		[0.160]	
lagged firm wage × ln(min wage)		0.137***	
		[0.0256]	
lagged ln(TFP) × ln(min wage)			0.00219
			[0.00235]
Observations	4,024,982	3,531,449	3,529,321
R-squared	0.026	0.022	0.021

Table 7: Minimum Wage and Export Price

VARIABLES	(1) ln(unit value)	(2) ln(unit value)	(3) ln(unit value)
TFP	0.0246***	0.0265***	0.0311***
	[0.00412]	[0.00518]	[0.00514]
ln(min wage)	0.230***	0.162***	0.0505***
	[0.0284]	[0.0253]	[0.0136]
ln(min wage)× Industry-City (S/L)	-0.528***		
	[0.0723]		
ln(min wage)× Industry-City ln(K/L)	-0.0321***		
	[0.00753]		
destination ln(GDP/population)	-0.0814***	-0.0998***	-0.104***
	[0.0209]	[0.0227]	[0.0228]
city ln(GDP/population)	-0.0716***	-0.0628***	-0.0626***
	[0.0106]	[0.0130]	[0.0131]
city ln(population)	0.00370	0.00474	-0.00872
	[0.0221]	[0.0259]	[0.0261]
lagged firm wage		0.298***	
		[0.0522]	
lagged firm wage × ln(min wage)		-0.0465***	
		[0.00836]	
lagged ln(TFP) × ln(min wage)			-0.00156**
			[0.000701]
Observations	4,024,982	3,531,449	3,529,321
R-squared	0.039	0.037	0.037

Table 8: Minimum Wage and Export Quantity

VARIABLES	(1) ln(export quantity)	(2) ln(export quantity)	(3) ln(export quantity)
TFP	0.251***	0.243***	0.232***
	[0.0230]	[0.0251]	[0.0222]
ln(min wage)	-1.024***	-0.392***	0.0577
	[0.0760]	[0.0756]	[0.0358]
ln(min wage)× Industry-City (S/L)	2.036***		
	[0.199]		
ln(min wage)× Industry-City ln(K/L)	0.229***		
	[0.0200]		
destination ln(GDP/population)	-0.0482	0.112	0.128*
	[0.0633]	[0.0705]	[0.0711]
city ln(GDP/population)	0.119***	0.150***	0.148***
	[0.0210]	[0.0252]	[0.0255]
city ln(population)	-0.150**	-0.0590	-0.0185
	[0.0593]	[0.0730]	[0.0769]
lagged firm wage		-1.141***	
		[0.161]	
lagged firm wage × ln(min wage)		0.184***	
		[0.0256]	
lagged ln(TFP) × ln(min wage)			0.00374
			[0.00240]
Observations	4,024,982	3,531,449	3,529,321
R-squared	0.010	0.007	0.007

6.5 First Difference Setup

In the next set of robustness checks, we first estimate all our key empirical specifications in the first difference setup. In this setup, we instrument the annual change in minimum wage by the 5-year lagged minimum wage, motivated by Amiti and Konings (2007). This restricts our sample to 2005-2007, since the earliest minimum wage in our sample is the year 2000. The instrument is also motivated by the Figure 9 which clearly demonstrates that initially low-minimum wage areas experienced a high growth in minimum wage in later years. The empirical specifications to be tested are described below.

From the transaction level trade data, we test whether export volume and quantity fall and export price increases with increase in minimum wage, and less so in more skill- or capital-intensive industries. The baseline regression, in first difference, is specified as follows.

$$\begin{aligned}\Delta ln(V_{ihcdt}) =&\alpha_1\Delta \cdot ln(mw_{ct}) + \beta_1\Delta \cdot ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_1\Delta \cdot ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ &+ \mu_1\Delta X_{ct} + \gamma_1\Delta Y_{dt} + \lambda_t + \varepsilon_{ihcdt},\end{aligned} \tag{31}$$

where the dependent variable ΔV_{ihdt} refers annual change in export value, price or quantity for firm i in city c, HS6 product h, destination d and time t. $\Delta ln(mw)_{ct}$ measures the change in log of minimum wages in prefectural city c in year t. To examine the differential impact of minimum wages on firms across different industries, we include an interaction term between change in minimum wage and an industry-city measure of skill intensity $(S/L)_{hc}$ and capital intensity $ln(K/L)_{hc}$, at the 4-digit Chinese Industrial Classification level , which is drawn from the 2004 ASIP data. To control for other concurrent economic factors at city-year level ΔX_{ct}, we use change in city GDP *per capita*, and population, and ΔY_{dt} controls for change in destination side characteristics, for which we use the *per capita* GDP of the destination country d. Given the first difference setup, we no longer use the firm-product-destination specific fixed effects so that our baseline and IV results remain directly comparable to the level regressions in Section 6. [31] A year dummy is used to control for any macro shocks. Thus, all regressions are at exporter-hs6-destination-year level, using 2005-2007 Custom data, with standard error clustered on city-product pair. In Table 9 we report OLS regression results for value, price and quantity in columns (1)-(3), and columns (4)-(6) reports the IV results using 5-year lag minimum wage of the city as the instrument for annual change in minimum wage. Both OLS and IV results, in the first difference setup, confirm our key theoretical predictions and baseline empirical findings: export volume and quantity falls and prices increase with rise in minimum wage, and the effects are weaker in more skill- or capital-intensive industries.

