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ABSTRACT

This paper develops a new model with heterogeneous firms under perfect competition in a Heckscher-Ohlin setting. We derive a novel prediction regarding the effect of minimum wages on selection, namely that a binding minimum wage will raise (or lower) TFP at the firm and industry level depending on whether the capital intensity of entry costs exceeds (falls short of) that of production. Exploiting rich regional variation in minimum wages across Chinese counties and using firm level production data, we find robust evidence in support of causal effects of minimum wages consistent with our theoretical predictions.

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1 Introduction

Minimum wages are clearly highly relevant for policy, especially today with growing inequality being a concern in most countries, particularly those without a strong redistribution policies in place. Despite its clear policy relevance and the extensive work in this area, impact of the minimum wage on firm productivity and exit remains poorly understood.

Our contribution is twofold. First, we build on the Heckscher-Ohlin-Samuelson model, but with heterogeneous firms with upward sloping supply curves. These curves arise from firms having a finite number of units of capacity, each with a (possibly) different marginal cost of production. TFP rises when high cost capacity is shut down by a firm and/or low productivity firms exit.[1]

We then use the model to make novel predictions about the effects of a minimum wage on productivity and exit patterns of heterogeneous firms in a Heckscher-Ohlin setting. Our work predicts a key role for a novel variable, the gap in the capital intensity in entry and production, as well as for overall capital intensity.[2] Second, we use firm survey data from China, where different counties set and frequently change minimum wages, to test the predictions of the model. We exploit the extremely rich regional variation to tease out the causal effect of minimum wages on firm level exit and productivity.

The novel predictions of the model, and the ones we focus on, have to do with selection and exit. The prediction is that a higher minimum wage makes selection stricter, and hence TFP at the firm and industry level higher, when entry costs are more capital intensive than production costs.[3] This is more so the higher is the gap in capital intensity in entry and production costs, and the lower is overall capital intensity. These are the two key variables in our regressions.

We also look at the predictions for exit. Selection is one part of this as output falls because firms shut down their higher cost capacity. This makes the predictions for exit the same as those for TFP. Exit will come only from selection in the short run as it is reasonable to expect firms to be able to shut down or turn on exiting capacity faster than entry can occur. In the longer run the mass of firms in the industry also adjusts. The total effect of a minimum wage on exit depends on how much total output falls, i.e. how both the mass of firms and selection are affected. This total effect is larger, other things equal, when the price increase due to the minimum wage is greater.[4] We show that the price of the overall labor intensive good rises, thereby reducing output, but that this predicted price increase is *smaller*, and hence *exit is smaller*, exactly when TFP is predicted to rise. Thus, the predictions on the coefficients of our two key variables are not clear ex-ante. We show that the short run effect via

[1]Note that as the minimum wage creates a distortion where none existed, welfare must fall with the introduction of a binding minimum wage even if TFP rises in some industries with a minimum wage. Nor does higher TFP at the firm level in a sector imply greater comparative advantage in that sector: TFP rises because high cost capacity is shut down.

[2]For example, building the factory might be labor intensive, while producing the good might be capital intensive or vice versa.

[3]The opposite happens when entry costs are less capital intensive than production costs.

[4]In general equilibrium, the minimum wage acts like a supply shock: firms will not produce the labor intensive good until the price reaches a cutoff level, so that output is demand driven.

selection seems to dominate in the data. In other words, we find that there is exit with a minimum wage when the gap in capital intensity in entry and production costs is positive. This exit is more so the higher is this gap and the lower is the overall capital intensity.[5]

We not only provide a new model, that makes novel predictions, but we also test these predictions, and show they are very much present in the data. In our empirical specification, guided by our model, we regress changes in firm level productivity and probability of exit on changes in log minimum wage and its interactions with the gap in capital intensity of entry and production as well as industry-city level average capital intensity, while controlling for a rich set of firm and industry year fixed effects. In order to address concerns regarding endogeneity of minimum wage growth in counties populated by more productive and dynamic firms, we rely on the nature of spatial variation in minimum wage in China where regions with lower initial level of minimum wage are found to register a higher growth in minimum wage later in the sample in line with the (implicit) policy objective of increasing regional synchronization. Hence, we use lagged level of minimum wage as an instrument for future year-to-year change in minimum wage in order to tease out the causal effects.

Our theoretical predictions regarding effects of minimum wage on selection of firms and exit find strong empirical support. For example, an increase of 500 Chinese Yuan a year, a roughly 10% increase in the minimum wage, leads to a roughly 4.4% increase in firm total factor productivity (TFP). Similarly, the probability of exit rises by 2.8 percentage points.

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

The bulk of empirical research in labor economics has focused on effect of minimum wages on low-skill employment, in particular on fast food restaurants, with mixed results.[6] 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.[7] 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

[5]We do not look at the effects on unemployment: Chinese unemployment data is incomplete. Urban unemployment is based on a household survey and how well migrant workers without residence are counted is unclear. Rural unemployment is not measured. See Barrett (2020).

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

[7]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.

wages that are, in some cases, significantly higher than state or federal levels.[8] Recent work (Jardim, Long, Plotnick, van Inwegen, Vigdor and Wething, 2017) on a significant hike of the minimum wage in Seattle suggests a much more central role for minimum wages. For example, Luca and Luca (2019) show that higher minimum wages result in the exit of lower quality (rated by Yelp) restaurants.

The literature has also turned to looking at other impacts of the minimum wage. For example, Autor, Manning and Smith (2016) and Lee (1999) study the relationship between minimum wages and inequality using variation in state level minimum wages in the US, while DiNardo, Fortin and Lemieux (1996) follows a semi-parametric approach to do so. Monras (2019) argues that higher real minimum wages in a state in the US resulted in lower unskilled labor migration.[9] 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 as in Engbom and Moser (2018). There is also very recent work on the effect of an unanticipated hike in the minimum wage on the valuation of firms, for example Bell and Machin (2018), and on the incidence of this increase in cost, for example Harasztosi and Lindner (2019). Cooper, Luengo-Prado and Parker (2019) show that in the US minimum wage increases are associated with reduced total debt among households with low credit scores and higher auto debt.

In the context of the literature in international trade, the seminal work of Brecher (1974) and Davis (1998) study the effects of a minimum wage in general equilibrium in a homogeneous firm setup. Brecher (1974) looks at the effects of a minimum wage in a standard two good, two factor, two country Heckscher-Ohlin setting.[10] 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 work extends this strand of literature in international trade in the context of firm heterogeneity, thus enabling us to study the effect of minimum wage on selection of firms.

Our addition of firm heterogeneity to the perfectly competitive Heckscher-Ohlin setting is new in itself and gives novel predictions on selection. In addition, we take the model to the data to test for exit and productivity effects of minimum wages. Our empirical application to China is tailor-made for this. Different counties in China set different minimum wages, often at fairly high levels, and

[8] In the District of Columbia, the hourly minimum wage in January 2021 was \$15.00 for non tipped workers and \$5.00 for non tipped workers compared to a Federal one of \$7.25. Similar or higher rates are planned for many large cities, especially in California. See http://www.paywizard.org/main/salary/minimum-wage/California/california.

[9] We do not study migration in this paper, but hope to do so in future work.

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

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.[11]

There is a recent empirical literature on minimum wages in China. Wang and Gunderson (2012) look at minimum wages and employment in Eastern China using the standard difference in difference approach using data from 2003. They find little effect, and speculate this may be because the minimum wages are not enforced very strictly before 2004. In contrast, Fang and Lin (2015) using data from household surveys, find significant effects of minimum wages on employment. Huang, Loungani and Wang (2014) studies the effects of minimum wages on firm employment exploiting the fact that counties in China set different minimum wages and these vary over time, and find that minimum wages reduce employment, particularly for low wage firms.

A prominent paper in this literature, Hau, Huang and Wang (2020), finds 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." They attribute these effects to differences in management practices and "catch up" by low productivity firms in the face of competitive pressure. Mayneris, Poncet and Zhang (2018) find significant exit and improvement in TFP that they associate with increases in the minimum wage.[12] Our model provides a new reason why we might see productivity gains and exit in response to a minimum wage. Moreover, it predicts the pattern of such changes in a manner borne out by the data. To our knowledge, no one has looked for model based implications for selection and exit as we do.[13]

There is also a literature in macro and search that relates to our work. We are not the first ones to make the point that the denomination of entry costs relative to variable costs is crucial to generate selection. Bollard, Klenow and Li (2016) also focus on what goes into entry costs relative to variable costs and we build on the way they extract estimates of the labor share of entry costs for the US in their work to develop our gap measure. They do not focus on variation across industries in terms of capital intensity of entry cost relative to the capital intensity of production as we do.[14] Using a proxy for difference in relative capital intensity among young and old firms, we provide empirical

[11] We provide more background on the institutional setting and the patterns of minimum wages set in Section 4.

[12] Their baseline regressions include an exposure to minimum wages dummy (this is 1 if the average wage paid by the firm is below the minimum wage) and they find that TFP rose for exposed firms and more so after 2004. The minimum wage itself is not an explanatory variable in these regressions.

[13] For example, though Hau et al. (2020) look at the response of labor substitution, productivity, exit, export value and volume to the minimum wage as do we, their specification only uses one dimension of "bindingness", what they call the impact factor. The idea is that if the average wage paid relative to the minimum wage is low, the impact will be high and this impact will fall but at a decreasing rate as the ratio of average to minimum wage rises. In contrast, our model suggests that factor intensity in production versus entry costs will be critical and our specification is geared to look for this.

[14] They instead focus on whether entry cost, on average, should be denominated in terms labor or output, and more broadly on the role of the form of entry costs on economic development. They conclude that entry costs denominated in terms of labor are consistent with the facts. Since empirically the present discounted value of profits rises with the level of development, so must entry cost if there is free entry.

evidence that entry is indeed more labor intensive than production on average. Bento and Restuccia (2017) focuses on correlated idiosyncratic distortions or size dependent policies that have a greater impact on larger, more productive, firms and shows how such policies reduce the productivity of all establishments and hence aggregate TFP. Their setting is a Ricardian one, while our focus is on selection in a Heckscher-Ohlin setting due to minimum wages. Free entry plays a key role in both their model and ours. However, in their setting a minimum wage would not be a size dependent policy: with labor as the only factor of production, a minimum wage would apply uniformly across establishments.[15] Bento and Restuccia (2017) and Bento and Restuccia (2020) uncover quantitatively large impacts of such correlated idiosyncratic distortions on aggregate productivity.[16]

Davidson, Martin and Matusz (1988) build an elegant two sector two factor GE model embedding search and matching frictions in one of the sectors and uses the model to analyse implications of various policies, including minimum wages, on unemployment (both voluntary and involuntary). This is a valid alternative framework to ours. However, we observe only firm level average wages and total employment, without any further information on types of labor.[17] Because of the lack of rich labor market data, we model a frictionless competitive labor market and focus on implications of minimum wage on firm exit and productivity.

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

One could incorporate Melitz (2003) in a Heckscher-Ohlin setting as in Bernard, Redding and Schott (2007). Melitz (2003) highlights the cleansing effect of trade, and Bernard et al. (2007) show that this cleansing effect of trade liberalization is greater in the comparative advantage sector but

[15]In practice though, minimum wage policy is likely to be more binding for smaller firms that employ more unskilled workers and thus is expected to have the opposite effect of increasing firm and industry productivity in the Bento and Restuccia (2017) framework.

[16]Bento and Restuccia (2020) expand the analysis to account for differences in entry cost, misallocation and establishment size between manufacturing and services.

[17]Only in one year, 2004, is there a little more data as we observe skilled (more than high school) and unskilled labor.

only *in the presence of costly trade*.[18] The selection effect that are at the heart of our model come from allowing factor intensity to differ in entry costs relative to production costs. By assuming that factor intensity is the same in both entry and production costs within a sector, Bernard et al. (2007) rule out the selection effects at work in our model. The Eaton and Kortum (2002) approach to firm heterogeneity based on Ricardian comparative advantage has been augmented to include two factors of production.[19] We chose not to use this approach as we want to focus on the qualitative channels through which minimum wages affect outcomes, rather than estimate a quantitative model in this paper.

The paper proceeds as follows. The setting is explained in Section 2. Section 3 incorporates minimum wages, and lays out the key predictions of the model. It is the heart of the paper. Section 4 explains how minimum wages are set in China, points to some patterns in minimum wages over space, and explains our identification strategy. Section 5 tests the novel predictions of the model. Section 6 concludes. Details of some proofs are in the Appendix.

