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Should the Industrial Region Fear Hollowing Out by Raising the Minimum Wage? *

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Abstract

This paper develops a spatial general equilibrium model with exogenous minimum wages to investigate regional minimum wage disparities in the New Economic Geography. Numerical simulations in a two-region economy reveal the impact of minimum wage hikes on the spatial distribution of firms. We observe industrial hollowing out beyond a critical minimum wage gap threshold, yet regions with higher minimum wages can remain attractive as the core, particularly with low transport costs. Such attractiveness can be interpreted as agglomeration rent. We further examine the sustainability of the core-periphery pattern and the impact of minimum wage increases on the local labor market.

Keywords: Spatial general equilibrium model; Minimum wage; Core-periphery pattern; Transport cost

JEL Classification: F12; F16; R12

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1 Introduction

The minimum wage has been among the most debated topics of labor market institutions (Boeri and Ours, 2014; Dube and Lindner, 2024). Economic theories offer different perspectives on the response of firms to the wage hike. On the one hand, the neoclassical theory in labor economics predicts that the minimum wage reduces employment in a competitive labor market and may lead to more employment in monopsony models (Neumark and Wascher, 2008). Recently, Azar et al. (2023) uses a model of oligopsonistic competition and provides compelling empirical evidence that there is more room to raise wages without reducing employment in more highly concentrated labor markets with fewer firms.

On the other hand, the wage equation in the New Economic Geography (NEG) suggests another possibility. Pioneered by Krugman (1991b) and synthesized in Fujita et al. (1999), NEG has provided modern tools in economic theory to explain the location of economic activity (Fujita, 2010; Brakman et al., 2019). With the agglomeration force stemming from the interactions among increasing returns, transport costs, and factor mobility, regions that could offer higher wage rates are characterized by larger home markets, easier access to larger markets, and less competitive environments, which are all attractive to firms (Fujita et al., 1999). This opens up the possibility of agglomeration under a competitive labor market.

The minimum wage policy can either be unattractive to firms while increasing their production costs or possibly be attractive when increasing households' aggregate income (Méjean and Patureau, 2010). From the perspective of NEG, the former is an ingredient reinforcing the dispersion force at work, while the latter provides a larger home market and contributes to the agglomeration force. Nesting these two potential channels into the process of cumulative causation, the ultimate net effect is currently ambiguous.

In this paper, we incorporate these two effects into a spatial general equilibrium model and explore the impact of the minimum wage on the spatial distribution of firms numerically and analytically. Following the presentation of the theoretical NEG model with exogenous minimum wages, we conduct numerical simulations within a two-region economy and provide several possible scenarios. The simulation results suggest that the spatial outcome depends on the interplay of transport costs, minimum wage thresholds, and historical path dependence. When transport costs are sufficiently low and disparities in minimum wages fall below critical thresholds, the industrial region can retain its core advantages due to agglomeration rents, even with higher minimum wages. In other cases, however, the risk of hollowing out becomes more pronounced.

Furthermore, we analytically examine the core-periphery pattern, where Region 1 remains the industrial core with a higher minimum wage. Specifically, we investigate the sustainability of this pattern and argue that there exists scope for raising the local minimum wage while maintaining the core region's attractiveness to firms, a phenomenon explained by agglomeration rent. The agglomeration rent declines with sufficiently low transport costs because firms are more sensitive to cost differentials. The extent to which the core region can increase minimum wages without causing firm relocation is constrained by the balance between the positive impact of higher minimum wages on the home market effect and increased production costs. We finally examine the effect of the minimum wage increase on the local labor market within this core-periphery pattern.

Our contribution to the literature is twofold. First, we introduce asymmetric minimum wages within the framework of the NEG model. We adopt the *footloose entrepreneur model* presented in Forslid and Ottaviano (2003), using both high-skill mobile and low-skill immobile workers in the manufacturing sector, and extend it by introducing exogenous minimum wages bonded with unskilled workers in the manufacturing sector.

In addition, the theoretical studies of Pflüger (2004b) and Méjean and Patureau (2010) are closely related to our research interests. Méjean and Patureau (2010) focuses on the substitutability between skilled and unskilled workers (who are both immobile across regions) and argues that the minimum wage hike is more likely to reduce the local region's attractiveness continuously with endogenous skilled wages. Pflüger (2004b) assumes exogenously fixed wages for immobile unionised workers to investigate the impact of labor market regulations on firms' location decisions. By assuming a quasi-linear upper-tier utility function, he analytically provides one theoretical rationale that the core region with historical agglomeration advantages may have more generous social policies (unemployment benefits and wage taxes) than the periphery region without inducing an exit of industry. By comparison, this paper employs the Cobb-Douglas upper-tier utility function and allows skilled workers to move across regions, as in the standard *core-periphery model*, and offers several possible scenarios under different transport costs. This setting allows us to fully capture the home market effect including the positive demand feedback for manufactured varieties from a higher minimum wage, which strengthens the agglomeration forces.[1]

Second, our work is also relevant to studies on the impact of minimum wage hikes on firms' location behavior. Compared to the large body of literature examining the effects of the minimum wage on labor market outcomes,[2] there is a paucity of studies examining firms' responses to the minimum wage policy. The empirical results indicate that minimum wage increases may not be sufficiently detrimental to affect the overall dynamics of firm entry, exit, or relocation. For instance, Rohlin (2011) highlights the negligible impact of minimum wages on overall business activity. The findings indicate that the minimum wage policy deters new entries but has little effect on the location decisions of existing firms, which account for more than 95% of the total business in the United States. The absence of a negative effect on firm entry/exit is also demonstrated in Card and Krueger (1994) for McDonald's restaurants in the United States, Draca et al. (2011) for the national minimum wage introduction in the United Kingdom, and Harasztosi and Lindner (2019) for Hungary. Li et al. (2023) finds that business relocation (using a unique measure) is rare and firms do not respond significantly to cross-border minimum wage gaps in China. Our results based

[1]It is widely recognized that the quasi-linear upper-tier utility function, unlike the Cobb-Douglas upper-tier utility function, fails to capture the income effect in the demand for manufactured goods and displays weaker agglomeration forces. These models also predict different shapes of the bifurcation pattern (tomahawk or pitchfork). See Pflüger (2004a) and Pflüger and Südekum (2008) for more detailed discussions.

[2]This strand of literature has been exhaustively reviewed, see Neumark and Wascher (2008), Belman and Wolfson (2014) and Card and Krueger (2016), for example.

on a spatial general equilibrium model point to one rationale for these empirical findings and highlight the importance of considering transport costs in future empirical research on the impact of minimum wage policy on job migration and firms' location decisions.

The rest of the paper is organized as follows. Section 2 develops the theoretical framework of our spatial general equilibrium model with exogenous minimum wages. Section 3 illustrates and investigates the numerical simulation results in a two-region economy. Section 4 identifies the critical condition for the sustainability of the core-periphery pattern and provides further policy discussion. Section 5 concludes.

2 Theoretical Framework

In this section, we present the framework of our theoretical model. In particular, Section 2.1 shows the structure of demand and supply in our model setup, and Section 2.2 gives the market clearing conditions and the spatial equilibrium conditions.

2.1 Basic Structures

The economy consists of R discrete regions. Each region consists of two production sectors and two factors of production: Mobile skilled workers are employed only in the manufacturing sector and immobile unskilled workers in both sectors, as the *footloose entrepreneur model* presented in Forslid and Ottaviano (2003). We extend this by introducing exogenous minimum wages bonded with unskilled workers in the manufacturing sector.