In the next empirical exercise, we test whether increase in minimum wage leads to substitution away from low skilled labor by investigating how firms change their capital- intensity, employment of labor and capital and cost share of labor in response to a change in minimum wage. The regression equation is specified as follows.

$$\begin{aligned}\Delta ln(E_{it}) =&\alpha_1 \Delta \cdot ln(mw_{ct}) + \beta_1 \Delta \cdot ln(mw)_{ct} \cdot (S/L)_{hc} + \beta_1 \Delta \cdot ln(mw)_{ct} \cdot ln(K/L)_{hc} \\ &+ \mu_1 \Delta X_{ct} + \lambda_t + \varepsilon_{it},\end{aligned} \tag{32}$$

where the dependent variable ΔE_{it} refers annual change in capital intensity, labor, capital or labor cost share for firm i and time t. $\Delta ln(mw)_{ct}$ measures the change in log of minimum wages in prefectural city c in year t. To examine the differential impact of minimum wages on firms across different industries, we include an interaction term between change in minimum wage and an industry-city measure of skill intensity $(S/L)_{hc}$ and capital intensity $ln(K/L)_{hc}$, at the 4-digit level. As before, we use five-year lagged minimum wage at the prefecture level as the instrument for annual change. Columns (1)-(8) show the OLS results, and columns (9)-(16) the corresponding IV results. Table 10 confirms the theoretical predictions and baseline empirical results. However, as observed in the baseline level regressions, the interaction effects for skill-intensity are often of the opposite sign, possibly due to capital-skill complementarity.

Next, we investigate whether industry-city level productivity responds to a change in minimum wage in the fashion predicted by our theoretical framework. An increase in minimum wage leads to a tougher competitive environment and stricter selection among firms such that only higher productivity firms can survive in the market, and this selection effect is stronger in more low-skill labor intensive industries. This endogenous selection mechanism would lead to growth in average industry productivity in cities experiencing an increase in minimum wage, but less so in industry-city pairs with higher skill- or capital-intensity. In order to test this, we estimate the following

[31] In the final set of robustness exercise, we do check whether our key empirical predictions hold if we allow for firm- or product- specific trends.

regression equation:

$$\Delta TFP_{cht} = \alpha_1 \cdot \Delta ln(mw_{ct}) + \beta_1 \cdot \Delta ln(mw)_{ct}(Bindingness)_{hc} + \mu_1 \Delta X_{ct} + \lambda_t + \varepsilon_{cht}, \tag{33}$$

The dependent variable is the annual change in the mean productivity of each 4-digit industry in each city. Independent variables of interest are the change in minimum wage and its interaction with a measure of how binding the minimum wage is in an industry, $(Bindingness)_h$. The two options we use for this are skill or capital intensity at the 4-digit industry-city level and the share of surveyed firms with wage lower than minimum wage of each 2-digit industry in each city. The results are demonstrated in Table 11. Columns (1)-(2) show the OLS results for different measures of bindingness of minimum wage and columns (3)-(4) are the corresponding IV results.

In our final set of robustness checks, we confirm if our results hold allowing for firm- or product- specific time trends. In order to test this, the most comprehensive setup would be to include firm-product-destination specific fixed effects in the first-difference setup (which already absorbs the firm-product-destination specific time-invariant fixed effects). However, such a setup leads to absorbing all remaining variation in the data. Instead in our exercise, we allow for different firm or product characteristics to lead to different trend growth based on current literature. For example, based on empirical firm dynamics literature (Evans (1987)) we allow for different trend growth depending on age of the firm. We also allow for different trends for firms in special economic zones and for high-tech firms. Also, based on the spectacular growth observed by least traded goods in Kehoe and Ruhl (2013), we allow for a product-specific trend growth if the product is a least traded good in our sample. The empirical specification is

$$\Delta ln(V_{ihdt}) = \alpha_1 \Delta \cdot ln(mw_{ct}) + \beta_1 \Delta \cdot ln(mw)_{ct} \cdot (S/L)_h + \beta_1 \Delta \cdot ln(mw)_{ct} \cdot ln(K/L)_h + \mu_1 \Delta X_{ct} + \gamma_1 \Delta Y_{dt} + \lambda_t + \lambda_i + \lambda_h + \varepsilon_{ihdt}, \tag{34}$$

where relative to Equation (32), we add firm- and product- specific trends. In order to construct our firm- specific trend dummies, here we use our merged sample. Table 12 confirms our results. In this Table, columns (1)-(3) show the response of change in volume of export in the baseline, after controlling for firm-specific trends and after controlling for firm- *and* product-specific trends, respectively. Similarly, columns (4)-(6) show the response of change in export price, and columns (7)-(9) show the response of change in export quantity, in the same order. In all cases, firm- and product- specific trends reduce the magnitudes of the impact of minimum wage, but our empirical predictions continue to hold.