2 The Setting

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

Consumers have a utility function

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

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

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

and $\sigma_x = \frac{1}{1-\rho_x}$ and $\sigma_y = \frac{1}{1-\rho_y}$ are the constant elasticity of substitution between varieties of X and Y respectively. We assume that there are $j \in J$ counties.

Each county j has a capital endowment K^j and labor endowment L^j. These factors earn rental

[18] 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.

[19] See, for example, Chor (2010). This approach can be extended to incorporate minimum wages and obtain the kind of insights we obtain in our framework.

rate r^j and wage w^j. We will suppress j for simplicity hereon till needed. Firms in a county can make the county's variety of the two manufactured goods, x and y. Thus, within a county and for a given industry all manufacturing firms make the *same* variety of the manufactured good. How much a firm can make depends on its "capacity" as explained below.

The goods differ in their factor intensities, and we assume that good x is labor intensive both in terms of its production costs and in terms of its total costs (entry plus production costs). Producers of manufactured goods do not know their costs *ex-ante*, but discover them *ex-post*. First they pay the fixed entry costs in an industry of $f^e c^e(w, r)$. This entitles them to produce a single unit of the good at the cost $c(w, r)\theta$ where $c(\cdot)$ is the base unit cost and θ is the inverse of its realized productivity. Firms draw their θ from the distribution $f(\theta)$. A higher θ denotes lower productivity or higher costs. A firm is just a collection of random draws. A firm with many draws will pay the fixed cost for each draw and have a higher potential capacity. Firms with low cost draws will be willing to supply even at a low price, while firms with high cost draws will not. Firms with many low cost draws will have elastic supply at low prices, while firms with only a few draws all of which are high cost will be willing to supply (a small quantity) only if prices are high.[20] At a given price, if a firm has no viable draws, it exits. Firms with no draws at all have no supply at any price.[21]

There is free entry so that the number of draws made in the sector (which determines the supply curve in the sector) is endogenously determined. Each firm in a county is competitive and takes the price for the county's variety as well as factor prices as given. The cutoff, $\tilde{\theta}$, will determine which of its capacity draws a firm will choose to use in the given equilibrium. Firms choose to use the draws associated with costs below the (endogenous) selection cutoff as firms use all their profitable capacity. This will provide a model of firm level heterogeneity in supply functions. Of course, industry supply will just be the horizontal sum of the firm supply functions.[22] As firms are ex-post heterogeneous, some firms earn quasi rents. There are no financing frictions or credit constraints. In this way we get a standard competitive model with upward sloping supply curves, and hence, quasi-rents in the short run. The assumption that the production cost for the unit of capacity is not known at the time of paying the entry cost means that a firm (which is a collection of production cost draws) can earn quasi rents. Of course, ex-ante profits are zero due to free entry. Had production cost been known at the time of paying entry cost, the firm with the lowest production cost would expand and become a monopoly.

[20]Note that even this simple model predicts many of the patterns seen in data. See, for example Bernard, Jensen, Redding and Schott (2012). Firms with many draws will have a better best draw and a worse worst draw. Thus, by the logic of order statistics, larger firms will tend to be willing to supply at prices smaller firms will not and larger firms will look like they are more productive - a common feature of the data. In the presence of transport costs, firms whose best θ draws put their costs above the transport cost adjusted price will not export. This will give rise to another feature often pointed out in the data - larger more productive firms tend to export.

[21]Note that we need to assume a finite number of draws of capacity per firm, for our interpretation to work. With a continuum of draws, the distribution of each firm's draws would replicate the distribution of costs.

[22]Firms will be indifferent between the number of draws made as free entry will ensure the ex ante profits of a draw are zero.

Recall that each county produces its own variety of each of the two goods and all firms in a given county produce the *same* variety. X and Y are aggregate goods and made in a constant elasticity of substitution (CES) fashion from the individual varieties (x and y) made in different counties. Let p_x^j and p_y^j denote the *factory prices* of the variety made in county j. There is an integrated market for each variety of each good so that each county pays the factory price (which is obtained by the producer) plus any transport costs. Demand for a variety j of x (similarly for y) in county k is denoted by $x^{jk}(p_x^{jk}, P_X^k, P_Y^k, I^k)$. p_x^{jk} and p_y^{jk} denote the prices in county k of the variety manufactured in county j. We assume that transport costs take an iceberg form and that there are no transport costs incurred for a county's own variety. As a result, $p_x^{jk} = p_x^j T^{jk}$ and $p_y^{jk} = p_y^j T^{jk}$, where p_x^j is the factory price of variety j of good x, and T^{jk} is the iceberg transport cost between j and k. Note that the price of the aggregate good, P_X^k and P_Y^k will vary by county: well connected counties will tend to have lower aggregate prices than counties that are more remote. I^k denotes the income of county k.

Demand for a typical variety comes from all the counties and from the rest of the world (which can be treated as another county). The demand for variety j made by county j of good x comes from all counties $k = 1...J$ and takes the following form:

$$D_x^j(\cdot) = \sum_{k=1,..J} x^{jk}(p_x^{jk}, P_X^k, P_Y^k, I^k) = \sum_{k=1,..J} T^{jk} \left(\frac{p_x^j T^{jk}}{P_X^k}\right)^{-\sigma_x} \left(\frac{P_X^k}{P^k}\right)^{-\sigma} \frac{I^k}{P^k}.$$

The aggregate price index P_X^k (P_Y^k) for X (Y) in county k takes the usual form:

$$\begin{aligned} P_X^k &= \left(\sum_{j=1,..J} (p_x^j T^{jk})^{1-\sigma_x}\right)^{\frac{1}{1-\sigma_x}} \\ P_Y^k &= \left(\sum_{j=1,..J} (p_y^j T^{jk})^{1-\sigma_y}\right)^{\frac{1}{1-\sigma_y}}, \end{aligned}$$

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

$$P^k = \left(\sum_{s=X,Y} (P_s^k)^{1-\sigma}\right)^{\frac{1}{1-\sigma}}.$$

We will use these definitions when we come to the market equilibrium defined below. We will first analyze what happens in a single county and then extend our model to many counties. For a given county and sector (x or y), we first show how factory prices (p_x^j, p_y^j) define selection cutoffs for 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 demand to solve for equilibrium prices.

If the price of the good is p, only those suppliers who draw a production cost below p will produce, that is, $\theta c(w,r) \le p$, or $\theta \le \tilde{\theta}(\cdot) = \frac{p}{c(w,r)}$. This defines the marginal firm as having $\theta = \tilde{\theta}(\cdot)$. Given N, the mass of firms/draws, and $f(\theta)$, the density of θ, supply of the county's variety at price p is:

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

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. In the long run, firms enter until their expected profits equal the fixed cost of entry.

Lemma 1. *(i) If entry costs in a sector are more (less) capital intensive than production costs, then an increase in wage w makes selection stricter (weaker). (ii) If entry costs in a sector are paid solely in terms of the good being made in that sector so that entry and production costs have the same capital intensity, the identity of the marginal firm, $\tilde{\theta}$, is fixed and there are no selection effects coming from factor price changes.*

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

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

where the second line above follows from integration by parts.[23] Thus,

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

Note that $\frac{c^e(w,r)}{c(w,r)}$ moves in the same direction as $\tilde{\theta}$. If entry costs are less (more) labor intensive than production costs, then an increase in w will raise production costs by more (less) than entry costs and reduce (raise) the ratio of entry costs to production costs and make selection stricter (weaker). 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 production 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.

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

If $\frac{c^e(w,r)}{c(w,r)}$ is a constant, 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. Note that we only focus on the selection effect coming from factor price changes and call it "selection" for simplicity from this point forward. □

The free entry condition in equation (2) can be interpreted as the expected quasi rents, $\int_0^{\tilde{\theta}} F(\theta)d\theta$, being equal to $\frac{c^e(w,r)}{c(w,r)} f^e$, which can be thought of as the cost of entry in terms of the units of the good being made or the real cost of entry. This is what drives cutoffs. With a unit mass of firms entering, supply at a cutoff θ is just $F(\theta)$.

We incorporate a minimum wage into the model and derive comparative static properties of the model with a change in minimum wage. A binding minimum wage raises the wage rental ratio and makes selection stricter (which raises firm TFP and increases exit) when the entry costs are less labor intensive than production costs.[24]

3 Minimum Wages and Outcomes

How would a minimum wage affect the two key variables we focus on, exit and selection? Our analysis builds on the work of Davis (1998). As each variety is unique, and all goods are essential in demand, all goods are made and price equals cost for the marginal firm making each good. 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. As firms pay the minimum wage, their input decisions are dictated by it. Consider a particular county. Equilibrium will be given by the system of equations.

$$p_x = \tilde{\theta}_x(\bar{w}, r) c_x(\bar{w}, r) \tag{3}$$

$$p_y = \tilde{\theta}_y(\bar{w}, r) c_y(\bar{w}, r) \tag{4}$$

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

$$\int_0^{\tilde{\theta}_x(\bar{w},r)} F_x(\theta)d\theta = \frac{c_x^e(\bar{w}, r) f_x^e}{c_x(\bar{w}, r)} \tag{5}$$

$$\int_0^{\tilde{\theta}_y(\bar{w},r)} F_y(\theta)d\theta = \frac{c_y^e(\bar{w}, r) f_y^e}{c_y(\bar{w}, r)}. \tag{6}$$

[24]It acts like a negative supply shock: price rises but quantity falls. In contrast, an increase in the price of the labor intensive good will move the economy along its production possibility frontier raising its supply.

In equilibrium the total unit input requirement of factor $\ell = L, K$ in sector $i = x, y$, denoted by $A_{\ell i}$, depends on the minimum wage and the rental rate:

$$\begin{aligned} A_{Li}(\bar{w}, r) &= c_{wi}(\bar{w}, r)\bar{\theta}_i(\tilde{\theta}_i(\bar{w}, r)) + f^e c^e_{wi}(\bar{w}, r) \\ A_{Ki}(\bar{w}, r) &= c_{ri}(\bar{w}, r)\bar{\theta}_i(\tilde{\theta}_i(\bar{w}, r)) + f^e c^e_{ri}(\bar{w}, r), \end{aligned}$$

where $\bar{\theta}(\tilde{\theta}) = \int_0^{\tilde{\theta}} \theta f(\theta) d\theta$, $c_{wi}(w, r) = \frac{\partial c_i(w,r)}{\partial w} = a_{Ki}$ and $c_{ri}(w, r) = \frac{\partial c_i(w,r)}{\partial r} = a_{Li}$ and $a_{\ell i}$ denotes the unit input requirement in production of factor $\ell = L, K$ in sector $i = x, y$.[25] Demand for labor cannot exceed supply, and with a binding minimum wage there is unemployment, while capital markets clear so that:

$$N_x A_{Lx}(\bar{w}, r) + N_y A_{Ly}(\bar{w}, r) = L^D < L \tag{7}$$

$$N_x A_{Kx}(\bar{w}, r) + N_y A_{Ky}(\bar{w}, r) = K \tag{8}$$

where L^D denotes labor demand. Note that as in the standard model, for given factor prices, equations (7) and (8) are just straight lines, with their intersections defining the analogue of outputs: N_x and N_y.[26]

Income, I, in the county is

$$I = \bar{w}L^D + rK. \tag{9}$$

Goods market clearing will give product price for x:

$$D_x(p_x, I) = N_x(p_x, p_y = 1, \bar{w}, L^D, K)F_x(\tilde{\theta}_x(\cdot)). \tag{10}$$

We first analyze the effect of change in minimum wage on selection. Lemma 2 shows formally that an increase in the minimum wage makes selection stricter when capital intensity in entry exceeds that in production.

Lemma 2. *(Selection) An increase in the minimum wage makes TFP rise if* $(k^e_i - k_i) > 0$ *and fall if* $(k^e_i - k_i) < 0$*, where* $k^e_i = \frac{a^e_{Ki}}{a^e_{Li}}$ *and* $k_i = \frac{a_{Ki}}{a_{Li}}$ *are the capital intensities of entry and production for industry* $i = x, y$*. The effect is more pronounced the larger is* $|k^e_i - k_i|$ *and the smaller is the average or overall capital intensity.*

Proof. See the Appendix. □

[25] Clearly, $\bar{\theta}(\tilde{\theta})$ moves in the same direction as $\tilde{\theta}$.