2.1.1 Main assumptions

As the NEG standard setting for production sectors, the agricultural sector produces a single, homogeneous good under constant-returns-to-scale in a perfectly competitive market structure. The agricultural good is produced with unskilled labor only, and is assumed to be freely tradeable across regions with the same price p^A. Consequently, it is convenient to choose the agricultural good as the numéraire, i.e., $p^A = 1$.

The manufacturing sector produces a large variety of differentiated goods under increasing-returns-to-scale in a Dixit-Stiglitz monopolistically competitive market structure (Dixit and Stiglitz, 1977). Manufactured goods are produced with both unskilled and skilled labor, and are assumed to be costly to trade across regions with the iceberg transport costs.

For production factors, the economy is endowed with $\bar{H}$ skilled workers and $\bar{L}$ unskilled workers. Specifically,

$$\begin{aligned} \bar{H} &= \sum_{r=1}^{R} H_r \\ \bar{L} &= \sum_{r=1}^{R} L_r = \sum_{r=1}^{R} \left(L_r^A + L_r^M \right) \end{aligned} \tag{1}$$

where H_r and L_r are the populations of skilled and unskilled workers, respectively, in Region r. Skilled workers (H_r) are spatially mobile and receive an endogenously determined wage

w_r. Unskilled workers (L_r) are immobile and assumed to be evenly spread across regions; they are either employed in the manufacturing sector (L_r^M) with an exogenous minimum wage $\underline{w}_r$, or employed in the agricultural sector (L_r^A) with a numéraire wage w_r^A.[3]

To avoid the economy collapsing into a single region, we assume a sufficient number of unskilled workers so that the agriculture sector always exists in each region. Moreover, $\underline{w}_r > w_r^A$ also holds in our model due to no-black-hole condition. The setting in which the unskilled wage in the manufacturing sector ($\underline{w}_r$) is greater than that in the agricultural sector (w_r^A) is not quite odd, as it partly reveals the incentive for sectoral mobility associated with unskilled workers.

2.1.2 Consumer behavior

We assume that consumers share the same Cobb-Douglas preferences for agricultural good and manufactured goods, and have identical constant-elasticity-of-substitution (CES) preferences for the continuum varieties of differentiated manufactured goods,

$$\begin{aligned} U &= A^{1-\mu} M^{\mu}, \quad 0 < \mu < 1 \\ M &= \left[\int_0^n m(i)^{\frac{\sigma-1}{\sigma}} \, \mathrm{d}i \right]^{\frac{\sigma-1}{\sigma}}, \quad \sigma > 1 \end{aligned} \tag{2}$$

where U is the utility level, A is the consumption of the agricultural good, M is the consumption of manufactured goods, and μ denotes the expenditure share of manufactured goods. In the quantity index of M, n is the total number of available varieties, $m(i)$ denotes the consumption of a particular variety i, and σ represents both the elasticity of substitution between any two varieties and the constant price elasticity of demand for every variety.

Consumers' problem is to choose their consumption bundle given a set of prices to maximize their utility, as expressed in Equation (2), subject to the following budget constraint under the wage income Y:

$$p^A A + \int_0^n p(i) m(i) \, \mathrm{d}i = Y \tag{3}$$

where $p(i)$ is the price for each differentiated variety.

Utility maximization yields the demand functions for the agricultural good,

$$A = (1-\mu) Y / p^A \tag{4}$$

and for each variety of manufactured goods,

$$m(j) = \mu Y p(j)^{-\sigma} G^{\sigma-1} \quad \text{for} \quad j \in [0, n] \tag{5}$$

where $G \equiv \left[\int_0^n p(i)^{1-\sigma} \, \mathrm{d}i \right]^{\frac{1}{1-\sigma}}$ denotes the price index for differentiated manufactured

[3] To some extent, our wage setting process uses the same technique as in Strauss-Kahn (2005). In her model, unemployment always occurs in the two manufacturing sectors, and workers who are not employed in the manufacturing sectors produce a homogeneous good at home as an outside option.

goods. Substituting (4) and (5) into (2), we obtain the indirect utility function,

$$V = \mu^{\mu}(1-\mu)^{1-\mu} Y G^{-\mu} (p^A)^{-(1-\mu)} \tag{6}$$

and the term $G^{-\mu}(p^A)^{-(1-\mu)}$ can be considered the cost-of-living index in the economy.

To obtain the total consumption demand in the multiple-location setting, some simplifications and clear definitions are essential: (i) we assume that the production of all varieties in a particular region is symmetric with the same technology. That is, for consumers in production region r, all n_r varieties are available at the same mill price p_r. (ii) The specific definition of the iceberg transport technology in the manufacturing sector is that, $\tau_{rs}(>1)$ units of goods need to be shipped from production region r to ensure that one unit reaches consumption region s. This also implies that if the mill price of a manufactured variety in production region r is p_r, then the delivered price of that variety in consumption region s, denoted by p_{rs}, is given by $p_{rs} = p_r \tau_{rs}$ (Samuelson, 1954).

Taking together, we first derive the price index in region r, denoted by G_r.

$$G_r = \left[\sum_{s=1}^{R} n_s \left(p_s \tau_{sr} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{7}$$

Then, using Equation (5), the consumption demand in region s for a single variety produced in region r, denoted by m_{rs}, is written as $m_{rs} = \mu Y_s \left(p_r \tau_{rs} \right)^{-\sigma} G_s^{\sigma-1}$. To meet this amount of demand, τ_{rs} times it has to be delivered, in other words, $q_{rs} = \mu Y_s \left(p_r \tau_{rs} \right)^{-\sigma} G_s^{\sigma-1} \tau_{rs}$ must be produced and shipped from region r.

Summing across regions, we finally obtain the total amount of a single manufactured variety that should be produced in region r, denoted by q_r,

$$q_r = \sum_{s=1}^{R} \mu Y_s \left(p_r \tau_{rs} \right)^{-\sigma} G_s^{\sigma-1} \tau_{rs} = \mu p_r^{-\sigma} \sum_{s=1}^{R} Y_s G_s^{\sigma-1} \tau_{rs}^{1-\sigma} \tag{8}$$

to supply its total consumption demand in the economy.

2.1.3 Producer behavior

Turning to the supply side, in the agricultural sector, we assume that one unit of output requires one unit of unskilled labor. The constant-returns-to-scale technology within the perfect competition environment implies the marginal cost pricing rule and the unskilled wage in the agricultural sector equals its price, i.e., $w_r^A = p^A = 1$.