7 Conclusion

This paper has three components. First, it develops a new heterogeneous firm model of supply in general equilibrium under competition 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 the how minimum wages affect selection, production, prices, technique of production, exports and entry/exit patterns. In other words, unlike

Table 9: Minimum Wage and Export Value, Quantity and Price

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δ ln(export value)	Δ ln(unit value)	Δ ln(export quantity)	Δ ln(export value)	Δ ln(unit value)	Δ ln(export quantity)
Δ ln(min wage)	-0.513***	0.323***	-0.836***	-0.908***	-0.0404	-0.867***
	[0.127]	[0.0578]	[0.0977]	[0.0662]	[0.0284]	[0.0688]
Δ ln(min wage) × Industry-City ln(K/L)	0.745***	-0.457***	1.202***	1.281***	-0.545***	1.826***
	[0.138]	[0.115]	[0.172]	[0.0699]	[0.0300]	[0.0726]
Δ ln(min wage) × Industry-City (S/L)	0.100***	-0.0402***	0.140***	0.133***	-0.0838***	0.217***
	[0.0191]	[0.00961]	[0.0155]	[0.00762]	[0.00327]	[0.00792]
Δ city ln(GDP/population)	0.0954***	0.112**	-0.0162	0.0958***	0.117***	-0.0217***
	[0.0272]	[0.0480]	[0.0314]	[0.00544]	[0.00233]	[0.00565]
Δ city ln(population)	0.0811***	0.134	-0.0531	0.124***	0.234***	-0.110***
	[0.0236]	[0.0905]	[0.107]	[0.0184]	[0.00789]	[0.0191]
Δ destination ln(GDP/population)	0.337***	0.477***	-0.140	0.524***	0.929***	-0.405***
	[0.0889]	[0.0455]	[0.100]	[0.0583]	[0.0250]	[0.0605]
Observations	4,661,267	4,661,267	4,661,267	4,661,266	4,661,266	4,661,266
R-squared	0.000	0.002	0.000	0.000	-0.002	0.000

Table 10: Minimum Wage and Factor Intensity

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
VARIABLES	Δ ln(K/L)	Δ ln(L)	Δ ln(K)	Δ Labor cost share	Δ ln(K/L)	Δ ln(L)	Δ ln(K)	Δ Labor cost share
Δ ln(min wage)	1.203***	-0.239***	0.964***	-0.0186***	2.051***	-0.00666	2.044***	-0.0631***
	[0.0612]	[0.0373]	[0.0633]	[0.00147]	[0.218]	[0.141]	[0.259]	[0.00641]
Δ ln(min wage) × Industry-City (S/L)	0.147	0.110**	0.258***	-0.000616	0.306***	0.326***	0.632***	-0.00436
	[0.0925]	[0.0558]	[0.0905]	[0.00222]	[0.112]	[0.0701]	[0.120]	[0.00345]
Δ ln(min wage) × Industry-City ln(K/L)	-0.301***	0.0873***	-0.214***	0.00409***	-0.480***	0.130***	-0.350***	0.00595***
	[0.0144]	[0.00903]	[0.0150]	[0.000347]	[0.0193]	[0.0118]	[0.0211]	[0.000606]
Δ city ln (GDP/population)	0.131***	-0.00555	0.125***	-0.00279***	0.142***	0.0151	0.157***	-0.00475***
	[0.0130]	[0.00866]	[0.0132]	[0.000417]	[0.0185]	[0.0121]	[0.0207]	[0.000576]
Δcity ln (population)	-0.122***	0.0923***	-0.0294	0.000994	-0.132***	0.0610**	-0.0710	0.00337***
	[0.0365]	[0.0231]	[0.0353]	[0.000809]	[0.0449]	[0.0301]	[0.0486]	[0.00130]
Observations	448,236	448,236	448,236	416,090	448,234	448,234	448,234	416,088
R-squared	0.004	0.004	0.004	0.003	0.002	-0.007	-0.004	-0.058

Table 11: Minimum Wage and Average Productivity

VARIABLES	(1) Δ Avg TFP	(2) Δ Avg TFP	(3) Δ Avg TFP	(4) Δ Avg TFP
Δ ln (min wage)	0.364***	0.375***	1.275***	1.386***
	(0.0567)	(0.0568)	(0.331)	(0.351)
Δ ln (min wage) × Industry-City S/L	0.0839	0.0810	-0.324*	-0.339**
	(0.0985)	(0.0984)	(0.169)	(0.172)
Δ ln (min wage) × Industry-City ln(K/L)	-0.0678***	-0.0676***	-0.0426*	-0.0413
	(0.0141)	(0.0141)	(0.0256)	(0.0258)
Δ ln (min wage) × (shr of firms¡min wage in 2001)		0.0607		-0.0625
		(0.0383)		(0.117)
Δ city ln(avg wage)	0.0232**	0.0161*	-0.0563*	-0.0769**
	(0.00914)	(0.00915)	(0.0321)	(0.0356)
Δcity ln(population)	-0.113*	-0.109*	-0.187***	-0.192***
	(0.0625)	(0.0625)	(0.0718)	(0.0727)
Δ population density	-0.402	-0.416	-0.167	-0.171
	(0.460)	(0.460)	(0.484)	(0.487)
Observations	85,131	85,131	85,043	85,043
R-squared	0.002	0.003	-0.072	-0.085

Robust standard errors in parentheses, clustered on industry-city pair.
*** p<0.01, ** p<0.05, * p<0.1

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, it tests these predictions using Chinese customs and survey data at the firm level. The OLS and the IV results provide robust empirical evidence in favor of the entire range of theoretical predictions.