[26] In a companion paper, see Bai, Chatterjee, Krishna and Ma (2021), we show that even with selection, the model retains its basic properties: the total input requirement, $A_{\ell i}$, has the same properties as the unit input requirement, $a_{\ell i}$, there is a positive supply response to price, and the Stolper-Samuelson, Rybczynski and HOS theorems go through.

Formally, Lemma 2 shows that

$$\begin{aligned}
\overset{\wedge}{\tilde{\theta}_i} &= v_i\left(\frac{s_{Li}^e - s_{Li}}{1-\bar{s}_{Ly}}\right)\hat{w} \\
&= v_i\left(\frac{1}{1-\bar{s}_{Ly}}\right)\left(\frac{-\omega\left(k_i^e - k_i\right)}{\left(\omega + k_i^e\right)\left(\omega + k_i\right)}\right)\hat{w}, \qquad (11)
\end{aligned}$$

where $i = x, y$; $\overset{\wedge}{\tilde{\theta}_i}$ denotes the percentage change in the cutoff productivity $\tilde{\theta}_i$; $v_i = \frac{\int_0^{\tilde{\theta}_i} F(\theta)d\theta}{F(\tilde{\theta}_i)\tilde{\theta}_i}$, with $v_i \in (0,1)$; s_{Li} (s_{Li}^e) are the cost share of labor for production (entry) of good i; $\bar{s}_{Li} = [(1-v_i)s_{Li} + v_i s_{Li}^e]$; and ω denotes the wage rental ratio. Thus, our theoretical prediction is that TFP in sector i rises with an increase in the minimum wage if entry is more capital intensive than production, and falls with it otherwise. The impact is more pronounced when the capital intensity in both entry and production fall or the difference in the capital intensity of entry and production is greater.

What about exit? Selection is one part of exit and operates in the short run. In the short run, existing firms can exit, i.e., shut down all their capacity. Assuming it takes time for new firms to enter, selection effects would dominate in the short run. Thus, if we do see the same pattern for exit as we see for selection, it could be because we are picking up exit primarily coming from short run effects. In the long run, exit occurs when output falls and comes from the change in the mass of firms and selection. Output falls more, other things given, when the price increases by more. Below we look for predictions on the direction and extent of price increases caused by a minimum wage. Lemma 3 addresses how prices respond to changes in minimum wage.

Lemma 3. *(Price) An increase in the minimum wage raises the price of the overall labor intensive good. The percentage increase in the price of the labor intensive good in response to a percentage increase in the minimum wage of $\hat{w}$ is given by:*

$$\begin{aligned}
\hat{p}_x &= \left[\frac{\bar{s}_{Lx} - \bar{s}_{Ly}}{(1-\bar{s}_{Ly})}\right]\hat{w} > 0 \qquad (12) \\
&= \left[\frac{\left(\frac{\omega(k_y - k_x)}{(\omega+k_x)(\omega+k_y)}\right) - v_x\left(\frac{(k_x^e - k_x)}{(\omega+k_x)(\omega+k_x^e)}\right) - v_y\left(\frac{\left(k_y - k_y^e\right)}{(\omega+k_y)\left(\omega+k_y^e\right)}\right)}{\left(\frac{k_y}{\omega+k_y} - v_y\left(\frac{\left(k_y - k_y^e\right)}{(\omega+k_y)\left(\omega+k_y^e\right)}\right)\right)}\right]\hat{w}, \qquad (13)
\end{aligned}$$

where $\bar{s}_{Li} = [(1-v_i)s_{Li} + v_i s_{Li}^e]$ is the weighted average of cost shares of labor in production and entry in good i. The weight on the cost share of labor in entry, v_i, equals $\frac{\int_0^{\tilde{\theta}_i} F(\theta)d\theta}{F(\tilde{\theta}_i)\tilde{\theta}_i}$.

Proof: In the Appendix.

From equation (12) we see that an increase in the minimum wage raises the price of good x if

$\bar{s}_{Lx} > \bar{s}_{Ly}$.[27] Expanding equation (12) shows that taking the capital intensity of y in production and entry as given, an increase in the capital intensity in production in x reduces the price increase caused by the minimum wage (the first term).[28] The second term has the same form as that in Lemma 2 but the opposite sign. Recall

$$\overset{\wedge}{\tilde{\theta}}_i = \left[(v_i)\left(\frac{1}{1-\bar{s}_{Ly}}\right)\right]\left(\frac{-\omega\left(k_i^e - k_i\right)}{\left(\omega + k_i^e\right)\left(\omega + k_i\right)}\right)\hat{w} \tag{14}$$

so that when $\frac{\left(k_i^e - k_i\right)}{\left(\omega + k_i^e\right)\left(\omega + k_i\right)}$ rises, $\overset{\wedge}{\tilde{\theta}}_i$ falls, TFP and exit rise due to stricter selection. However when $\frac{\left(k_i^e - k_i\right)}{\left(\omega + k_i^e\right)\left(\omega + k_i\right)}$ rises in equation (13), $\hat{p}^x$ falls and overall exit (from selection and the mass of firms) *falls*. As a result, though we can argue that the same variables should be used when examining the effect on exit and TFP, the predicted signs of these variables for exit will differ in the short run and long run.

To better understand Lemma 3, let us re-visit the relationships between factor prices and product prices. Consider the determination of factor prices given product prices in the absence of a minimum wage in Figure 1. The curves $p_x^E = \tilde{\theta}_x^E c_x(w, r)$ and $p_y^E = 1 = \tilde{\theta}_y^E c_y(w, r)$ are depicted as the two thick curves, where the superscript *E* denotes equilibrium. Thus, $\tilde{\theta}_i^E = \tilde{\theta}_i^E(w^E, r^E)$. As x is labor intensive, the former is flatter than the latter at any given $\frac{w}{r}$. At the given equilibrium product prices, and no minimum wage, factor prices are given by the intersection of the two curves, which gives equilibrium factor prices, (w^E, r^E).

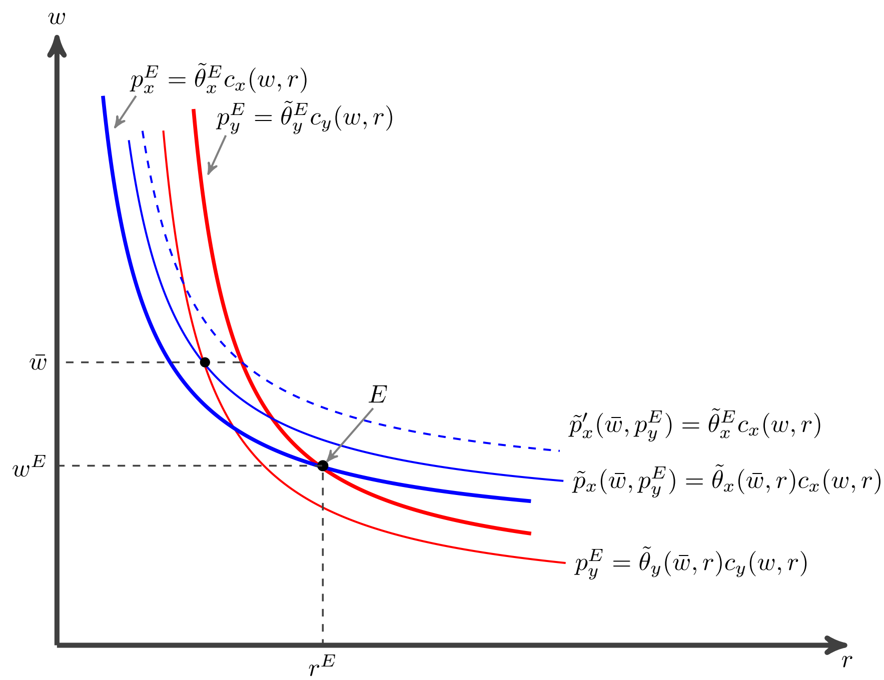
A minimum wage, $\bar{w}$, which is binding at equilibrium prices in the absence of a minimum wage is depicted in Figure 1. At (p_x^E, p_y^E) the minimum wage is binding as $\bar{w}$ exceeds w^E. Since good y can afford to pay a higher r (along its price equal to cost curve) than x can, at these prices only the variety of good y is made. As a result, given $p_y^E = 1$, the supply of x is zero until its price reaches the cutoff price, the level such that price just covers cost and both goods can afford to be made given the minimum wage. As a result, demand and supply for x intersect at a higher price and lower quantity. In defining this cutoff price one needs to incorporate the fact that a higher price changes selection in both goods, which in turn changes the cutoff price needed to produce good x. The equilibrium price with a minimum wage when all this is taken into account is defined as $\tilde{p}_x(\bar{w}, p_y^E)$. At this or higher prices of good x in Figure 2, both goods are made. Below it, only good y is made.

We can relate the three terms in equation (13) to what is going on in the background using Figure 1. The price equal cost curves in the equilibrium with the minimum wage are depicted by the thin solid red and blue curves in Figure 1. Note that they intersect at $\bar{w}$. The price equal to cost curves in the equilibrium without a minimum wage are depicted by the bold red ad blue curves and intersect at

[27]It is easy to check that this is ensured if x is labor intensive in production and entry costs in the two sectors have the same labor intensity.

[28]This will be captured by fixed effects in the regressions.

Figure 1: Product Prices and Factor Prices with a Minimum Wage



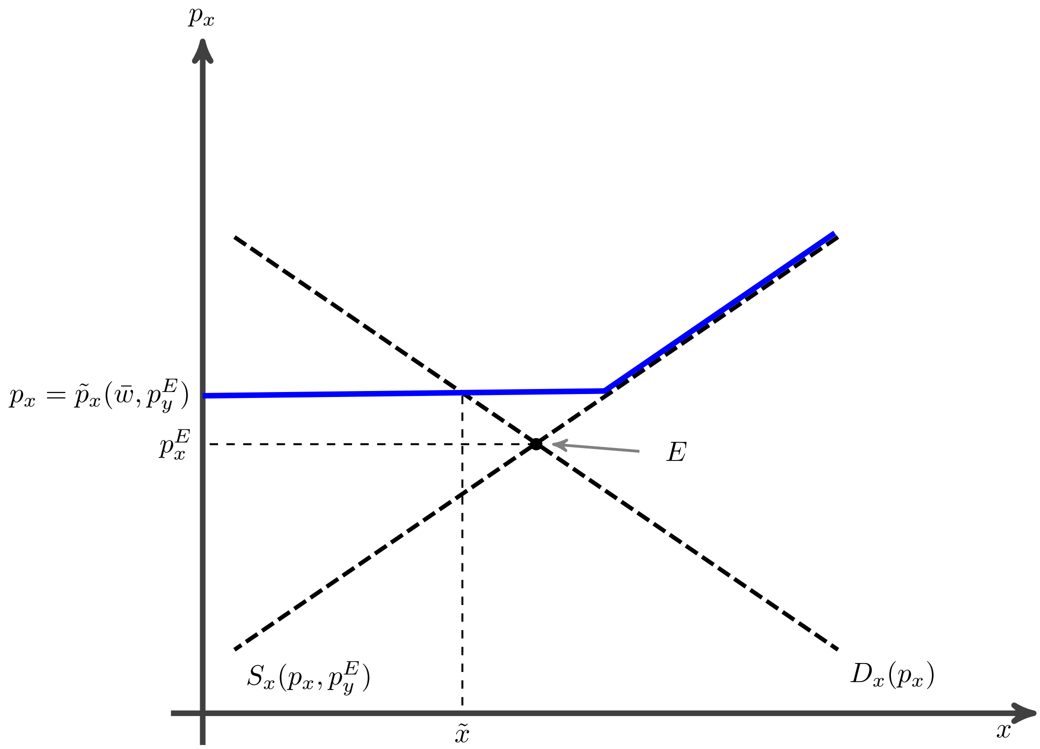
the undistorted equilibrium factor prices. Starting from the undistorted equilibrium, with cutoffs fixed in x and y it can be seen that price of x needs to rise to $\tilde{p'}_x$ for good x to be made. This is depicted by the dashed blue curve. Note that it intersects the bold red curve at the minimum wage. The more labor intensive is good x, the larger is this price increase. This is what lies behind the presence of the term $\left(\frac{\omega(k_y-k_x)}{(\omega+k_x)(\omega+k_y)}\right)$ in equation (13).