Manufactured goods are produced by increasing-returns-to-scale technology under a monopolistically competitive market structure. The specific production technology involves a fixed input f of skilled labor and a marginal input requirement β of unskilled labor, as in Forslid and Ottaviano (2003). Consider a representative firm in the manufacturing sector producing a single variety in region r. Given the wage levels expressed in Section 2.1.1, the firm's total production cost function is given as:

$$\text{TotalCost}_r = w_r f + \underline{w}_r \beta q_r \tag{9}$$

where q_r is the production amount of the variety. Then, given the price index G_r in Equation (7) and the production amount q_r associated with the consumption demand in Equation (8), the firm maximizes profit, denoted by π_r:

$$\pi_r = p_r q_r - (w_r f + \underline{w}_r \beta q_r) \tag{10}$$

Profit maximization gives the standard pricing rule in the monopolistic framework,

$$p_r = \frac{\sigma}{\sigma - 1} \beta \underline{w}_r \tag{11}$$

that is, the equilibrium price is a constant markup over the minimum wage.[4]

Moreover, we assume that there is free entry and exit such that each firm makes zero profit in equilibrium. The zero-profit condition indicates that the equilibrium output of every active firm in Region r is as follows.

$$q_r = \frac{f(\sigma - 1)}{\beta} \frac{w_r}{\underline{w}_r} \tag{12}$$

2.2 Spatial General Equilibrium

The conditions for the spatial general equilibrium of our model are established in two steps. First, *market equilibrium* refers to the situation where supply and demand are met and the labor markets are clear, given the distribution of skilled workers. Second, *spatial equilibrium* requires that mobile skilled workers and firms have no incentives to relocate from their locations.

2.2.1 Market equilibrium

Market equilibrium is derived under several market clearing conditions and can be described with the price index equation, the income equation, and the wage equation.

Skilled labor market clearing. Given the skilled labor distribution H_r and the fixed input requirement f for each firm, skilled labor market clearing implies that the number of manufacturing firms/varieties in Region r is determined by:

$$n_r = \frac{H_r}{f} \tag{13}$$

[4]Eqs. (9) and (11) show that increasing the minimum wage raises the production cost and the equilibrium price accordingly. Hirsch et al. (2015) proposes several potential channels of adjustment to minimum wage increases that may explain the generally small and insignificant effect of the minimum wage on employment found in empirical studies. One of these channels is higher prices. Firms may offset the higher labor cost binding with the higher minimum wage by increasing product prices. See Schmitt (2015) for further discussion and see Bodnár et al. (2018) for empirical evidence.

This result greatly simplifies our analysis of firms' location decisions and the spatial distribution of the manufacturing sector, as the number of local firms is equivalent to the population of skilled workers. By substituting equations for the number of firms (13) and the equilibrium price (11) into (7), we can rewrite the price index equation.

$$G_r^{1-\sigma} = \frac{1}{f}\left(\frac{\beta\sigma}{\sigma-1}\right)^{1-\sigma}\sum_{s=1}^{R} H_s \underline{w}_s^{1-\sigma}\tau_{sr}^{1-\sigma} \tag{14}$$

Unskilled labor market clearing. Given the endowment of unskilled labor L_r and that a single manufacturing firm requires βq_r unskilled workers, the numbers of unskilled workers employed in the manufacturing sector (L_r^M) and the agricultural sector (L_r^A) are as follows.

$$\begin{aligned} L_r^M &= n_r\beta q_r = (\sigma-1)\frac{w_r}{\underline{w}_r}H_r \\ L_r^A &= L_r - L_r^M \end{aligned} \tag{15}$$

Then, given the different wage levels associated with each type of labor, the following income equation can be easily derived.

$$\begin{aligned} Y_r &= w_r H_r + \underline{w}_r L_r^M + L_r^A \\ &= \left(\sigma - \frac{\sigma-1}{\underline{w}_r}\right) w_r H_r + L_r \end{aligned} \tag{16}$$

Every single manufactured variety market clearing. The equilibrium output in Equation (12) should be exactly the same as the production amount required to supply the total consumption demand of all regions in Equation (8). Substituting (11), (14), and (16) into (8) and solving for w_r yields the following wage equation:

$$w_r = \frac{\mu}{f\sigma}\left(\frac{\beta\sigma}{\sigma-1}\right)^{1-\sigma}\underline{w}_r^{1-\sigma}\sum_{s=1}^{R} Y_s G_s^{\sigma-1}\tau_{sr}^{1-\sigma} \tag{17}$$

2.2.2 Spatial equilibrium

Additionally, *spatial equilibrium* is reached when mobile skilled workers and manufacturing firms have no incentive to move between regions. We simply assume that skilled workers move toward regions with higher real wages. Recall that $G^{-\mu}(p^A)^{-(1-\mu)}$ is the cost-of-living index in the economy and $p^A = 1$, the real wage for skilled workers in region r, denoted by ω_r, is defined as:

$$\omega_r = w_r G_r^{-\mu} \tag{18}$$

Since firms follow skilled workers' footsteps in choosing locations, as shown in Equation (13), firms' location decisions are finalized once skilled workers no longer relocate.[5] We

[5]We take advantage of simplification for a fixed input of skilled workers. When variable input of mobile skilled workers is involved, Takatsuka (2011) provides compelling theoretical evidence that firms follow skilled workers rather than the reverse with decreasing trade costs.

assume that the migration of skilled workers is governed by the ad hoc replicator dynamics,

$$\dot{\lambda}_r = \gamma(\omega_r - \bar{\omega})\lambda_r \tag{19}$$

where λ_r is the share of region r's skilled workers and $\bar{\omega} = \sum_{r=1}^{R} \lambda_r \omega_r$ is the average real wage. Ultimately, the $4R$ equations – namely, the income equation (16), the price index equation (14), the wage equation (17), and the real wage equation (18) – together depict the spatial general equilibrium. The spatial equilibrium condition can be expressed as $\dot{\lambda}_r = 0$ and $\omega_r = \omega$ for any r.

3 Numerical Simulations in a Two-Region Economy

Although the general R-region framework is appealing, it is analytically difficult to gain explicit insights. To further examine the effect of minimum wage increases on the spatial distribution of manufacturing firms, in this section, we conduct simulation exercises within a two-region economy and discuss the results in detail.

3.1 A Two-Region Version of the Economy

Consider a two-region version of the economy, Region 1 and Region 2.

To fully rewrite the eight equations describing the spatial general equilibrium in a concise form, without loss of generality, we assume that (i) the total population in the economy ($\bar{H} + \bar{L}$) is 1 and the share/number of skilled workers in the total population ($\frac{\bar{H}}{\bar{H}+\bar{L}}$) is denoted by θ; then, each region is endowed with $(1-\theta)/2$ unskilled workers; (ii) there is no transport cost within each region and the transport cost between two regions is symmetric, i.e., $\tau_{12} = \tau_{21} \equiv \tau$; and (iii) units are chosen such that $\beta = f(\sigma - 1) = (\sigma-1)/\sigma$ to simplify the wage equation and the price index equation.