In future work we plan to look at two related aspects that we do not study here. First, we want to explore migration patterns and their response to minimum wages. It is often presumed that higher minimum wages attract more migrants. However, this need not be the case if employment opportunities for migrants shrink fast enough with the rise in the minimum wage. Second, we want to look for evidence of agglomeration effects. If agglomeration effects are strong and higher minimum wages do not attract low skilled workers, differences in minimum wages could magnify inequality. Cities with high minimum wages could end up attracting skill intensive sectors and high skilled labor whose returns are magnified by agglomeration effects. US cities are beginning to set their own minimum wages in a bid to offer workers a living wage, It would be ironic if this attempt backfired and resulted in even more inequality through this channel.

Table 12: Minimum Wage and Export Value, Quantity and Price

VARIABLES	(1) Δ ln(export value)	(2) Δ ln(export value)	(3) Δ ln(export value)	(4) Δ ln(unit value)	(5) Δ ln(unit value)	(6) Δ ln(unit value)	(7) Δ ln(export quantity)	(8) Δ ln(export quantity)	(9) Δ ln(export quantity)	(10)	(11)	(12)
Δ ln(min wage)	-0.607***	-0.599***	-0.574***	0.404***	0.394***	0.388***	-1.011***	-0.992***	-0.962***			
	[0.118]	[0.113]	[0.114]	[0.0435]	[0.0419]	[0.0410]	[0.112]	[0.105]	[0.107]			
Δ ln(min wage) × Industry-City (S/L)	1.222***	1.277***	1.227***	-0.512***	-0.489***	-0.478***	1.734***	1.766***	1.705***			
	[0.254]	[0.268]	[0.265]	[0.112]	[0.105]	[0.106]	[0.265]	[0.278]	[0.275]			
Δ ln(min wage) × Industry-City ln(K/L)	0.165***	0.159***	0.155***	-0.0388***	-0.0351***	-0.0340***	0.204***	0.194***	0.189***			
	[0.0319]	[0.0319]	[0.0320]	[0.00971]	[0.00998]	[0.00980]	[0.0291]	[0.0281]	[0.0284]			
Δ TFP	0.228***	0.220***	0.220***	0.0261***	0.0265***	0.0266***	0.202***	0.193***	0.193***	0.221***	0.0287***	0.193***
	[0.0158]	[0.0155]	[0.0154]	[0.00452]	[0.00446]	[0.00445]	[0.0166]	[0.0161]	[0.0161]	[0.0153]	[0.00435]	[0.0156]
Δ city ln(GDP/population)	0.0813***	0.0787***	0.0781***	0.0457	0.0470	0.0472	0.0356	0.0318	0.0310	0.0889***	0.0498	0.0391
	[0.0194]	[0.0191]	[0.0190]	[0.0291]	[0.0294]	[0.0294]	[0.0277]	[0.0284]	[0.0283]	[0.0219]	[0.0471]	[0.0400]
Δ city ln(population)	-0.0983	0.00946	0.0107	0.0244	-0.000420	-0.000862	-0.123	0.00988	0.0116	0.0463	0.0422	0.00408
	[0.0979]	[0.0413]	[0.0415]	[0.0648]	[0.0595]	[0.0593]	[0.151]	[0.0480]	[0.0468]	[0.0513]	[0.0720]	[0.0462]
Δ destination ln(GDP/population)	0.143*	0.222***	0.213***	0.241***	0.234***	0.236***	-0.0976	-0.0118	-0.0231	0.314***	0.391***	-0.0776
	[0.0776]	[0.0794]	[0.0786]	[0.0259]	[0.0254]	[0.0253]	[0.0803]	[0.0815]	[0.0808]	[0.0861]	[0.0336]	[0.0852]
young		0.126***	0.126***		-0.00545**	-0.00545**		0.131***	0.131***	0.124***	-0.00649***	0.130***
		[0.00755]	[0.00754]		[0.00225]	[0.00223]		[0.00761]	[0.00758]	[0.00762]	[0.00228]	[0.00767]
old		0.0151*	0.0128		-0.00528	-0.00483		0.0204**	0.0176*	0.0175*	-0.00560	0.0231**
		[0.00856]	[0.00859]		[0.00519]	[0.00511]		[0.0101]	[0.0100]	[0.00892]	[0.00490]	[0.0104]
1 if firm is in Special Economic Zone		-0.0351***	-0.0340***		0.0105	0.0103		-0.0456***	-0.0443***	-0.0385***	-0.000484	-0.0380***
		[0.0123]	[0.0123]		[0.00808]	[0.00811]		[0.0128]	[0.0128]	[0.0129]	[0.0101]	[0.0124]
1 if firm is a high-tech firm		0.0242*	0.0230*		-0.0205***	-0.0202***		0.0448***	0.0432***	0.0396***	-0.0251***	0.0648***
		[0.0130]	[0.0129]		[0.00495]	[0.00492]		[0.0125]	[0.0124]	[0.0130]	[0.00567]	[0.0129]
least traded goods			0.0695***			-0.0163***			0.0858***	0.0803***	-0.0206***	0.101***
			[0.0110]			[0.00500]			[0.0132]	[0.0112]	[0.00515]	[0.0135]
Observations	1,663,673	1,663,673	1,663,249	1,663,673	1,663,673	1,663,249	1,663,673	1,663,673	1,663,249	1,663,249	1,663,249	1,663,249
R-squared	0.003	0.004	0.004	0.004	0.004	0.004	0.002	0.004	0.004	0.003	0.003	0.003

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8 Appendix

8.1 Proofs of the Propositions

Lemma 1: If entry costs are in terms of the numeraire good, then **0** $<\frac{dp}{dc}\frac{c}{p} < 1$.