Now allow the cutoffs to change. As the price of x has risen, w has risen and r has fallen. The free entry conditions thus dictate that selection becomes stricter in x and weaker in y, $\tilde{\theta}_x(\cdot)$ falls and $\tilde{\theta}_y(\cdot)$ rises. Due to the selection cutoff in y rising, the solid red curve shifts in to the thin solid red one. This is what lies behind the term $-v^y\left(\frac{\left(k_y-k_y^e\right)}{(\omega+k_y)\left(\omega+k_y^e\right)}\right)$ in equation (13).

The selection in x becoming stricter shifts the price equal to cost for x outward, but the price for x must be such that the price equal to cost curve for x intersects the thin red curve for y exactly at the minimum wage. These two factors are what lie behind the dashed blue curve moving inward to the thin solid blue curve. This is captured by the term $-v^x\left(\frac{(k_x^e-k_x)}{(\omega+k_x)(\omega+k_x^e)}\right)$. Note that as Lemma 3 shows, even with selection, as long as $\bar{s}_{Lx} - \bar{s}_{Ly} > 0$, the net effect of a higher minimum wage is a higher price of x and thus a lower demand and production of x.

It is worth pointing out that the output is driven by demand, not supply (which is horizontal) when the minimum wage binds. Overall, the minimum wage acts like a negative supply shock in the labor intensive sector. This raises price and reduces quantity sold. The output of x is lower as shown in Figure 2, despite a higher equilibrium price, $\tilde{p}_x(\bar{w}, p_y^E)$. Supply is $NF(\tilde{\theta}_x(\cdot))$ so this must fall as well. Note that the fall in $\tilde{\theta}_x(\cdot)$ drives what we call exit due to selection. A fall in the mass of firms in x

Figure 2: Supply and Demand of x with a Minimum Wage



would be exit due to a change in the mass of firms. Our results show that overall exit must occur in x.

We focus on our novel predictions on selection and exit in our empirical work. Our theoretical framework predicts that selection becomes stricter with a rise in minimum wage, and this in turn raises firm level productivity, and this effect is stronger the lower is the capital intensity of production and the higher is the gap in capital intensity between entry and production. In the next section we show that the data supports selection effects driving exit as would be the case in the short run.

4 The Data and Patterns

4.1 How is the Minimum Wage Set in China?

The Chinese Government published its first formal "*Minimum Wage Regulation*" in 1993, 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 counties adopted minimum wages and the growth in minimum wage was small.

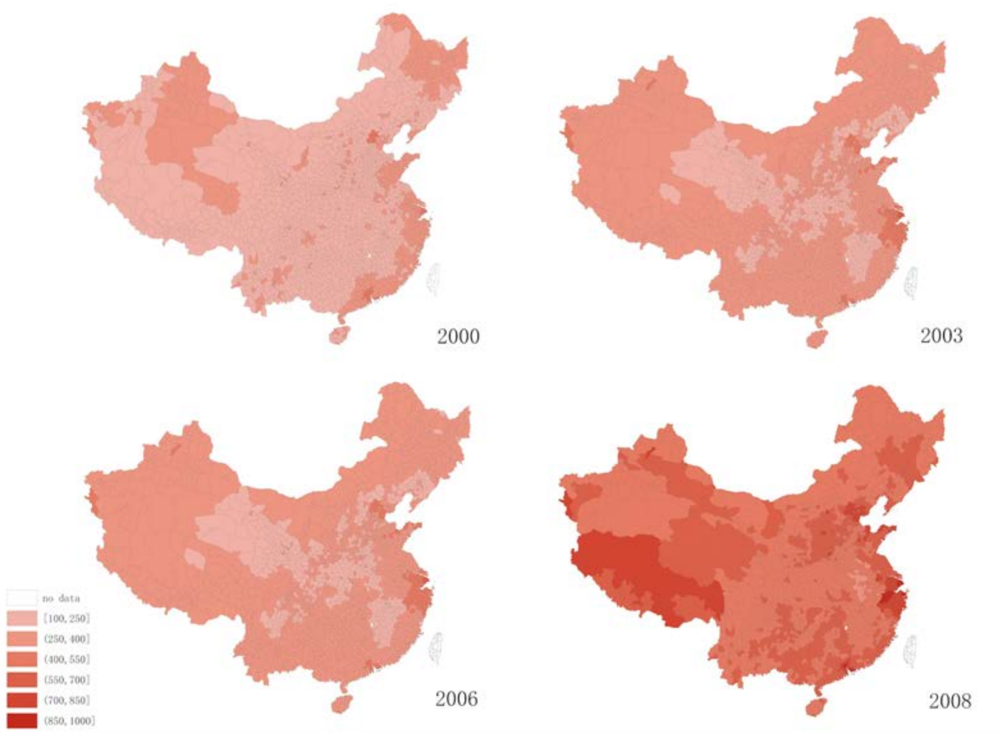
In March 2004, the Ministry of Human Resource and Social Security issued a new regulation, "*The 2004 Regulation on Minimum Wage*", which established a more comprehensive coverage of minimum wage standards. The regulation provided a guideline formula for minimum wage.[29] Notably, it also

[29]There are two methods that the local governments can use to set their own level of minimum wages. *The proportion*

strengthened the enforcement by raising the non-compliance penalty[30] and requiring more frequent adjustments – at least once every two years (Hau et al., 2020; Mayneris et al., 2018).

In practice, the adjustments of minimum wages are set by the provincial administration (Gan, Hernandez and Ma, 2016), while counties negotiate with their provincial administration to determine their actual level of minimum wage (Du and Wang, 2008; Casale and Zhu, 2013). Counties in each province are divided into several groups according to their levels of economic development. Within each group, counties generally have the same minimum wage and follow the same adjustment. However, if a county is substantially less developed than other counties in the group, it can be allowed to adopt the minimum wage of the next less-developed group (Gan et al., 2016).

Figure 3: Geography of Minimum Wages, 2000-2008



This figure depicts monthly minimum wages in Chinese Yuan across counties in China between 2000 and 2008.

The monthly minimum wage data used here was hand collected from local government's websites and statistical bulletins.[31] Figure 3 illustrates the geographical difference in minimum wages across counties of mainland China. It also shows the evolution of minimum wage over time by presenting

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

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

[31]We are grateful to Churen Sun, Yi Huang, and Gewei Wang for generously sharing their minimum wage data.

separately the geographical distribution in 2000, 2003, 2006, and 2008. Several interesting patterns emerge: First, there are large variations in minimum wages across regions: the coastal areas usually set higher minimum wages than the western regions. For example, in 2004, Shanghai had the highest minimum wage, at 635 Chinese Yuan per month (about 77 US dollars at the 2004 exchange rate), while most counties in Henan province in central China had the lowest level of minimum wage at 240 Chinese Yuan (29 US dollars). Second, there is significant, but unbalanced growth in minimum wages across regions over time, with the western regions catching up very quickly in later years. Thirdly, within each province, there are usually several groups of counties that adopt different levels of minimum wages – usually the capital city and other large counties adopt higher minimum wage levels than smaller counties. For example, in 2004, within Guangdong province, the highest monthly minimum wage was in Shenzhen at 610 Chinese Yuan (74 US dollars), while the lowest was set in Heyuan at 290 Chinese Yuan (35 US dollars).

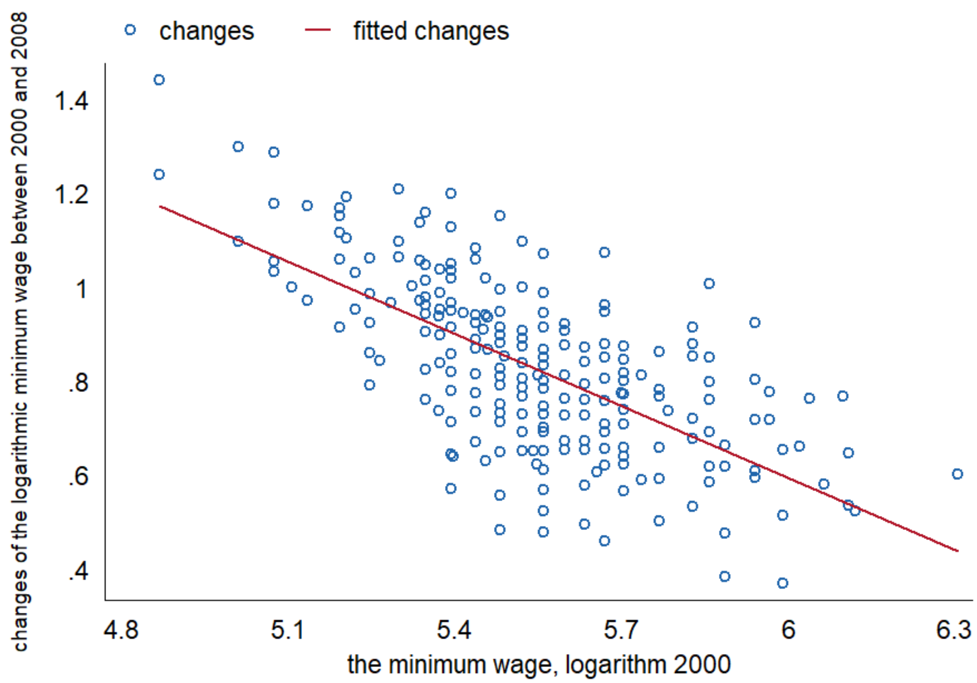
4.2 Endogeneity of Minimum Wage

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

To correct for endogeneity bias, we adopt an instrumental variable strategy. Figures 3 and 4 demonstrate that initially low-minimum wage areas experienced a high growth in minimum wage in later years, confirming a clear policy initiative of bringing minimum wages closer together. Specifically, we depict monthly minimum wages across counties between 2000 and 2008 in Figure 3 and the relationship between the changes in (log) minimum wages (2000-2008) against the levels of initial (log) minimum wage (2000) in Figure 4. We use this insight to instrument the annual changes in minimum wage by the 4-year lagged minimum wage.[32] This lead to a first-difference setup. We also allow for firm-specific and industry-specific dynamic trends and the identification comes from firms' time-varying exposure to minimum wage changes.

[32]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 *changes*. Topalova (2007) also uses initial tariffs in India interacted with a post-liberalization dummy as an additional instrument for tariff *levels*. Our use of the initial minimum wage as an instrument for future *changes* in the minimum wage is closer to the setup in the former.

Figure 4: Minimum Wages: Changes (2000-2008) v.s. Initial (2000)



This figure presents the changes in (log) minimum wages over 2000-2008, against the level of (log) minimum wage in 2000 for each county in China.

4.3 Chinese Firm Data

In addition to county level minimum wage data, our main empirical results are based on data from the Annual Surveys of Industrial Production (ASIP) during the period 1998-2007. This data is collected by the China National Bureau of Statistics (CNBS). The 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). The dataset contains information on the firms' industry of production, ownership type, age, employment, capital stocks, total material inputs, value of output and value-added, as well as the value of the firms' output that is exported. There is no information on prices and quantity separately. Monetary values in the ASIP data including the total revenue, firm average wage, and capital are all measured in thousand Chinese Yuan per year. Thus we define the minimum wage in terms of the same unit, i.e., thousand Chinese Yuan per year, for comparison. We follow Hau et al. (2020) to construct the sample used in the empirical analysis.[33]

Table 1 provides the summary statistics for the sample. The mean, standard deviation and the

[33]This includes dropping observations with missing, zero, or negative values for key production variables, excluding observations if certain critical variables are below the 1% percentile or above the 99% percentile of its annual distribution, and limiting our sample to firms that are present for at least two years. See Appendix B in Hau et al. (2020) for more detailed data cleaning procedures.

1st, 10th, 50th, 90th and 99th percentile values are given for each variable to help interpret the size of the estimates below. As discussed previously, we adopt a first-difference setup and use lagged minimum wage as the instrument for future change in minimum wage in our empirical specifications to correct for potential endogeneity bias. Thus we report the annual changes in the (log) values of key time-varying variables.