Let λ denote Region 1's industrial share, defined as the proportion of skilled workers and manufacturing firms in Region 1. Accordingly, $1-\lambda$ represents the share in Region 2. Eight equations are then presented as follows:

$$\begin{aligned}
Y_1 &= \left(\sigma - \frac{\sigma - 1}{\underline{w}_1}\right) \lambda\theta w_1 + \frac{1-\theta}{2} \\
Y_2 &= \left(\sigma - \frac{\sigma - 1}{\underline{w}_2}\right) (1-\lambda)\theta w_2 + \frac{1-\theta}{2} \\
G_1^{1-\sigma} &= \sigma\theta \left[\lambda \underline{w}_1^{1-\sigma} + (1-\lambda)\underline{w}_2^{1-\sigma}\tau^{1-\sigma}\right] \\
G_2^{1-\sigma} &= \sigma\theta \left[\lambda \underline{w}_1^{1-\sigma}\tau^{1-\sigma} + (1-\lambda)\underline{w}_2^{1-\sigma}\right] \\
w_1 &= \mu \underline{w}_1^{1-\sigma} \left(Y_1 G_1^{\sigma-1} + Y_2 G_2^{\sigma-1}\tau^{1-\sigma}\right) \\
w_2 &= \mu \underline{w}_2^{1-\sigma} \left(Y_1 G_1^{\sigma-1}\tau^{1-\sigma} + Y_2 G_2^{\sigma-1}\right) \\
\omega_1 &= w_1 G_1^{-\mu} \\
\omega_2 &= w_2 G_2^{-\mu}
\end{aligned} \tag{20}$$

As these equations are symmetric, a symmetric solution can be readily verified in the case of a symmetric minimum wage rate. That is to say, given the same exogenous minimum wage, firms are distributed evenly between two regions with symmetric equilibrium values of income, price index, and wage rate.[6] Applying the procedure in Fujita et al. (1999, Chapter 4.5) confirms the presence of agglomeration forces, namely the *price index effect* and the *home market effect*, in our model. Specifically, the region with the larger home market has a more than proportionately larger manufacturing sector, and the region with the larger manufacturing sector tends to have a lower price index and higher demand for manufactured goods. Moreover, the minimum wage rate serves as both a dispersion force and an agglomeration force, resulting in a higher price index and a larger home market. (See Appendix A for the proof.)

3.2 Simulation Results

Starting from the symmetric equilibrium, we conduct numerical simulations and allow a local minimum wage increase to determine how firms respond and how the spatial distribution is reshaped. The simulation parameters, i.e., the expenditure share of manufactured goods in the utility function $\mu = 0.4$ and the elasticity of substitution between any two varieties $\sigma = 5$, are taken from Fujita et al. (1999, Chapter 5.3). We set the share of skilled workers in the total working population $\theta = 0.3$, which is consistent with the proportion of China's labor force with at least a high school education in the early 2010s.[7] The regional minimum wage is initially set arbitrarily at $\underline{w} = 1.3$.[8]

Our simulation results indicate that the spatial distribution of manufacturing firms is highly sensitive to the level of transport costs and the extent of the minimum wage increase. The simulation results with different transport costs τ and minimum wage gaps are reported in Figure 1 (a high transport cost), Figure 2 (a low transport cost), and Figure 3 (an intermediate transport cost). The figures in panel (a) demonstrate cases without a minimum wage difference between regions, and other panels allow for a gradual increase in Region 1's minimum wage. In each figure, we plot the real wage differential between two regions ($\omega_1 - \omega_2 \gtreqless 0$) against the share of manufacturing firms in Region 1 ($\lambda \in [0, 1]$) in the market equilibrium as presented in Section 2.2. The solid line indicates market equilibrium; the hollow and solid dots indicate unstable and stable spatial equilibrium, respectively. It tells that as long as $\omega_1 - \omega_2 > 0$ on the solid line, Region 1 is more attractive, and λ keeps increasing to the right, and vice versa.

[6] Moreover, the No-Black-Hole condition ($\sigma - 1 > \mu$) is assumed to hold from now on.

[7] As reported in *China Human Capital Index Report 2023* (`https://humancapital.cufe.edu.cn/en/Human_Capital_Index_Project.htm`), which is conducted by the China Center for Human Capital and Labor Research Center (CHLR) in the Central University of Finance and Economics, the proportion of China's labor force with at least a high school education increased from 19.01% in 2000 to 28.68% in 2010, and to 43.13% in 2020.

[8] Simulation exercises with several parameter combinations of μ, σ, θ, and $\underline{w}$ show that, as for now, our main arguments have not substantially altered.