Proof:

Totally differentiating the above WRT $c(.)$ and p gives

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

so that

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

Also, as

$$F(\frac{p}{c(w,r)})\frac{p}{c(w.r)} > \int\limits_0^{\frac{p}{c(w.r)}} F(\theta)d\theta = \frac{f_e}{c(w,r)},$$

we know that

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

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

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

$$\begin{aligned} p^x &= \tilde{\theta}^x(w,r)c^x(w,r) && (35) \\ p^y &= \tilde{\theta}^y(w,r)c^y(w,r) && (36) \end{aligned}$$

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:

$$\begin{aligned} \hat{p}^x &= \theta_{Lx}\hat{w} + \theta_{Kx}\hat{r} + \widehat{\left(\tilde{\theta}^x\right)} && (37) \\ \hat{p}^y &= \theta_{Ly}\hat{w} + \theta_{Ky}\hat{r} + \widehat{\left(\tilde{\theta}^y\right)} && (38) \\ \hat{p}^e &= \theta_{Le}\hat{w} + \theta_{Ke}\hat{r} && (39) \end{aligned}$$

where θ_{ij} is the cost share of i in j for $i = L, K$ and $j = x, y, e$ while $\hat{p}^e = \frac{dc^e(w,r)}{c^e(w,r)}$.

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 $\left[\int\limits_0^{\tilde{\theta}} F(\theta)d\theta\right] = \frac{c^e(w,r)f_e}{c(w,r)}$,

$$\frac{d\tilde{\theta}^j}{\tilde{\theta}^j} = \frac{\left[\int\limits_0^{\tilde{\theta}^j} F(\theta)d\theta\right]}{\tilde{\theta}^j F(\tilde{\theta}^j)} \left[\left(\theta_{Le} - \theta_{Lj}\right)\hat{w} + \left(\theta_{ke} - \theta_{kj}\right)\hat{r}\right]$$

Consequently:

$$\widehat{\left(\tilde{\theta}^x\right)} = v^x \left[(\theta_{Le} - \theta_{Lx})\hat{w} + (\theta_{Ke} - \theta_{Kx})\hat{r}\right] \tag{40}$$

$$\widehat{\left(\tilde{\theta}^y\right)} = v^y \left[(\theta_{Le} - \theta_{Ly})\hat{w} + (\theta_{Ke} - \theta_{Ky})\hat{r}\right] \tag{41}$$

where $\left[\frac{\int\limits_0^{\tilde{\theta}^x} F^x(\theta)d\theta}{F(\tilde{\theta}^x)\tilde{\theta}^x}\right] = v^x$, $\left[\frac{\int\limits_0^{\tilde{\theta}^x} F^y(\theta)d\theta}{F(\tilde{\theta}^y)\tilde{\theta}^y}\right] = v^y$. Note that $v^x, v^y \in (0, 1)$.

Substituting (40) and (41) into (37) and (38) gives:

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

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

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

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

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.

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

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

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

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

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

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

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

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

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

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.

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

Proof: We know

$$\begin{aligned} \bar{\theta}(\tilde{\theta}) &= \int_0^{\tilde{\theta}} \theta f(\theta) d\theta \\ &= \tilde{\theta} F(\tilde{\theta}) - \int_0^{\tilde{\theta}} F(\theta) d\theta \end{aligned} \tag{42}$$

Hence

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

where we use equation (42) 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

$$A_K = c_r(.) \bar{\theta}(\tilde{\theta}(w,r)) + f_e c_r^e(.)$$

Thus,

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

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

$$
\frac{\left[\tilde{\theta}^x F(\tilde{\theta}^x) + \frac{c^{ex}_w(w,r)f_e}{c^x_w(w,r)}(1 - \frac{\theta_{Lx}}{\theta^e_{Lx}})\right]}{\left[\tilde{\theta}^x F(\tilde{\theta}^x) + \frac{f_e c^{ex}_r(.)}{c^x_r(.)}(1 - \frac{\theta_{Kx}}{\theta^e_{Kx}})\right]} < \frac{\tilde{\theta}^x F(\tilde{\theta}^x)}{\tilde{\theta}^x F(\tilde{\theta}^x)} = 1
$$

so

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

By the same argument,

$$
\left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{c^{ey}_w(w,r)f_e}{c^y_w(w,r)}(1 - \frac{\theta_{Ly}}{\theta^e_{Ly}})\right] > \left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{f_e c^{ey}_r(.)}{c^y_r(.)}(1 - \frac{\theta_{Ky}}{\theta^e_{Ky}})\right]
$$

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

$$
\begin{aligned}
\frac{A_{Ly}}{A_{Ky}} &= \frac{a_{Ly}}{a_{Ky}} \frac{\left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{f_e c^{ey}_w(w,r)}{c^y_w(w,r)}(1 - \frac{\theta_{Ly}}{\theta^e_{Ly}})\right]}{\left[\tilde{\theta}^y F(\tilde{\theta}^y) + \frac{f_e c^{ey}_r(.)}{c^y_r(.)}(1 - \frac{\theta_{Ky}}{\theta^e_{Ky}})\right]} \\
&> \frac{a_{Ly}}{a_{Ky}}.
\end{aligned}
$$