Exit is a dummy variable that indicates whether firm f is observed in $t-1$ but not in t. Recall that the survey data has a lower bound on firm revenue. Could a firm be dropped from the survey data without exiting from the industry? This could affect our estimates. However, Brandt, Van Biesebroeck and Zhang (2014) and Mayneris et al. (2018) argue that the churning in the sample due to the minimum-size threshold is virtually nonexistent. They show that exit from the survey is exit from the industry as firms that are in the survey stay in the survey even if they fall below the cutoff levels for firms to be included in the survey. As a result, it is safe to treat firm's disappearing from the ASIP data as exit from production. Mean exit is about 9.7% a year. This is close to that in the US. Using information on output and input deflators as in Brandt, Van Biesebroeck and Zhang (2012) we estimate the total factor productivity (TFP) for each firm following Levinsohn and Petrin (2003).[34] The mean annual productivity growth is around 6.1%. At the 10th percentile, TFP growth is negative 40% and for the first percentile it is a whopping -137%.

To see the extent to which minimum wages were binding, we also look at the ratio of the firm's average wage to the county-level minimum wage. The lower this ratio for a firm, the more binding the minimum wage is likely to be. Note that the mean of this ratio is 2.687 and around 2% of the firm-year observations have the average wage lower than the minimum wage. We follow Hau et al. (2020) to construct the impact function to proxy for the non-linear impact of increases in the minimum wage on a firm's average wage increase.[35] In their paper this measures the heterogeneous exposure of firms to minimum wage shocks. In our model, this heterogeneity is model based and arises from the differences in the capital intensity in entry and production.

The capital intensity is constructed as the average capital intensity for each industry-city pair. Capital intensity varies considerably. To proxy for the difference in the capital intensity in entry and in production, we leverage the fact that the total cost of old firms and of young ones will differ in terms of the weight on entry costs.

The observed capital intensity, $\bar{k}$, at the firm level is a weighted average of the capital intensity in

[34]TFP estimates should reflect differences in costs of production, while according to our model, entry costs are also incurred. To deal with this we estimate TFP for old firms only in order to reduce the influence of entry costs in productivity estimation. The results are similar and are reported in Tables B.5 and B.6 in Appendix B. Our results are also robust to different TFP measurements as reported in the same table.

[35]Specifically, we follow Hau et al. (2020) and impose a convex function $IF_{ft} = (\frac{w_{f,t-1}}{w^{min}_{c,t-1}})^{-(k+1)}$, where $w_{f,t-1}$ is (lag) firm average wage, $w^{min}_{c,t-1}$ is the (lag) county minimum wage, and the convexity parameter k is estimated using a maximum likelihood-based non-linear least square. Intuitively, if the average wage paid relative to the minimum wage is low, the impact will be high, and this impact will fall but at a decreasing rate as the ratio of average to minimum wage rises.

Table 1: Summary Statistics

		Mean	S.D.	P1	P10	P50	P90	P99
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
Exit	X_{ft}	0.097	0.296	0	0	0	0	1
Δ Productivity	ΔTFP_{ft}	0.061	0.487	-1.375	-0.405	0.055	0.527	1.548
Δ ln (Min. Wage)	$\Delta \ln w_{ct}^{min}$	0.107	0.077	0.000	0.009	0.101	0.208	0.355
Firm wage/Min. Wage	w_{ft}/w_{ct}^{min}	2.687	1.583	0.708	1.354	2.281	4.427	9.299
Impact Function	IF_{ft}	0.508	5.577	0.105	0.228	0.439	0.747	1.645
ln (K/L): Average	$\ln \bar{k}_{ic}^{avg}$	4.023	0.588	2.537	3.204	4.077	4.711	5.271
ln (K/L): Gap	$\ln \bar{k}_{ic}^{gap}$	0.018	0.627	-1.801	-0.620	0.018	0.678	1.828
Number of observations	1,026,014							

Note: Monetary values in the ASIP data, including the minimum wage, firm average wage, capital, are measured in thousand Chinese Yuan per year. Exit is a dummy variable that indicates whether firm f is observed in the ASIP data in $t-1$ but not in t. Productivity is measured for each firm-year observation following Levinsohn and Petrin (2003). The Impact Function IF_{ft} measure is constructed following Hau et al. (2020), see also footnote 35 for details. The average capital intensity is calculated at industry (i)-city (c) level. The difference in the capital intensity in entry and in production (i.e. the gap) is calculated at industry-city level as the (log) average capital intensity for the young firms minus that for the old firms.

entry (k^e) and in production (k) so that

$$\bar{k} = \Lambda k^e + (1-\Lambda)k$$

where $\Lambda = \frac{a_L^e}{a_L^e + a_L}$ is the share of labor used in entry. We would expect young firms to incur more entry costs than older ones so that their weight on entry costs will be greater, i.e., $1 \geq \Lambda^{young} > \Lambda^{old} \geq 0$. Hence the difference of capital intensity between young and old firms is,

$$k^{young} - k^{old} = (\Lambda^{young} - \Lambda^{old})(k^e - k). \tag{15}$$

Since $(\Lambda^{young} - \Lambda^{old}) > 0$, the difference in observed capital intensity of young and old firms in an industry is monotonically related to $(k^e - k)$ and can give us a measure of the gap between capital intensity in entry and production. In our empirical specifications, we define young firms as those younger than 4 years, while those who have been operating for more than 4 years are defined as old firms. We use the difference between the (log) average capital intensity of young and old firms to proxy for the difference in the capital intensity in entry and in production costs.[36] As seen from Table

[36]One could be concerned about using only age to define our proxy for $k^e - k$. It could be that some old firms are expanding fast and so should have overall capital intensity closer to the capital intensity of young firms than stagnant old firms. For this reason, we construct an additional proxy for the difference in capital intensity ($k^e - k$) using the capital intensity of young firms versus slow growing old firms at the industry-city level. The results using this alternative measure are shown in Tables B.5 (column 3) and B.6 (column 4) in Appendix B for TFP and Exit respectively. Though the estimates change slightly, the signs of the coefficients are the same. The ideal way to deal with the above concern is to look at changes in capital intensity over time within firms. If capital intensity falls with age after controlling for other firm-specific factors like its growth, we would infer that $k^e - k$ is positive, while if it rises with age we would infer the opposite. To move in this direction, we estimate industry-city level capital intensity of young versus old firms after

1, this gap in capital intensity measure displays substantial variation.

5 Empirical Results

Our theoretical framework predicts that a binding minimum wage will make selection stricter when capital intensity in entry exceeds that in production, and weaker when the opposite happens. Firms with all their capacity having a cost above the cutoff will exit while surviving firms drop their highest cost capacity, thereby becoming more productive on average. As discussed in Section 3, this generates two major empirical predictions, the first on TFP at the firm level and the second on the probability of exit.

5.1 TFP and the Minimum Wage

From equation (11) we see that TFP rises with an increase in the minimum wage if entry is more capital intensive than production, and falls with it otherwise. The impact is more pronounced when the capital intensity in both entry and production fall or the difference in the capital intensity of entry and production is greater. The right hand side of equation (11) is a non linear function of a number of variables. The first is $(1-\bar{s}_{Ly})$, which is common to all goods so can be treated as a constant. The second is the capital intensity gap between entry and production, $(k_i^e - k_i)$, which we proxy for using the difference in industry-city level capital intensity of the young versus the old firms ($\bar{k}_{ic}^{gap}$). The third term is $(\omega + k_i^e)(\omega + k_i)$, which we proxy for by $\bar{k}_{ic}^{avg}$, the average or overall industry-city level capital intensity, since given $(k_i^e - k_i)$, the only way k_i^e and k_i can move is if they move together and thereby move the average capital labor ratio.

In our empirical specification this nonlinear response of TFP is captured by a saturated regression in the key variables, namely the gap in capital intensity (proxied for by $\bar{k}_{ic}^{gap}$), the overall industry-city capital intensity $\bar{k}_{ic}^{avg}$, and the percentage change in the minimum wage. We can omit the level of overall industry-city capital intensity and the gap measure since we have firm fixed effects. Thus our estimating equation is:

$$\begin{aligned} \Delta TFP_{ft} &= \beta_1 \Delta \ln w_{ct}^{min} + \beta_2 \left[\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min}\right] + \beta_3 \left[\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}\right] \\ &+ \beta_4 \left[\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}\right] + \lambda_{it} + \lambda_f + \varepsilon_{ft}. \end{aligned} \tag{16}$$

We expect $\beta_2 > 0$ and $\beta_3 < 0$. This change in TFP (whether positive or negative) is larger when $\bar{k}_{ic}^{avg}$ is smaller, which is captured by $\beta_4 < 0$. Intuition would also suggest that on average, an increase

controlling for firm fixed effects. These results are shown in Tables B.5 (column 4) and B.6 (column 5) in Appendix B. Once again the results are robust. Our results are also robust to using an alternative age cutoff to separate young and old firms (column 2 in Table B.5 and column 3 in Table B.6).

in the minimum wage would raise TFP. This suggests $\beta_1 > 0$. In addition we add firm fixed effects (λ_f) and industry-time fixed effects dummies (λ_{it}).

Table 2: Firm TFP and Minimum Wage

Firm TFP	(1)	(2)	(3)	(4)	(5)
$\Delta \ln w_{ct}^{min}$	0.553**	5.202***	5.183***	3.893***	3.881***
	[0.276]	[0.628]	[0.627]	[0.712]	[0.712]
$\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min}$	-0.037	0.004	0.706***	0.547**	0.547**
	[0.057]	[0.057]	[0.238]	[0.230]	[0.230]
$\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$		-1.144***	-1.138***	-0.810***	-0.810***
		[0.146]	[0.146]	[0.173]	[0.173]
$\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$			-0.176***	-0.136**	-0.136**
			[0.059]	[0.057]	[0.057]
$IF_{ft} \times \Delta \ln w_{ct}^{min}$					0.016
					[0.015]
IF_{ft}					-0.002
					[0.002]
Firm	Y	Y	Y	Y	Y
Year	Y	Y	Y		
Industry $\times$ Year				Y	Y
Observations	838,528	838,528	838,528	838,528	838,528

Note: We report instrumental variable regressions to capture the effect of minimum wage changes on changes in firm TFP. The results of corresponding OLS regressions are reported in Table B.1 in Appendix B. Columns (1)-(4) report the baseline regression results. Column (5) adds the impact function that is central in Hau et al. (2020) as well as its interaction with the log change in the minimum wage. The firm-year level TFP measure is estimated at the 4-digit industry level following the control function method proposed in Levinsohn and Petrin (2003). $\ln \bar{k}_{ic}^{gap}$ measures the difference in (log) capital intensity between entry and production at the industry-city level and is constructed using the difference in capital intensity between young and old firms, while $\ln \bar{k}_{ic}^{avg}$ measures the overall industry-city capital intensity. The Impact Function IF_{ft} measure is constructed following Hau et al. (2020), see also footnote 35 for details. Robust standard errors in parentheses, clustered at the county-year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The Sanderson-Windmeijer (SW) chi-squared and F statistics test show that we can reject the null hypothesis of underidentification and weak identification separately for all of our endogenous variables (i.e. minimum wage and its interaction with other variables). SW chi-squared and F statistics of the baseline regression in column (4) are in Appendix B Table B.3.

In Table 2, we report the results for firm productivity, which clearly support the theoretical predictions. All the columns report the IV estimates as discussed in Section 4.2. With firm fixed effects, the estimates are driven by within firm variations. We build up to our baseline specification (column 4) in equation (16) by adding variables one at a time in columns (1)-(3). Columns (1)-(3) have year fixed effects which allows for time trends in a flexible way, while columns (4)-(5) have the more demanding industry-year fixed effects which allow these time trends to vary by industry. As predicted, the coefficient estimates $\hat{\beta}_1 > 0$, $\hat{\beta}_2 > 0$, $\hat{\beta}_3 < 0$ and $\hat{\beta}_4 < 0$ and they are highly significant in columns (3)-(5).

Column (5) adds the impact function that is central in Hau et al. (2020) as well as its interaction with the log change in the minimum wage. Note that neither is significant once our controls are in place. This suggests that the heterogeneous treatment effects in their setup are captured by the model based variables we control for in the baseline regression so that the impact function has no additional explanatory power.

5.2 Firm Exit and the Minimum Wage

As explained, exit comes from both selection and changes in the mass of entry. When selection gets stricter due to the minimum wage, as it does when the gap is positive, some firms may exit. This suggests using the same specification as the TFP regression for the exit one. One difference in the exit regression is that we control for changes in the firm level TFP. This is because firms with higher average cost draws, or lower TFP, are more likely to exit.[37] The coefficients are expected to have the same signs as the TFP regression if selection is driving exit.