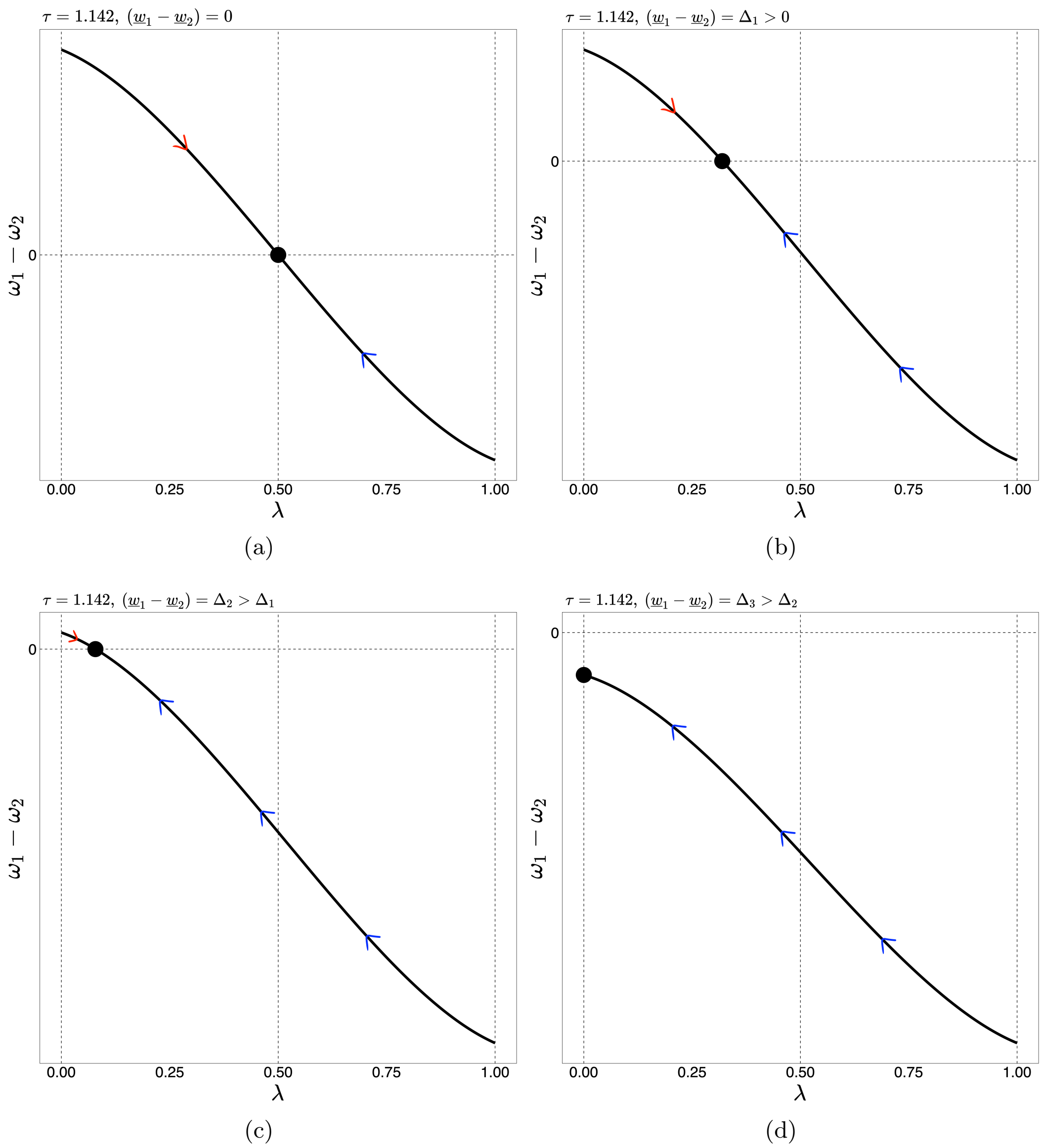


Figure 1: Simulation results with a high transport cost, $\tau = 1.142$

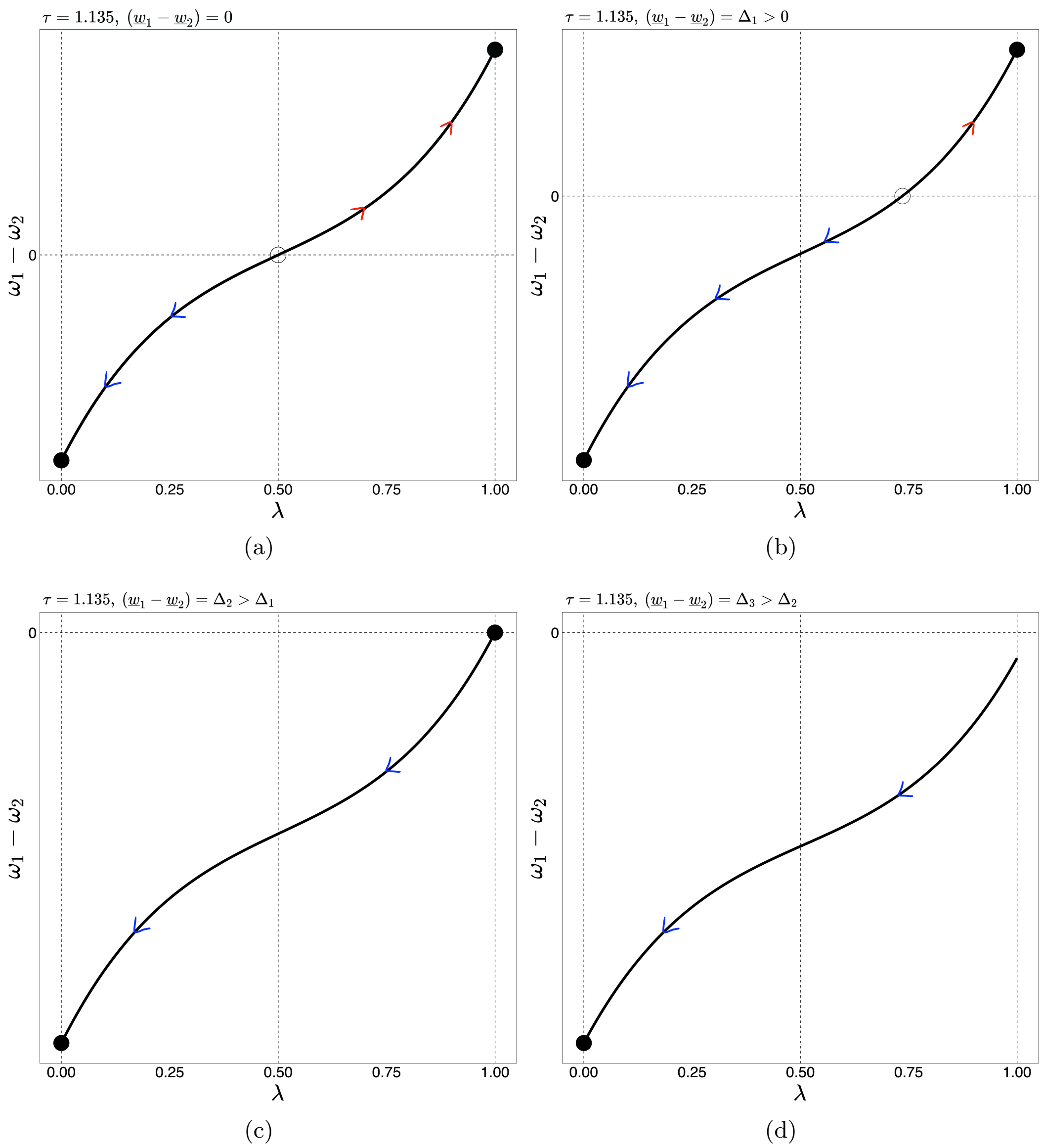


Figure 2: Simulation results with a low transport cost, $\tau = 1.135$

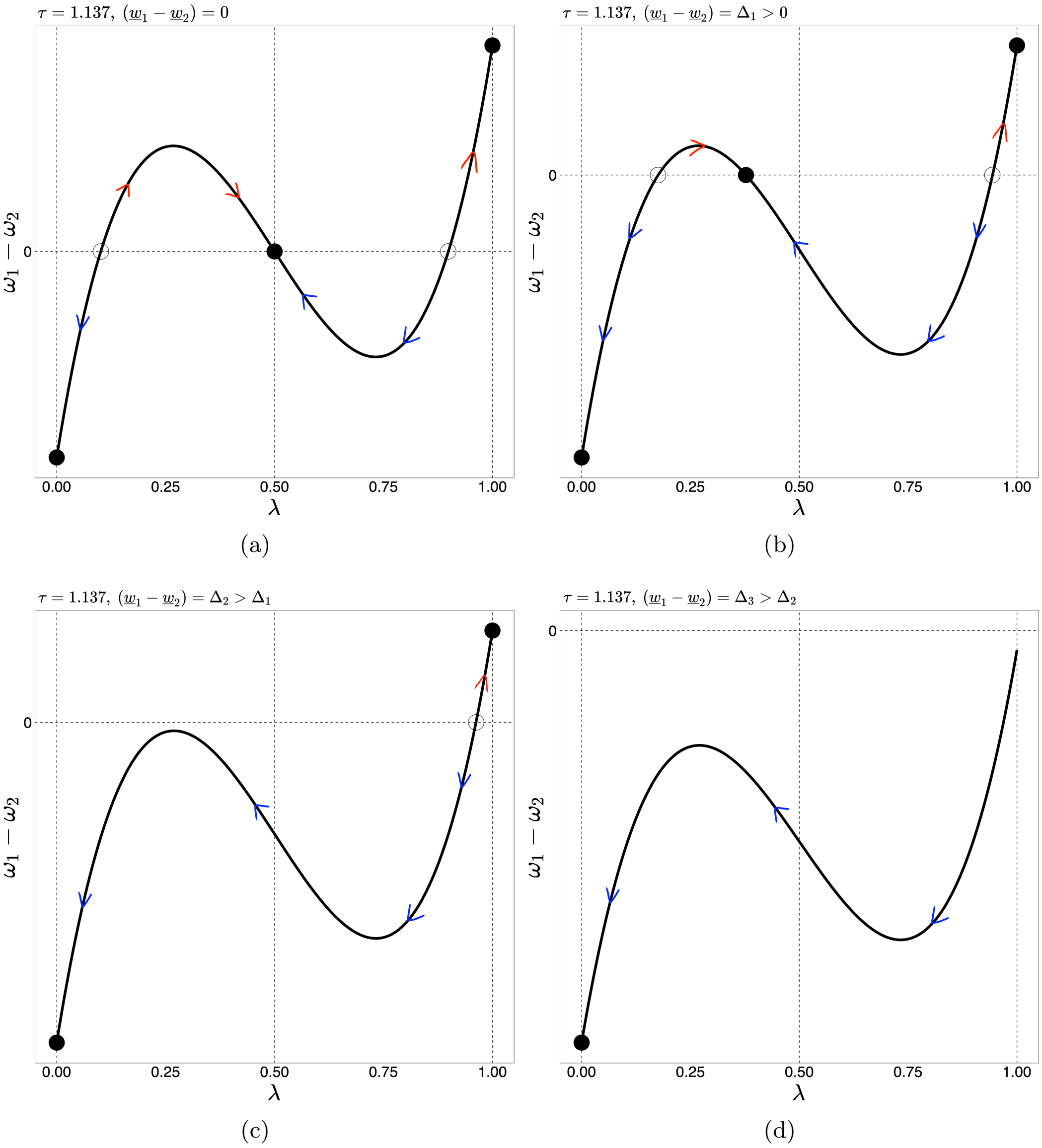


Figure 3: Simulation results with an intermediate transport cost, $\tau = 1.137$

3.2.1 Without a minimum wage gap

Starting with panel (a) cases where there is no minimum wage gap between the two regions, we confirm the initial spatial distribution of manufacturing firms.