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:

$$
\begin{aligned}
N^x c_w^x(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) + N^y c_w^y(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= G(w)L && (43)\\
N^x c_r^x(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) + N^y c_r^y(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= K && (44)
\end{aligned}
$$

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

$$
\begin{aligned}
a_{Lx}(.)\tilde{\theta}^x F(\tilde{\theta}^x) dN^x + a_{Ly}(.)\tilde{\theta}^y F(\tilde{\theta}^y) dN^y &= G(w)dL && (45)\\
a_{Kx}(.)\tilde{\theta}^x F(\tilde{\theta}^x) dN^x + a_{Ky}(.)\tilde{\theta}^y F(\tilde{\theta}^y) dN^y &= K && (46)
\end{aligned}
$$

so that

$$
\begin{aligned}
\lambda_{Lx}\hat{N}^x + \lambda_{Ly}\hat{N}^y &= \hat{L} && (47)\\
\lambda_{Kx}\hat{N}^x + \lambda_{Ky}\hat{N}^y &= \hat{K} && (48)
\end{aligned}
$$

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

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

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

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, $N^x(\overset{+}{p^x}, \overset{-}{p^y}; .)$, $N^y(\overset{-}{p^x}, \overset{+}{p^y}; .)$.
Recall that

$$\begin{aligned} c_w^x(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) &= A_{Lx}(w,r) \\ c_w^y(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= A_{Ly}(w,r) \\ c_r^x(w,r)\tilde{\theta}^x F(\tilde{\theta}^x) &= A_{Kx}(w,r) \\ c_r^y(w,r)\tilde{\theta}^y F(\tilde{\theta}^y) &= A_{Ky}(w,r). \end{aligned}$$

$$\frac{A_{Lx}}{A_{Kx}} = \frac{c_w^x(w,r)\tilde{\theta}F(\tilde{\theta})}{c_w^x(w,r)\tilde{\theta}F(\tilde{\theta})} = \frac{a_{Lx}(.)}{a_{Kx}(.)}$$

which is decreasing in w and increasing in r.

$$\begin{aligned} N^x A_{Lx}(w,r) + N^y A_{Ly}(w,r) &= G(w)L && (49) \\ N^x A_{Kx}(w,r) + N^y A_{Ky}(w,r) &= K && (50) \end{aligned}$$

Differentiating

$$\begin{aligned} \lambda_{Lx}\hat{N}^x + \lambda_{Ly}\hat{N}^y + \lambda_{Lx}\hat{A}_{Lx}(.) + \lambda_{Ly}\hat{A}_{Ly}(.) &= \hat{L} + \frac{wG'(w)}{G(w)}\hat{w} && (51) \\ \lambda_{Kx}\hat{N}^x + \lambda_{Ky}\hat{N}^y + \lambda_{Kx}\hat{A}_{Kx}(.) + \lambda_{Ky}\hat{A}_{Ky}(.) &= \hat{K} && (52) \end{aligned}$$

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

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

$$\begin{aligned} \lambda_{Lx}\hat{N}^x + \lambda_{Ly}\hat{N}^y + \lambda_{Lx}\hat{a}_{Lx}(.) + \lambda_{Ly}\hat{a}_{Ly}(.) &= \hat{L} + \frac{wG'(w)}{G(w)}\hat{w} && (53) \\ \lambda_{Kx}\hat{N}^x + \lambda_{Ky}\hat{N}^y + \lambda_{Kx}\hat{a}_{Kx}(.) + \lambda_{Ky}\hat{a}_{Ky}(.) &= \hat{K} && (54) \end{aligned}$$

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

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

as a_{Lj} is HD0 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

$$\lambda_{Lx}\hat{N}^x+\lambda_{Ly}\hat{N}^y = \frac{wG'(w)}{G(w)}\hat{w}-\left[\lambda_{Lx}\eta_w^{Lx}+\lambda_{Ly}\eta_w^{Ly}\right]\left(\hat{w}-\hat{r}\right) \tag{55}$$

$$\lambda_{Kx}\hat{N}^x+\lambda_{Ky}\hat{N}^y = -\left[\lambda_{Kx}\eta_w^{Kx}+\lambda_{Ky}\eta_w^{Ky}\right]\left(\hat{w}-\hat{r}\right) \tag{56}$$

Recall that

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

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

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

Denote by

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

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

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

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 $\frac{\hat{N}^y}{\hat{p}^y} > 0$. QED

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

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

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.

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 limited 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 values of N^x, 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.[32] 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.

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

[32]Note that as G(.) 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.