The benchmark regression for testing for exit is thus given by the linear probability model:

$$\begin{aligned} X_{ft} &= \beta_1 \Delta \ln w_{ct}^{min} + \beta_2 \left[\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min} \right] + \beta_3 \left[\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min} \right] \\ &+ \beta_4 \left[\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min} \right] + \Delta TFP_{ft} + \lambda_{it} + \lambda_f + \varepsilon_{ft}, \end{aligned} \tag{17}$$

where the dependent variable X_{ft} is a dummy variable that indicates whether firm f is active in $t-1$ but not in t. All estimates are estimated using the IV approach. Based on the model, we expect that $\beta_1 > 0$, $\beta_2 > 0$, $\beta_3 < 0$, and $\beta_4 < 0$ if exit from selection dominates. All the columns in Table 3 exactly correspond to their counterparts in Table 2. The estimates in Table 3 suggest that exit is being driven by selection effects as the sign and significance of the coefficients follows the same pattern as in Table 2.[38]

5.3 Economic Interpretations

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

First we discuss the effects of an increase of 500 Chinese Yuan in the average annual minimum

[37] At the firm level, the possibility of reverse causality between exit and TFP seems reasonably limited, and hence, we include changes in the TFP as a control in our baseline results. As a robustness check, we control for changes in the *residual* TFP from our baseline TFP regression to account for the change in firm level TFP that cannot be explained by changes in the minimum wage. The results are quite similar. They are reported in column (1) Table B.6 in Appendix B.

[38] Similar results are obtained for regressions run on SOEs, foreign firms, and exporters separately. See Tables B.5 (columns 6-8) and B.6 (columns 7-9) in Appendix B.

Table 3: Firm Exit and Minimum Wage

Firm Exit	(1)	(2)	(3)	(4)	(5)
$\Delta \ln w_{ct}^{min}$	0.447	0.967*	0.962*	1.123**	1.112**
	[0.378]	[0.505]	[0.505]	[0.562]	[0.566]
$\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min}$	0.034**	0.039**	0.204***	0.150**	0.150**
	[0.018]	[0.018]	[0.072]	[0.066]	[0.066]
$\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$		-0.127**	-0.126*	-0.195**	-0.195**
		[0.065]	[0.065]	[0.087]	[0.087]
$\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$			-0.041**	-0.031**	-0.031**
			[0.017]	[0.016]	[0.016]
ΔTFP_{ft}	-0.009***	-0.009***	-0.009***	-0.008***	-0.008***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
$IF_{ft} \times \Delta \ln w_{ct}^{min}$					0.014
					[0.013]
IF_{ft}					-0.002
					[0.002]
Firm	Y	Y	Y	Y	Y
Year	Y	Y	Y		
Industry $\times$ Year				Y	Y
Observations	960,898	960,898	960,898	960,898	960,898

Note: We report instrumental variable regressions to capture the effect of minimum wage changes on changes in firm exit. The results of corresponding OLS regressions are reported in Table B.2 in Appendix B. Columns (1)-(4) report the baseline regression results. Column (5) adds the impact function that is central in Hau et al. (2020) as well as its interaction with the log change in the minimum wage. Exit is a dummy variable that indicates whether firm f is observed in the ASIP data in $t-1$ but not in t. The firm-year level TFP measure is estimated at the 4-digit industry level following the control function method proposed in Levinsohn and Petrin (2003). The change in TFP when a firm exit in year t is the lagged TFP change ($TFP_{f,(t-1)} - TFP_{f,(t-2)}$), i.e., the change in TFP in the last year the firm was observed. $\ln \bar{k}_{ic}^{gap}$ measures the difference in (log) capital intensity between entry and production at the industry-city level and is constructed using the difference in capital intensity between young and old firms, while $\ln \bar{k}_{ic}^{avg}$ measures the overall industry-city capital intensity. The Impact Function IF_{ft} measure is constructed following Hau et al. (2020), see also footnote 35 for details. Robust standard errors in parentheses, clustered at the county-year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The Sanderson-Windmeijer (SW) chi-squared and F statistics test show that we can reject the null hypothesis of underidentification and weak identification separately for all of our endogenous variables (i.e. minimum wage and its interaction with other variables). SW chi-squared and F statistics of the baseline regression in column (4) are in Appendix B Table B.4.

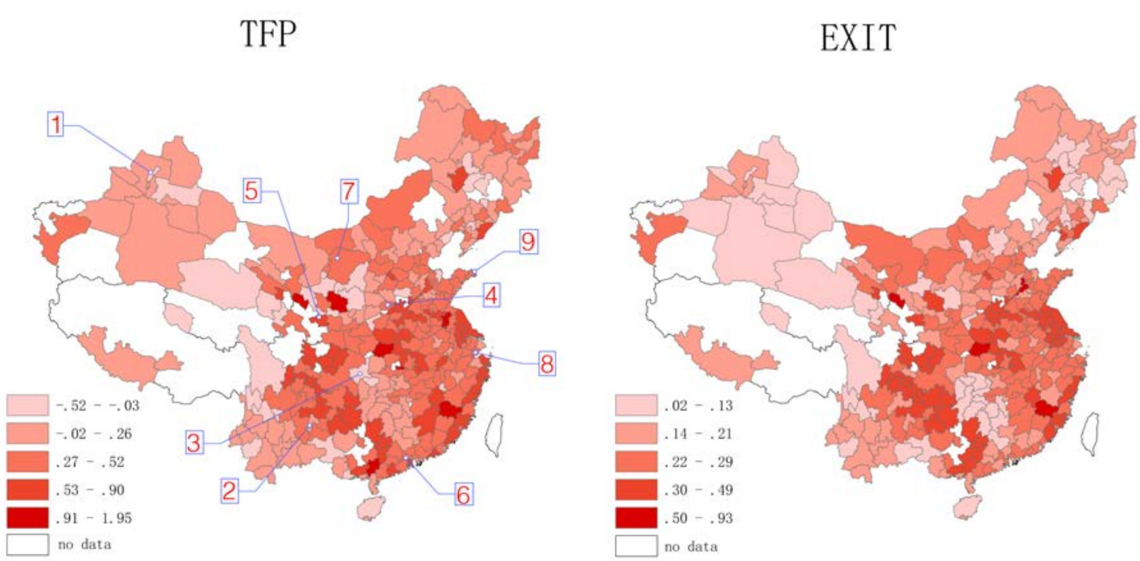
wage (for the period 2000-2007) of 4889.6 Chinese Yuan. This is about a 9.7% increase.[39] We ask, what the effect of this change would be on TFP and exit for the average firm. As shown in Tables 2 and 3, this depends on the average capital intensity and the average gap in capital intensity in entry and production costs. We weigh firms according to their revenues so that larger firms get more weight. Overall, firms tend to be slightly more capital intensive in production than in entry as the average gap is -0.006. The average capital intensity is 4.253. Based on the baseline estimates in column (4) of Tables 2 and 3, we find that a 10% increase in minimum wage raises TFP on average by about 4.4%

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

and results in a roughly 2.8 percentage point increase in the probability of exit. As the baseline exit rate is about 9.7% per year, this is about a 30% increase.[40]

In Figure 5, we go a step further and illustrate the geographic variation in the effects of minimum increase from 2000 to 2007 on firm exit probabilities and TFP across China. The weighted firm-level effects are averaged at city-year level and aggregated between 2000 and 2007. Darker colors indicate stronger effects. As can be seen, the patterns are roughly similar for exit and TFP, suggesting that some cities are uniformly more affected by changes in minimum wages than others. However, there are large variations across cities.

Figure 5: Effects of Increasing Minimum Wages, 2000-2007



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

It is worth noting that cities that experienced large increases in minimum wage as depicted by darker shapes in Figure 3, do not necessarily have large effects in Figure 5. This comes from the observation that cities which are less labor intensive in production than entry experience smaller effects from higher minimum wage increases. There are examples with large increases in minimum wages but small effects on firm outcomes, such as Karamay, Xinjiang (labelled "$\boxed{1}$" in the map), Liupanshui, Guizhou ($\boxed{2}$) and Enshi, Hubei ($\boxed{3}$). On the other hand, cities like Jincheng, Shanxi ($\boxed{4}$), Tianshui, Gansu ($\boxed{5}$), and Foshan, Guandong ($\boxed{6}$) had strong effects on outcomes from relatively small

[40] The economic consequences of a 10% increase in minimum wage on the different groups of firms discussed in Tables B.5 and B.6 are given in Table B.7 (weighted effects) and Table B.8 (unweighted effects) in Appendix B. Using the estimates from the last three columns in Table B.6 we show that the exit of SOEs would be more impacted by an increase in minimum wage. This could be because China has adopted a strategy to corporatize large SOEs and privatize or shut down under-performing small SOEs, known as the "grasp the large and let go of the small" strategy (Hsieh and Song, 2015; Berkowitz, Ma and Nishioka, 2017). During our sample period (1998-2007), SOEs were under less pressure to hire excess labor but under more pressure to become more profitable. Since SOEs also need to adhere more strictly to the minimum wage regulation, they may exit more in response to a rise in the minimum wage.

increases in minimum wage. This was due to their being more labor intensive in production than entry. More common are cities that had strong effects from large increases in minimum wage - like Ordos City, Inner Mongolia (7), Jiaxing, Zhejiang (8), and Weihai, Shandong (9).

6 Conclusion

In this paper we provide a new angle on the effects of the minimum wage. Using a new model of heterogeneous firms in a competitive setting, we derive a novel prediction on the effects of minimum wage increases on selection. We test our model and find evidence supporting it. We then quantify our estimates for China. Our work suggests that, at least in China, the policy followed of raising minimum wages with a view to spreading the gains from globalization led to a substantial improvement in TFP. These increases did increase exit of firms that were more labor intensive in production than in entry. A 10% increases in the minimum wage raised TFP by 4.4% and exit rates by about 30%.

The analysis in the paper leaves open a number of questions for future research. In the current model with perfectly competitive markets, minimum wages (or, any form of price restrictions) are distortionary and minimum wages must be welfare reducing. Nor can TFP improvements following an increase in minimum wage be interpreted as welfare improving. A perfectly competitive setting is clearly not the right one to study optimal minimum wage policy since it abstracts away from all types of labor market distortions (such as search and matching frictions and monopsony power in the labor market) that are the rationale for such policies. Incorporating selection effects of minimum wage in a model with labor market power is an exciting agenda for future research.

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Appendix A

Proof of Lemma 2

We need to show that

$$\begin{aligned}\hat{\tilde{\theta}}_i &= v_i \left(\frac{s^e_{Li} - s_{Li}}{1 - \bar{s}_{Ly}}\right)\hat{w} \\ &= v_i \left(\frac{1}{1 - \bar{s}_{Ly}}\right)\left(\frac{-\omega\left(k^e_i - k_i\right)}{\left(\omega + k^e_i\right)\left(\omega + k_i\right)}\right)\hat{w} \end{aligned}\tag{A.1}$$

where $i = x, y$ and $\ell = L, K$; $\hat{\tilde{\theta}}_i$ denotes the percentage change in the cutoff productivity $\tilde{\theta}_i$; $v_i = \frac{\int_0^{\tilde{\theta}_i} F(\theta)d\theta}{F(\tilde{\theta}_i)\tilde{\theta}_i}$, with $v_i \in (0,1)$; $s_{\ell i}$ ($s^e_{\ell i}$) are the cost share of factor ℓ for production (entry) of good i; $\bar{s}_{\ell i} = [(1 - v_i)s_{\ell i} + v_i s^e_{\ell i}]$; and ω denotes the wage rental ratio.