When the exogenous minimum wage is the same in two regions, the spatial distributions demonstrate the same patterns as in the standard *core-periphery model*.[9] That is, with a high transport cost in Figure 1(a), firms are evenly dispersed across two regions; with a low transport cost in Figure 2(a), the symmetric equilibrium becomes unstable and all firms tend to concentrate in one region; with an intermediate transport cost in Figure 3(a), firms may be evenly spread or concentrated in one region depending on the starting point of the economy.

3.2.2 With a local minimum wage increase

For our interest in the spatial distribution of manufacturing firms with a local minimum wage hike, we primarily examine Region 1 and discuss the results under different transport costs.

Figure 1: A high transport cost

With a sufficiently high transport cost ($\tau = 1.142$), as shown in Figure 1, the dispersed configuration ($0 < \lambda < 1$) holds in spatial equilibrium. The equilibrium is symmetric if $\underline{w}_1 = \underline{w}_2$ (panel (a)). As Region 1 increases its minimum wage, the economy moves to an asymmetric equilibrium (panel (b)). Further increases in Region 1's minimum wage cause its manufacturing share to shrink (panel (c)), until all manufacturing firms relocate to Region 2 ($\lambda = 0$), resulting in the complete deindustrialization of Region 1. This change occurs gradually.

Apparently, in a high transport cost case where the dispersion force is at work strongly, the region with a higher minimum wage would only be at a disadvantage compared to another region with lower production costs. This scenario is, to some extent, consistent with the simulation result in Méjean and Patureau (2010), which shows that the minimum wage hike is more likely to reduce the local region's attractiveness continuously.

Figure 2: A low transport cost

In contrast, with a sufficiently low transport cost ($\tau = 1.135$), as shown in Figure 2, the economy reaches spatial equilibrium only under complete agglomeration in one region ($\lambda = 1$ or $\lambda = 0$). Any dispersed configuration, indicated by a hollow dot, is unstable. Starting from $\underline{w}_1 = \underline{w}_2$ (panel (a)), as Region 1 raises its minimum wage, the existing agglomeration remains stable (panel (b)) until the minimum wage reaches a critical threshold (panel (c)). Established agglomerations benefit from strong intrinsic advantages, allowing the region to raise the minimum wage without fear of any manufacturing firms moving out. This scenario aligns with the theoretical rationale in Pflüger (2004b) and appears more consistent with the empirical findings of Rohlin (2011), which suggest that minimum wage policies deter new firms but have little effect on the location decisions of existing firms. Moreover, minimum wage increases are not sufficiently disruptive to induce relocation of established firms.

[9]See Fujita et al. (1999, Chapter 5.3) and Fujita and Thisse (2013, Chapter 8.2) among others.

If Region 1's minimum wage exceeds the critical threshold, the spatial structure undergoes a "sudden change" to complete agglomeration in Region 2 ($\lambda = 0$, panel (d)),[10] as all manufacturing firms relocate without transitioning through any asymmetric equilibrium ($0 < \lambda < 1$). This case represents a catastrophic hollowing out.

Figure 3: An intermediate transport cost

The case of an intermediate transport cost ($\tau = 1.137$) provides important insights into the impact of minimum wage increases on spatial structure. Figure 3 shows that the economy exhibits multiple equilibria, including both dispersed and agglomerated configurations.

As Region 1 raises its minimum wage from the initial level ($\underline{w}_1 = \underline{w}_2$, panel (a)) to $\underline{w}_1 > \underline{w}_2$ (panel (b)), two key observations emerge. First, the complete agglomeration equilibrium ($\lambda = 1$) is still maintained, while the evenly dispersed equilibrium ($\lambda = 0.5$) shifts to an asymmetric configuration with $\lambda < 0.5$. These patterns resemble those observed in Figures 1 and 2.

However, as Region 1 continues to raise its minimum wage, the asymmetric equilibrium collapses at the level depicted in panel (c), triggering a discontinuous shift to complete agglomeration in Region 2 ($\lambda = 0$). Notably, if the economy initially exhibits complete agglomeration in Region 1 ($\lambda = 1$), this structure remains stable at the same minimum wage level shown in panel (c). Further increases in Region 1's minimum wage push the economy toward the scenario in panel (d), where all manufacturing firms relocate to Region 2.

Thus, under intermediate transport costs, we find that the spatial structure follows multiple possible trajectories in response to unilateral minimum wage increases, depending on the initial configuration. In other words, our analysis underscores the role of historical path dependence in shaping spatial equilibrium outcomes.

To sum up, should the industrial region raising the minimum wage be concerned about hollowing out? Based on the spatial general equilibrium model developed in Section 2, our simulation results in a two-region economy suggest that the spatial outcome depends on the interplay of transport costs, minimum wage thresholds, and historical path dependence. In certain scenarios (with sufficiently low transport costs and minimum wages below critical thresholds), the region can retain its core advantages due to agglomeration rents, even with higher minimum wages. In other cases, however, the risk of hollowing out becomes more pronounced.

4 Analysis Within the Core-Periphery Pattern

Section 3 highlights the possibility that Region 1, despite having a higher minimum wage, can maintain its economic vitality without inducing the relocation of firms. This section further explores the core-periphery pattern, where Region 1 remains the core with its higher minimum wage. Section 4.1 investigates the sustainability of the core-periphery pattern both visually and analytically. Section 4.2 discusses the effect of the minimum wage increase