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 first example, 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 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 location 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 10:

Figure 11 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 a fall in migration with a rise in the minimum wage. This is not unexpected

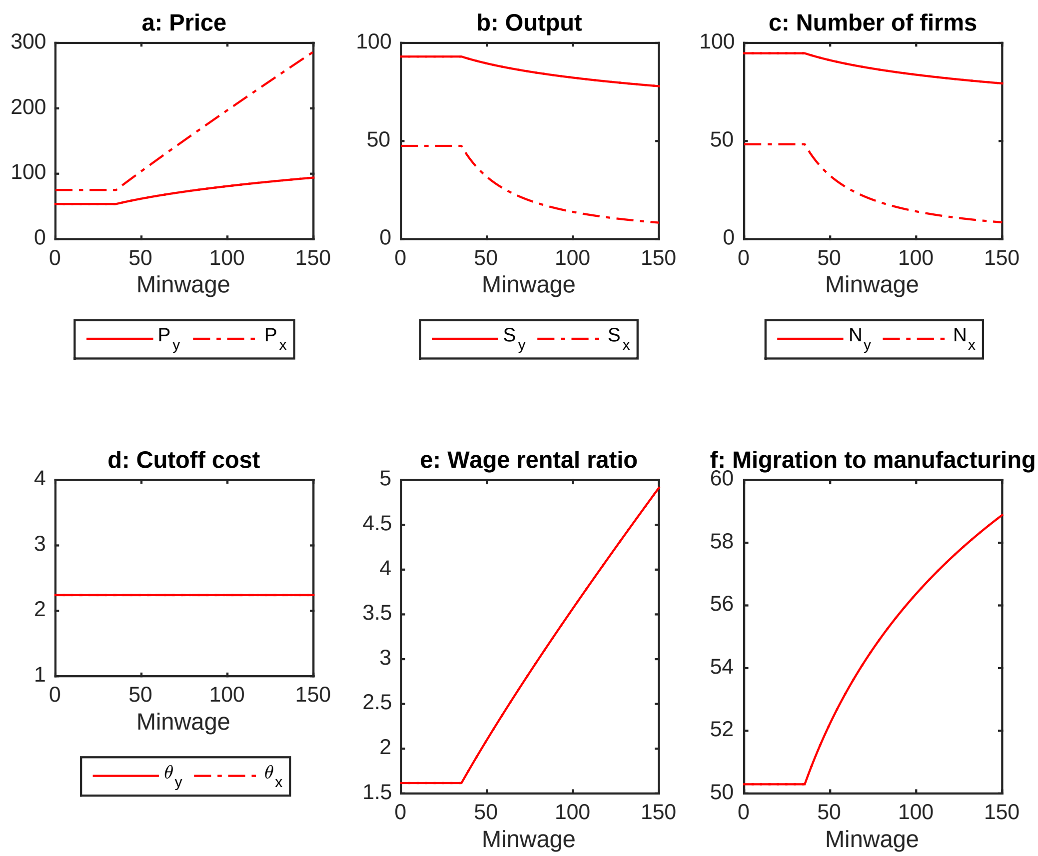

Figure 11. Comparative Statics of Minimum Wage without Selection

Table 13: Numerical Example: No Selection

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

- substitutability between x and y is large enough for the derived demand for labor to be elastic which ensures migration will fall 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 13, in order to allow for selection, we let $\eta_{e,x}$ to 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 13.

In this case, as documented in panel (d) of Figure 12, 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 12, 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.

8.3 First Stage Estimates

In Tables 14 to 17, we present the first stage regression results of the IV regressions. We do not have weak identification problems as the values for the Kleibergen-Paap rk Wald F statistics[33] (for Tables 14 and 15) and the Cragg-Donald Wald F statistics (for Tables 16 and 17) are above the critical levels.

[33]We use the Kleibergen-Paap rk Wald F statistics in these two tables as the standard errors are clustered.