Consider the price equal to cost equations for the marginal firms in sector x and y.

$$\begin{aligned} p_x &= \tilde{\theta}_x(w,r)c_x(w,r) \\ 1 = p_y &= \tilde{\theta}_y(w,r)c_y(w,r) \end{aligned}$$

Totally differentiating gives

$$\hat{p}_x = \hat{\tilde{\theta}}_x + \left(s_{Lx}\hat{w} + s_{Kx}\hat{r}\right), \tag{A.2}$$

$$\hat{p}_y = \hat{\tilde{\theta}}_y + \left(s_{Ly}\hat{w} + s_{Ky}\hat{r}\right), \tag{A.3}$$

where we use "hats" to denote percentage changes. For example, $\hat{p}_i$ denotes the percentage change in p_i, similarly for $\hat{r}$, $\hat{w}$ and $\hat{\tilde{\theta}}_i$. $s_{\ell i}$ ($s^e_{\ell i}$) are the cost share of factor $\ell = L, K$ for production (entry) of good $i = x, y$. $\hat{\tilde{\theta}}_i$ for $i = x, y$ can be found as follows.[41]:

Recall that the free entry condition is

$$\int_0^{\tilde{\theta}} F(\theta)d\theta = \frac{c^e(w,r)f^e}{c(w,r)}. \tag{A.4}$$

Totally differentiating this gives:

$$\begin{aligned}\tilde{\theta}F(\tilde{\theta})\frac{d\tilde{\theta}}{\tilde{\theta}} &= \frac{f^e\left[c^e_w(w,r)dw + c^e_r(w,r)dr\right]}{c(w,r)} - \frac{c^e(w,r)f^e}{c(w,r)}\left[\frac{wc_w(w,r)}{c(w,r)}\frac{dw}{w} + \frac{rc_r(w,r)}{c(w,r)}\frac{dr}{r}\right] &\text{(A.5)} \\ &= \frac{c^e(w,r)f^e}{c(w,r)}\left[\left(s^e_L\hat{w} + s^e_K\hat{r}\right) - \left(s_L\hat{w} + s_K\hat{r}\right)\right] &\text{(A.6)}\end{aligned}$$

[41]For ease of notation here we will not differentiate entry and production costs by industry, but it is easy to check the same proofs go through if we do.

Substituting from equation (A.4) for $\frac{c^e(w,r)f^e}{c(w,r)}$ and dividing both sides by $\tilde{\theta}F(\tilde{\theta})$ reveals that

$$\overset{\wedge}{\tilde{\theta}}_i = v_i \left[(s^e_{Li} - s_{Li})\hat{w} + (s^e_{Ki} - s_{Ki})\hat{r} \right], i = x, y \tag{A.7}$$

where $v_i = \int_0^{\tilde{\theta}_i} F(\theta)d\theta \;/\; F(\tilde{\theta}_i)\tilde{\theta}_i$, so that $v_i \in (0,1)$ for $i = x, y$.

Substituting the expression for $\overset{\wedge}{\tilde{\theta}}_i, i = x, y$ (i.e. equation (A.7)) into price equations (A.2) and (A.3) and rearranging terms gives

$$\begin{aligned}
\hat{p}_x &= \left[(1-v_x)s_{Lx} + v_x s^e_{Lx}\right]\hat{w} + \left[(1-v_x)s_{Kx} + v_x s^e_{Kx}\right]\hat{r} \\
\hat{p}_y &= \left[(1-v_y)s_{Ly} + v_y s^e_{Ly}\right]\hat{w} + \left[(1-v_y)s_{Ky} + v_y s^e_{Ky}\right]\hat{r}
\end{aligned}$$

or,

$$\begin{bmatrix} \hat{p}_x \\ \hat{p}_y \end{bmatrix} = \begin{bmatrix} \bar{s}_{Lx} & \bar{s}_{Kx} \\ \bar{s}_{Ly} & \bar{s}_{Ky} \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix}, \tag{A.8}$$

where $\bar{s}_{\ell i} = [(1-v_i)s_{\ell i} + v_i s^e_{\ell i}]$ for $i = x, y$ and $\ell = L, K$.

We want to know how $\tilde{\theta}_x$ and $\tilde{\theta}_y$ change with the minimum wage when the price of y is fixed at one. Thus, setting $\hat{p}_y = 0$ in equation (A.8) we get

$$\hat{r} = -\frac{\bar{s}_{Ly}}{1 - \bar{s}_{Ly}}\hat{w}. \tag{A.9}$$

Note that $s_{Li} + s_{Ki} = s^e_{Li} + s^e_{Ki} = \bar{s}_{Li} + \bar{s}_{Li} = 1$ for $i = x, y$. Thus, substituting (A.9) into (A.8) and arranging terms gives:

$$\begin{aligned}
\overset{\wedge}{\tilde{\theta}}_i &= v_i \left((s^e_{Li} - s_{Li})\hat{w} - (s^e_{Ki} - s_{Ki})\frac{\bar{s}_{Li}}{1 - \bar{s}_{Li}}\hat{w} \right) && \text{(A.10)} \\
&= v_i \left((s^e_{Li} - s_{Li}) - (s^e_{Ki} - s_{Ki})\frac{\bar{s}_{Li}}{1 - \bar{s}_{Li}} \right)\hat{w} && \text{(A.11)} \\
&= v_i \left((s^e_{Li} - s_{Li})(1 - \bar{s}_{Li}) + (s^e_{Li} - s_{Li})\bar{s}_{Li} \right) \frac{\hat{w}}{(1 - \bar{s}_{Li})} && \text{(A.12)} \\
&= v_i \frac{(s^e_{Li} - s_{Li})}{(1 - \bar{s}_{Li})}\hat{w} && \text{(A.13)} \\
&= v_i \frac{\omega(k_i - k^e_i)}{(1 - \bar{s}_{Li})}\hat{w} && \text{(A.14)}
\end{aligned}$$

using the fact that $s_{Li} = \frac{1}{1+k_i \frac{r}{w}}$, and $s^e_{Li} = \frac{1}{1+k^e_i \frac{r}{w}}$. Thus:

$$\hat{\tilde{\theta}}_x = v_x \left(\frac{s^e_{Lx} - s_{Lx}}{1 - \bar{s}_{Ly}} \right) \hat{w} = v_x \left(\frac{\omega \left(k_x - k^e_x \right)}{\left(\omega + k^e_x \right) \left(\omega + k_x \right) \left(1 - \bar{s}_{Ly} \right)} \right) \hat{w} < 0 \tag{A.15}$$

$$\hat{\tilde{\theta}}_y = v_y \left(\frac{s^e_{Ly} - s_{Ly}}{1 - \bar{s}_{Ly}} \right) \hat{w} = v_y \left(\frac{\omega \left(k_x - k^e_x \right)}{\left(\omega + k^e_y \right) \left(\omega + k_y \right) \left(1 - \bar{s}_{Ly} \right)} \right) \hat{w} > 0. \tag{A.16}$$

where $k_i = \frac{a_{Ki}}{a_{Li}}$ and $k^e_i = \frac{a^e_{Ki}}{a^e_{Li}}$ for $i = x, y$. The signs of the two equations follow from the observation that entry costs use both goods as inputs so that entry costs lie between k_y and k_x. Thus, an increase in the minimum wage makes selection stricter in x and weaker in y. This is also more so the greater the difference in the capital intensity in entry versus production.

Proof of Lemma 3:

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. From the proof of Lemma 2,

$$\begin{bmatrix} \hat{p}_x \\ \hat{p}_y \end{bmatrix} = \begin{bmatrix} \bar{s}_{Lx} & \bar{s}_{Kx} \\ \bar{s}_{Ly} & \bar{s}_{Ky} \end{bmatrix} \begin{bmatrix} \hat{w} \\ \hat{r} \end{bmatrix}$$

Setting $\hat{p}_y = 0$ we get

$$\hat{r} = -\frac{\bar{s}_{Ly}}{(1 - \bar{s}_{Ly})} \hat{w}.$$

Substituting this into the equation for $\hat{p}^x$ gives how much the price of x needs to change to keep price equal to cost when the price of good y is fixed and we move along the price equals cost curve for good y.

$$\hat{p}_x = \left[\bar{s}_{Lx} - \bar{s}_{Kx} \frac{\bar{s}_{Ly}}{(1 - \bar{s}_{Ly})} \right] \hat{w} \tag{A.17}$$

$$= \left[\frac{\bar{s}_{Lx} \left(1 - \bar{s}_{Ly} \right) - \bar{s}_{Ly} \left(1 - \bar{s}_{Lx} \right)}{(1 - \bar{s}_{Ly})} \right] \hat{w} \tag{A.18}$$

$$= \left[\frac{\bar{s}_{Lx} - \bar{s}_{Ly}}{(1 - \bar{s}_{Ly})} \right] \hat{w} > 0 \tag{A.19}$$

The sign follows from the observation that $\bar{s}_{Li}$ is a convex combination of s_{Li} and s^e_{Li}. Thus, we know that $s^e_{Lx} < \bar{s}_{Lx} < s_{Lx}$ and $s_{Ly} < \bar{s}_{Ly} < s^e_{Ly}$. Since $k_y > k_x$, and as

$$s_{Lx} - s_{Ly} = \frac{\omega (k_y - k_x)}{\left(\omega + k_y \right) \left(\omega + k_x \right)} \tag{A.20}$$

we know that $s_{Lx} > s_{Ly}$. If the share of labor in entry cost in x is close to that in y , we know $s_{Ly} < \bar{s}_{Ly} < s^e_{Ly} \approx s^e_{Lx} < \bar{s}_{Lx} < s_{Lx}$. As a result, $\bar{s}_{Lx} > \bar{s}_{Ly}$. This is what allows us to sign $\hat{p}_x$.

Looking at equation (A.19) in more detail:

$$\left[\frac{\bar{s}_{Lx}-\bar{s}_{Ly}}{(1-\bar{s}_{Ly})}\right] = \frac{\left[(1-\upsilon^{x})\, s_{Lx}+\upsilon^{x} s^{e}_{Lx}\right]-\left[(1-\upsilon^{y})\, s_{Ly}+\upsilon^{y} s^{e}_{Ly}\right]}{(1-\bar{s}_{Ly})} \tag{A.21}$$

$$= \frac{\left(s_{Lx}-s_{Ly}\right)-\upsilon^{x}\left(s_{Lx}-s^{e}_{Lx}\right)-\upsilon^{y}\left(s^{e}_{Ly}-s_{Ly}\right)}{\left(1-s_{Ly}-\upsilon^{y}\left[s^{e}_{Ly}-s_{Ly}\right]\right)} \tag{A.22}$$

$$= \frac{\frac{\omega(k_y-k_x)}{(\omega+k_x)(\omega+k_y)}-\upsilon^{x}\frac{(k^{e}_{x}-k_x)}{(\omega+k_x)(\omega+k^{e}_{x})}-\upsilon^{y}\frac{\left(k_y-k^{e}_{y}\right)}{(\omega+k_y)\left(\omega+k^{e}_{y}\right)}}{\left(\frac{k_y}{\omega+k_y}-\upsilon^{y}\left[\frac{\left(k_y-k^{e}_{y}\right)}{(\omega+k_y)\left(\omega+k^{e}_{y}\right)}\right]\right)} \tag{A.23}$$

Appendix B

Table B.1: Firm TFP and Minimum Wage: OLS

Firm TFP	(1)	(2)	(3)	(4)	(5)
$\Delta \ln w_{ct}^{min}$	0.049***	0.337***	0.340***	0.219***	0.221***
	[0.018]	[0.082]	[0.082]	[0.082]	[0.082]
$\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min}$	-0.002	0.000	0.185***	0.154***	0.154***
	[0.015]	[0.015]	[0.057]	[0.057]	[0.057]
$\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$		-0.071***	-0.072***	-0.044**	-0.044**
		[0.019]	[0.019]	[0.019]	[0.019]
$\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$			-0.047***	-0.038***	-0.038***
			[0.014]	[0.014]	[0.014]
$IF_{ft} \times \Delta \ln w_{ct}^{min}$					-0.003
					[0.004]
IF_{ft}					0.001
					[0.001]
Firm	Y	Y	Y	Y	Y
Year	Y	Y	Y		
Industry × Year				Y	Y
Observations	838,528	838,528	838,528	838,528	838,528

Note: We report OLS regressions to capture the effect of minimum wage changes on changes in firm TFP. Columns (1)-(4) report the baseline regression results. Column (5) adds the impact function that is central in Hau et al. (2020) as well as its interaction with the log change in the minimum wage. The firm-year level TFP measure is estimated at the 4-digit industry level following the control function method proposed in Levinsohn and Petrin (2003). $\ln \bar{k}_{ic}^{gap}$ measures the difference in (log) capital intensity between entry and production at the industry-city level and is constructed using the difference in capital intensity between young and old firms, while $\ln \bar{k}_{ic}^{avg}$ measures the overall industry-city capital intensity. The Impact Function IF_{ft} measure is constructed following Hau et al. (2020), see also footnote 35 for details. Robust standard errors in parentheses, clustered at the county-year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.2: Firm Exit and Minimum Wage: OLS