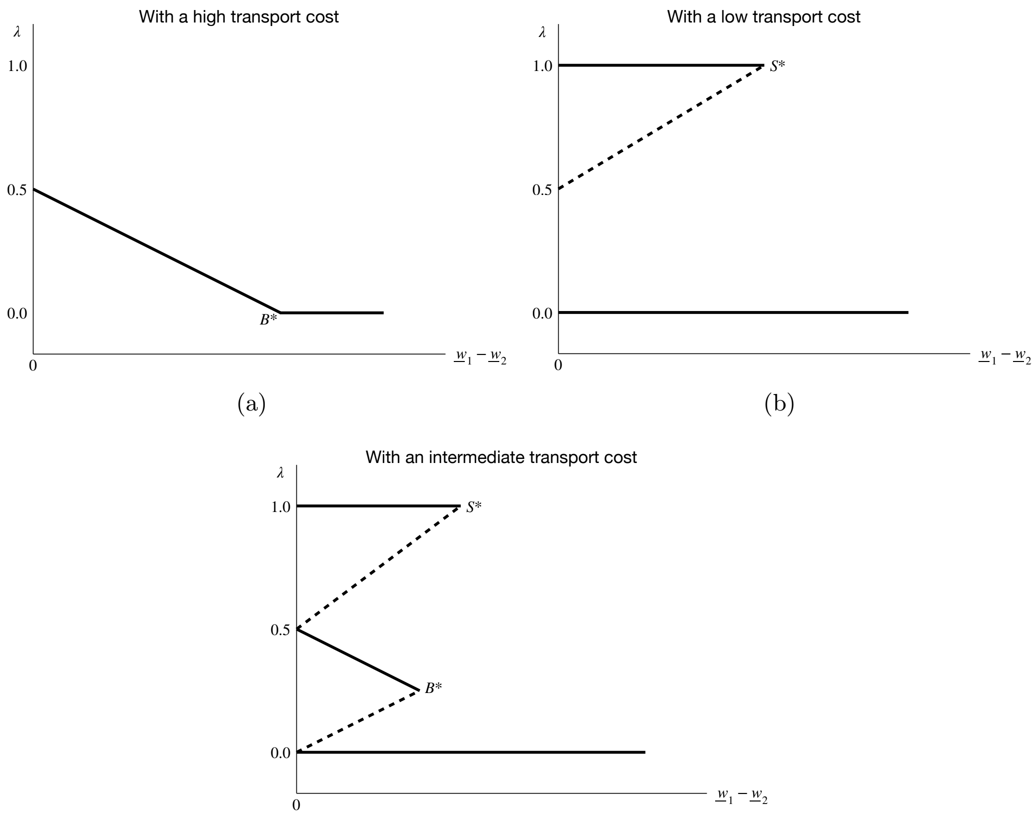
[10] See Krugman (1991a) for further discussion of the logic of "sudden change".

on the local labor market.

4.1 Sustainability of the Core-Periphery Pattern

The first question is to ask: When is the core-periphery pattern sustainable even with a higher minimum wage in Region 1? The answer is visualized in the bifurcation diagrams shown in Figure 4, which illustrates how the types of equilibria vary with regional minimum wage differentials under different transport costs.

Figure 4 plots the minimum wage gap ($\underline{w}_1 - \underline{w}_2 \geq 0$) against the share of manufacturing firms in Region 1 ($\lambda \in [0, 1]$) under different levels of transport costs. The solid lines indicate stable equilibria, and the dashed lines are unstable. The break point, marked as point B^*, shows where the asymmetric equilibrium (Region 1, with a higher minimum wage, still has a smaller manufacturing sector) must be broken. The sustain point, marked as point S^*, indicates where the core-periphery pattern (Region 1, with a higher minimum wage, is the core) can be sustained once established.



(c)

Notes: For an intermediate transport cost in panel (c), the minimum wage differential at point $S^*(\Delta_{S^*})$ is not necessarily always greater than that at point $B^*(\Delta_{B^*})$. For example, $\Delta_{S^*} > \Delta_{B^*}$ when $\tau = 1.137$ (the case in Figure 3); and $\Delta_{S^*} < \Delta_{B^*}$ when $\tau = 1.1373$.

Figure 4: Bifurcation diagrams with a local minimum wage increase in Region 1

Panel (a) shows that if transport costs are sufficiently high, starting from the symmetric equilibrium, the share of manufacturing firms in Region 1 will decrease until it reaches zero as the minimum wage gap continues to increase. In contrast, if transport costs are low or intermediate, the sustain points in panels (b) and (c) suggest that Region 1 has the potential to be the core, i.e., the core-periphery pattern (Region 1, with a higher minimum wage, is the core) can be sustainable under certain critical conditions.

In addition, we explicitly identify the critical condition that the core-periphery equilibrium with all manufacturing firms concentrated in Region 1 sustains. As detailed in Appendix B, we first posit a situation in which $\lambda = 1$, and then derive the condition that $\omega_1 \geq \omega_2$ holds to ensure that skilled mobile workers and firms have no incentive to move out of Region 1. The sustainability condition is as follows:

$$\frac{(1+\mu)\sigma\underline{w}_1 - \mu(\sigma-1)}{(1-\mu)\sigma\underline{w}_1 + \mu(\sigma-1)} \geq \frac{\tau^{\sigma-1-\mu} - \widetilde{\underline{w}}}{\widetilde{\underline{w}} - \tau^{1-\sigma-\mu}}, \quad \text{where} \quad \widetilde{\underline{w}} \equiv \left(\frac{\underline{w}_1}{\underline{w}_2}\right)^{1-\sigma} \tag{21}$$

which defines the relationship between exogenous parameters ($\tau, \underline{w}_1, \underline{w}_2, \mu$, and σ). When τ or $\underline{w}_1$ is exorbitant, the right-hand side of Equation (21) becomes arbitrarily large and the condition is unlikely to hold. This is consistent with our discussions in Section 3.2 that the core-periphery pattern (Region 1, with a higher minimum wage, is the core) cannot exist when transport costs are sufficiently high or the regional minimum wage gap is too large.

However, the scope for raising the local minimum wage while remaining attractive, which can be interpreted as agglomeration rent, is limited.[11] Specifically, a higher minimum wage can have two opposite effects in our model. It may provide a larger home market, contributing to the agglomeration force, or it can raise the production cost, acting as the dispersion force. The outcome depends on the balance between these two effects under different transport costs. In the extreme case of $\tau = 1$ (no transport costs), the size of the home market associated with location no longer matters, and firms prefer regions with lower production costs. The agglomeration rent declines with sufficiently low transport costs because firms are more sensitive to cost differentials. In a nutshell, the balance between the positive impact of higher minimum wages on the home market effect and increased production costs constrains the extent to which the core region can increase minimum wages without causing firm relocation. Besides, Pflüger (2004b) argues that the relationship between the agglomeration rent and the level of transport costs is bell-shaped, regarding the balance between the income effect and the local competition effect. Our simulation results confirm the bell-shaped relationship with an alternative approach.[12]

4.2 Minimum Wage Effects on Local Labor Market

Under the condition of sustainability, Region 1 could increase the minimum wage without causing manufacturing firms to relocate, once it has established its agglomeration advantage

[11] In models of NEG, an agglomeration rent is accrued universally to the mobile factor in the core region. Baldwin et al. (2003) offers a comprehensive analysis of the bell-shaped agglomeration rent in a wide variety of models. For discussion about the agglomeration rent and public policy, see Baldwin and Krugman (2004) and Borck and Pflüger (2006) on tax competition, and Pflüger (2004b) on wage and social policies.

[12] For example, with the simulation parameters in Section 3.2, the agglomeration rent reaches a maximum at $\tau = 1.066$.

as the core. It is important, however, to take into account the impacts of the minimum wage increase on the local labor market.

Given the presence of the core-periphery pattern with all firms concentrated in Region 1 (with a higher minimum wage), we can derive the following expressions. (See Appendix C for the proof.)

$$\frac{\partial w_1}{\partial \underline{w}_1} > 0, \quad \frac{\partial Y_1}{\partial \underline{w}_1} > 0, \quad \frac{\partial (w_1/\underline{w}_1)}{\partial \underline{w}_1} < 0, \quad \frac{\partial L_1^M}{\partial \underline{w}_1} < 0, \quad \frac{\partial L_1^A}{\partial \underline{w}_1} > 0 \tag{22}$$

First, the minimum wage increase raises the nominal wage that skilled workers receive (w_1) as well as the total income (Y_1) in Region 1, revealing the positive demand feedback from minimum wage hikes that strengthens agglomeration forces. This is in line with Belman and Wolfson (2014, Chapter 5)'s conclusion, derived from a review of empirical studies, that a higher minimum wage results in a higher average wage.