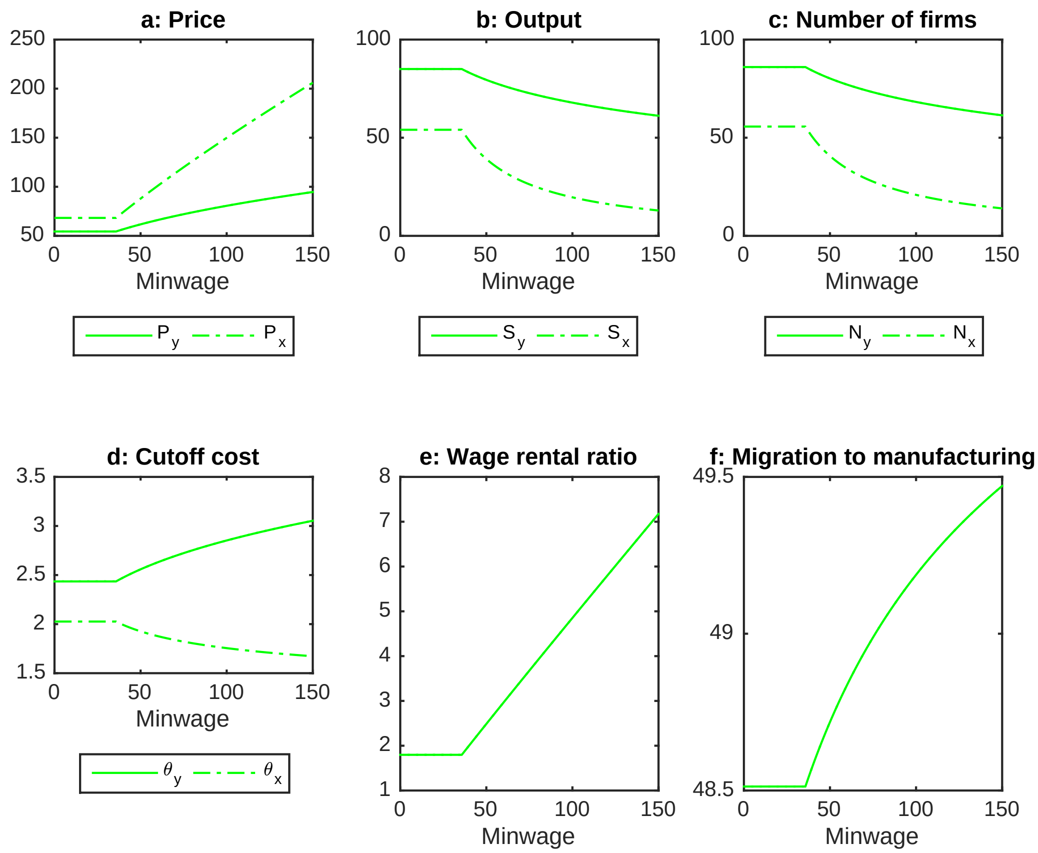

Figure 12. Comparative Statics of Minimum Wage with Selection

Table 14: Minimum Wage and Firm 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)
ln(min wage) IV	0.158***	-0.085***	-3.009***
	(0.010)	(0.001)	(0.034)
ln(min wage) IV× Industry-City (S/L)	0.010	0.993***	0.037
	(0.012)	(0.005)	(0.044)
ln(min wage) IV× Industry-City ln(K/L)	0.011***	0.001***	1.037***
	(0.002)	(0.000)	(0.006)
city ln(GDP/population)	-0.054***	-0.002***	-0.171***
	(0.003)	(0.000)	(0.011)
city ln(population)	-0.125***	-0.010***	-0.452***
	(0.007)	(0.001)	(0.024)
destination ln(GDP/population)	-0.054***	-0.004***	-0.172***
	(0.002)	(0.000)	(0.007)

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: Robust standard errors in parentheses, clustered on city-product pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Weak identification test (Kleibergen-Paap rk Wald F statistic): 286.216.

Table 15: 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)
ln(min wage) IV	0.256***	-0.096***	-2.860***
	(0.027)	(0.006)	(0.110)
ln(min wage) IV× Industry-City (S/L)	-0.019	0.941***	-0.067
	(0.044)	(0.024)	(0.188)
ln(min wage) IV× Industry-City ln(K/L)	-0.009*	0.000	0.939***
	(0.005)	(0.001)	(0.019)
city ln(GDP/population)	-0.011	0.001	-0.017
	(0.013)	(0.002)	(0.052)
city ln(population)	-0.103***	-0.015***	-0.391***
	(0.024)	(0.003)	(0.087)

Note: Robust standard errors in parentheses, clustered on city-product pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Weak identification test (Kleibergen-Paap rk Wald F statistic): 37.305.

Table 16: Minimum Wage and Mean 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)	(4) ln(min wage) × (share of firms < min wage in 2001)
ln(min wage) IV	0.355***	-0.095***	-2.507***	-0.056***
	(0.009)	(0.002)	(0.035)	(0.003)
ln(min wage) IV×Industry-City (S/L)	0.055***	1.005***	0.225***	0.005
	(0.011)	(0.002)	(0.046)	(0.003)
ln(min wage) IV×Industry-City ln(K/L)	0.001	0.000	0.993***	-0.000
	(0.001)	(0.000)	(0.006)	(0.000)
ln(min wage) IV×	-0.042***	-0.005***	-0.163***	0.957***
(share of firms< min wage in 2001)	(0.006)	(0.001)	(0.025)	(0.002)
city ln(avg wage)	0.003	0.003***	0.031***	-0.003***
	(0.002)	(0.000)	(0.010)	(0.001)
city ln(population)	-0.042***	-0.008***	-0.160***	-0.009***
	(0.008)	(0.002)	(0.033)	(0.002)
city population density	-0.013***	-0.002***	-0.066***	-0.002***
	(0.002)	(0.000)	(0.009)	(0.001)

Note: Robust standard errors in parentheses, clustered on city-product pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Weak identification test (Cragg-Donald Wald F statistic): 731.94.

Table 17: 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)	(4) ln(min wage) × (share of firms < min wage in 2001)
ln(min wage) IV	0.354***	-0.095***	-2.510***	-0.056***
	(0.009)	(0.002)	(0.035)	(0.003)
ln(min wage) IV×Industry-City (S/L)	0.055***	1.005***	0.225***	0.005
	(0.011)	(0.002)	(0.046)	(0.003)
ln(min wage) IV×Industry-City ln(K/L)	0.001	0.000	0.993***	-0.000
	(0.001)	(0.000)	(0.006)	(0.000)
ln(min wage) IV×	-0.043***	-0.006***	-0.167***	0.957***
(share of firms< min wage in 2001)	(0.006)	(0.001)	(0.025)	(0.002)
avg TFP	0.004***	0.000***	0.015***	0.001***
	(0.001)	(0.000)	(0.003)	(0.000)
city ln(avg wage)	0.003	0.003***	0.030***	-0.003***
	(0.002)	(0.000)	(0.010)	(0.001)
city ln(population)	-0.042***	-0.008***	-0.158***	-0.009***
	(0.008)	(0.002)	(0.033)	(0.002)
city population density	-0.013***	-0.002***	-0.067***	-0.002***
	(0.002)	(0.000)	(0.009)	(0.001)

Note: Robust standard errors in parentheses, clustered on city-product pair. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.
Weak identification test (Cragg-Donald Wald F statistic): 728.73.