Firm Exit	(1)	(2)	(3)	(4)	(5)
$\Delta \ln w_{ct}^{min}$	-0.106***	-0.080	-0.079	-0.090	-0.086
	[0.015]	[0.054]	[0.054]	[0.056]	[0.056]
$\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min}$	-0.002	-0.001	0.034	0.030	0.030
	[0.007]	[0.007]	[0.027]	[0.027]	[0.027]
$\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$		-0.007	-0.007	-0.005	-0.005
		[0.012]	[0.012]	[0.013]	[0.013]
$\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$			-0.009	-0.008	-0.008
			[0.006]	[0.006]	[0.006]
ΔTFP_{ft}	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
$IF_{ft} \times \Delta \ln w_{ct}^{min}$					-0.005**
					[0.002]
IF_{ft}					0.001**
					[0.000]
Firm	Y	Y	Y	Y	Y
Year	Y	Y	Y		
Industry × Year				Y	Y
Observations	960,898	960,898	960,898	960,898	960,898

Note: We report OLS regressions to capture the effect of minimum wage changes on changes in firm exit. Columns (1)-(4) report the baseline regression results. Column (5) adds the impact function that is central in Hau et al. (2020) as well as its interaction with the log change in the minimum wage. Exit is a dummy variable that indicates whether firm f is observed in the ASIP data in $t-1$ but not in t. The firm-year level TFP measure is estimated at the 4-digit industry level following the control function method proposed in Levinsohn and Petrin (2003). The change in TFP when a firm exit in year t is the lagged TFP change ($TFP_{f,(t-1)} - TFP_{f,(t-2)}$), i.e. the change in TFP in the last year the firm was observed. $\ln \bar{k}_{ic}^{gap}$ measures the difference in (log) capital intensity between entry and production at the industry-city level and is constructed using the difference in capital intensity between young and old firms, while $\ln \bar{k}_{ic}^{avg}$ measures the overall industry-city capital intensity. The Impact Function IF_{ft} measure is constructed following Hau et al. (2020), see also footnote 35 for details. Robust standard errors in parentheses, clustered at the county-year level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table B.3: First Stage Results: Firm TFP

	$\Delta \ln w^{min}_{ct}$ (1)	$\ln \bar{k}^{gap}_{ic} \times \Delta \ln w^{min}_{ct}$ (2)	$\ln \bar{k}^{avg}_{ic} \times \Delta \ln w^{min}_{ct}$ (3)	$\ln \bar{k}^{gap}_{ic} \times \ln \bar{k}^{avg}_{ic} \times \Delta \ln w^{min}_{ct}$ (4)
$\ln w^{min}_{c(t-4)}$	-0.070**	-0.016***	-0.386***	-0.068***
	(0.034)	(0.006)	(0.135)	(0.021)
$\ln \bar{k}^{gap}_{ic} \times \ln w^{min}_{c(t-4)}$	-0.003*	0.080***	-0.006	0.020
	(0.002)	(0.004)	(0.007)	(0.014)
$\ln \bar{k}^{avg}_{ic} \times \ln w^{min}_{c(t-4)}$	-0.002***	0.001	0.016***	0.002
	(0.001)	(0.000)	(0.004)	(0.002)
$\ln \bar{k}^{gap}_{ic} \times \ln \bar{k}^{avg}_{ic} \times \ln w^{min}_{c(t-4)}$	0.000	-0.001	0.000	0.070***
	(0.000)	(0.001)	(0.002)	(0.005)
Observations	838,528	838,528	838,528	838,528
SW F	461.48	766.13	375.3	729.94

Note: We report the results of the first-stage regressions of the baseline specification (column 4) in Table 2. The instrument variable for minimum wage, $\ln w^{min}_{c(t-4)}$, is the 4-year lagged minimum wage in the county. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The Sanderson-Windmeijer (SW) statistics are reported in the bottom row.

Table B.4: First Stage Results: Firm Exit

	$\Delta \ln w^{min}_{ct}$ (1)	$\ln \bar{k}^{gap}_{ic} \times \Delta \ln w^{min}_{ct}$ (2)	$\ln \bar{k}^{avg}_{ic} \times \Delta \ln w^{min}_{ct}$ (3)	$\ln \bar{k}^{gap}_{ic} \times \ln \bar{k}^{avg}_{ic} \times \Delta \ln w^{min}_{ct}$ (4)
$\ln w^{min}_{c(t-4)}$	-0.065*	-0.017***	-0.368***	-0.069***
	(0.033)	(0.006)	(0.133)	(0.021)
$\ln \bar{k}^{gap}_{ic} \times \ln w^{min}_{c(t-4)}$	-0.003*	0.080***	-0.006	0.027**
	(0.002)	(0.004)	(0.007)	(0.013)
$\ln \bar{k}^{avg}_{ic} \times \ln w^{min}_{c(t-4)}$	-0.002***	0.001	0.015***	0.002
	(0.001)	(0.000)	(0.004)	(0.002)
$\ln \bar{k}^{gap}_{ic} \times \ln \bar{k}^{avg}_{ic} \times \ln w^{min}_{c(t-4)}$	0.000	-0.001	0.000	0.068***
	(0.000)	(0.001)	(0.002)	(0.004)
ΔTFP_{it}	0.001	0.000	0.003	-0.000
	(0.001)	(0.000)	(0.002)	(0.001)
Observations	960,898	960,898	960,898	960,898
SW F	443.69	696.46	358.35	660.33

Note: We report the results of the first-stage regressions of the baseline specification (column 4) in Table 3. The instrument variable for minimum wage, $\ln w^{min}_{c(t-4)}$, is the 4-year lagged minimum wage in the county. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. The Sanderson-Windmeijer (SW) statistics are reported in the bottom row.

Table B.5: Robustness Checks: Firm TFP

Firm TFP		Alternative Gap			Subsamples			
	Alter. TFP	3 Year Cutoff	Stagnant Old	Firm FE	Old Firms	SOE	Foreign	Exporters
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta \ln w_{ct}^{min}$	0.598***	4.241***	5.615***	6.665***	2.543***	3.859**	5.053***	3.688***
	[0.187]	[0.703]	[0.654]	[0.736]	[0.467]	[1.602]	[1.247]	[0.900]
$\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min}$	0.280**	0.375*	0.550**	1.746***	0.583*	0.951**	1.118**	0.962***
	[0.111]	[0.198]	[0.266]	[0.489]	[0.303]	[0.406]	[0.442]	[0.341]
$\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$	-0.134***	-0.898***	-1.247***	-1.507***	-0.507***	-0.519	-1.262***	-0.980***
	[0.046]	[0.171]	[0.157]	[0.177]	[0.110]	[0.365]	[0.303]	[0.222]
$\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$	-0.068**	-0.083*	-0.139**	-0.538***	-0.136*	-0.228**	-0.311***	-0.262***
	[0.027]	[0.050]	[0.067]	[0.128]	[0.074]	[0.094]	[0.111]	[0.085]
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y
Industry*Year FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	853,866	844,364	831,266	839,631	527,474	253,964	202,497	372,348

Note: Column (1) uses an alternative TFP measure following Ackerberg, Caves and Frazer (2015). Columns (2)-(4) report the estimates using alternative measures of $k^e - k$. Specifically, an alternative age cutoff of three years is used to separate young and old firms in column (2). In column (3), the gap is measured using the capital intensity of young firms versus slow growing old firms at the industry-city level. Slow growing old firms are defined as the firms older than 4 years that have growth rates of revenue in the lower 75 percentile in the industry-city. In column (4), we estimate industry-city level capital intensity of young versus old firms after controlling for firm fixed effects and use the difference between the estimated industry-city level capital intensity of young and old firms to measure the gap. In column (5) we run the baseline regression (column 4 of Table 2) using the subsample with only firms that are more than four years old in order to reduce the influence of entry costs in productivity estimation. Columns (6), (7) and (8) run the baseline regression separately for State Owned Enterprises (SOE), foreign firms, and exporters.

Table B.6: Robustness Checks: Firm Exit

Firm Exit			Alternative Gap			Subsamples			
	TFP Residual	Alter. TFP	3 Year Cutoff	Stagnant Old	Firm FE	Old Firms	SOE	Foreign	Exporters
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta \ln w_{ct}^{min}$	0.798*	0.963*	1.176**	0.840*	1.044**	1.280***	3.323***	0.663	0.764*
	[0.454]	[0.544]	[0.559]	[0.491]	[0.525]	[0.431]	[1.108]	[0.589]	[0.435]
$\ln \bar{k}_{ic}^{gap} \times \Delta \ln w_{ct}^{min}$	0.129**	0.136**	0.126**	0.251***	0.395***	0.021	0.334*	0.275***	0.188**
	[0.061]	[0.063]	[0.060]	[0.072]	[0.135]	[0.074]	[0.172]	[0.089]	[0.080]
$\ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$	-0.105	-0.189**	-0.203**	-0.112*	-0.162**	-0.230***	-0.329*	-0.202**	-0.148**
	[0.071]	[0.086]	[0.086]	[0.065]	[0.071]	[0.056]	[0.183]	[0.091]	[0.075]
$\ln \bar{k}_{ic}^{gap} \times \ln \bar{k}_{ic}^{avg} \times \Delta \ln w_{ct}^{min}$	-0.027*	-0.029*	-0.031**	-0.050***	-0.038	-0.009	-0.070*	-0.060***	-0.040**
	[0.015]	[0.015]	[0.014]	[0.017]	[0.044]	[0.018]	[0.040]	[0.022]	[0.019]
ΔTFP_{ft}	0.001	0.002	-0.008***	-0.009***	-0.008***	-0.010***	-0.014***	-0.005***	-0.007***
	[0.001]	[0.004]	[0.001]	[0.001]	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]
Firm FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Industry*Year FE	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	892,188	977,338	967,823	952,440	962,238	615,156	307,216	223,727	409,223

Note: Column (1) controls for changes in the residual TFP to account for the change in firm level TFP that cannot be explained by changes in the minimum wage. Column (2) uses an alternative TFP measure following Ackerberg et al. (2015). Columns (3)-(5) report the estimates using alternative measures of $k^e - k$. Specifically, an alternative age cutoff of three years is used to separate young and old firms in column (3). In column (4), the gap is measured using the capital intensity of young firms versus slow growing old firms at the industry-city level. Slow growing old firms are defined as the firms older than 4 years that have growth rates of revenue in the lower 75 percentile in the industry-city. In column (5), we estimate industry-city level capital intensity of young versus old firms after controlling for firm fixed effects and use the difference between the estimated industry-city level capital intensity of young and old firms to measure the gap. In column (6) we run the baseline regression (column 4 in Table 3) using the subsample with only firms that are more than four years old in order to reduce the influence of entry costs in productivity estimation. Columns (7), (8) and (9) run the baseline regression separately for State Owned Enterprises (SOE), foreign firms, and exporters.

Table B.7: Quantifying the Effects of Minimum Wage Increases (Weighted)

10% Increase in Minimum Wage: Weighted				
	Δ TFP	$\Delta Pr(Exit)$	$\ln \bar{k}_{hc}^{avg}$	$\ln \bar{k}_{hc}^{gap}$
Overall	0.044	0.028	4.253	-0.006
SOE	0.154	0.181	4.297	0.050
Foreign	-0.031	-0.019	4.263	-0.034
Exporter	-0.044	0.013	4.237	-0.030

Note: The overall effects are calculated using estimates from the baseline regressions (column 4) from Tables 2 and 3. Weights are revenue shares. Effects by firm types on TFP and Exit are calculated from columns (6)-(8) of Table B.5 and columns (7)-(9) of Table B.6 respectively.

Table B.8: Quantifying the Effects of Minimum Wage Increases (Unweighted)

10% Increase in Minimum Wage: Unweighted				
	Δ TFP	$\Delta Pr(Exit)$	$\ln \bar{k}_{ic}^{avg}$	$\ln \bar{k}_{ic}^{gap}$
Overall	0.062	0.033	4.023	0.184
SOE	0.170	0.194	4.078	0.033
Foreign	0.001	-0.014	3.991	-0.005
Exporter	-0.011	0.018	3.877	-0.023

Note: The overall effects are calculated using estimates from the baseline regressions (column 4) from Tables 2 and 3. Effects by firm types on TFP and Exit are calculated from columns (6)-(8) of Table B.5 and columns (7)-(9) of Table B.6 respectively.