Second, the minimum wage demonstrates two distinct effects on the two forms of wage inequality present in our model. An increase in the minimum wage narrows the wage gap between skilled and unskilled workers within the manufacturing sector. Conversely, the wage gap between unskilled workers in the manufacturing and agriculture sectors widens, given that the latter receive the numéraire wage in the model.

Finally, another issue to consider is the effect of the minimum wage on employment. In labor economics, the neoclassical competitive model predicts that a higher minimum wage reduces employment as firms substitute unskilled with skilled workers (Neumark and Wascher, 2008). There is no unemployment in our model, but unskilled workers do move between sectors. Within the core-periphery pattern, Equation (22) shows that Region 1 with a higher minimum wage could still retain all of its skilled workers, but the employment of unskilled workers would decrease in the manufacturing sector (L_1^M) and increase in the agricultural sector (L_1^A). However, it is worth bearing in mind that industrial hollowing out, i.e., the disappearance of all manufacturing employment in Region 1, both skilled and unskilled, could occur if Region 1 raises the minimum wage too high or if transport costs become sufficiently expensive.

5 Conclusion

In this paper, we developed a spatial general equilibrium model with exogenous minimum wages and explored regional minimum wage disparities in the New Economic Geography. Numerical simulations within a two-region economy revealed the impact of minimum wage hikes on the spatial distribution of manufacturing firms. We observed industrial hollowing out beyond a critical minimum wage gap threshold. However, the core region with a higher minimum wage can remain attractive without fear of any manufacturing firms moving out, given sufficiently low transport costs.

Such attractiveness within the core-periphery pattern, where Region 1 remains the industrial core with its higher minimum wage, can be interpreted as agglomeration rent. The agglomeration rent declines with sufficiently low transport costs because firms are more sensitive to cost differentials. Specifically, in our model, a higher minimum wage can have two opposite effects on the economy: it can contribute to the agglomeration force by providing larger home markets, or it can serve as the dispersion force by raising production costs. The balance between these effects constrains the extent to which the core region can increase minimum wages without causing manufacturing firms to relocate. Moreover, the sustainability of this core-periphery pattern and the effect of the minimum wage increase on the local labor market were examined analytically.

Although the arguments of this paper relied partially on numerical parameters, our simulation results, based on a spatial general equilibrium model, offer a novel perspective on the need for national balancing of regional minimum wages to take into account the state of transport costs. That is, considering the key role of transport costs is on the agenda for further empirical research on the impact of minimum wage policies on job migration and firms' location decisions.

References

Azar, J., Huet-Vaughn, E., Marinescu, I., Taska, B., and Von Wachter, T. (2023). Minimum Wage Employment Effects and Labour Market Concentration. *The Review of Economic Studies*, page rdad091.

Baldwin, R., Forslid, R., Martin, P., Ottaviano, G., and Robert-Nicoud, F. (2003). *Economic Geography and Public Policy.* Princeton University Press.

Baldwin, R. E. and Krugman, P. (2004). Agglomeration, Integration and Tax Harmonisation. *European Economic Review*, 48(1):1–23.

Belman, D. and Wolfson, P. J. (2014). *What Does the Minimum Wage Do?* W.E. Upjohn Institute for Employment Research.

Bodnár, K., Fadejeva, L., Iordache, S., Malk, L., Paskaleva, D., Pesliakaitė, J., Jemec, N. T., Tóth, P., and Wyszyński, R. (2018). How do Firms Adjust to Rises in the Minimum Wage? Survey Evidence From Central and Eastern Europe. *IZA Journal of Labor Policy*, 7:1–30.

Boeri, T. and Ours, J. v. (2014). *The Economics of Imperfect Labor Markets.* Princeton University Press, Second edition.

Borck, R. and Pflüger, M. (2006). Agglomeration and Tax Competition. *European Economic Review*, 50(3):647–668.

Brakman, S., Garretsen, H., and Van Marrewijk, C. (2019). *An Introduction to Geographical and Urban Economics: A Spiky World.* Cambridge University Press, Third edition.

Card, D. and Krueger, A. B. (1994). Minimum Wages and Employment: A Case Study of the Fast-Food Industry in New Jersey and Pennsylvania. *The American Economic Review*, 84(4):772–793.

Card, D. and Krueger, A. B. (2016). *Myth and Measurement: The New Economics of the Minimum Wage*. Princeton University Press, Twentieth-Anniversary edition.

Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic Competition and Optimum Product Diversity. *The American Economic Review*, 67(3):297–308.

Draca, M., Machin, S., and Van Reenen, J. (2011). Minimum Wages and Firm Profitability. *American Economic Journal: Applied Economics*, 3(1):129–151.

Dube, A. and Lindner, A. (2024). Minimum Wages in the 21st Century. In Dustmann, C. and Lemieux, T., editors, *Handbook of Labor Economics*, volume 5, pages 261–383. Elsevier.

Forslid, R. and Ottaviano, G. I. (2003). An Analytically Solvable Core-Periphery Model. *Journal of Economic Geography*, 3(3):229–240.

Fujita, M. (2010). The Evolution of Spatial Economics: From Thünen to the New Economic Geography. *The Japanese Economic Review*, 61(1):1–32.

Fujita, M., Krugman, P. R., and Venables, A. (1999). *The Spatial Economy: Cities, Regions, and International Trade*. The MIT Press.

Fujita, M. and Thisse, J.-F. (2013). *Economics of Agglomeration: Cities, Industrial Location, and Globalization*. Cambridge University Press, Second edition.

Harasztosi, P. and Lindner, A. (2019). Who Pays for the Minimum Wage? *American Economic Review*, 109(8):2693–2727.

Hirsch, B. T., Kaufman, B. E., and Zelenska, T. (2015). Minimum Wage Channels of Adjustment. *Industrial Relations: A Journal of Economy and Society*, 54(2):199–239.

Krugman, P. (1991a). *Geography and Trade*. The MIT Press.

Krugman, P. (1991b). Increasing Returns and Economic Geography. *Journal of Political Economy*, 99(3):483–499.

Li, X., Shi, D., and Zhou, S. (2023). The Minimum Wage and the Locations of New Business Entries in China: Estimates Based on a Refined Border Approach. *Regional Science and Urban Economics*, 99:103876.

Méjean, I. and Patureau, L. (2010). Firms' Location Decisions and Minimum Wages. *Regional Science and Urban Economics*, 40(1):45–59.

Neumark, D. and Wascher, W. L. (2008). *Minimum Wages*. The MIT Press.

Pflüger, M. (2004a). A Simple, Analytically Solvable, Chamberlinian Agglomeration Model. *Regional Science and Urban Economics*, 34(5):565–573.

Pflüger, M. (2004b). Economic Integration, Wage Policies, and Social Policies. *Oxford Economic Papers*, 56(1):135–150.

Pflüger, M. and Südekum, J. (2008). A Synthesis of Footloose-Entrepreneur New Economic Geography Models: When is Agglomeration Smooth and Easily Reversible? *Journal of Economic Geography*, 8(1):39–54.

Rohlin, S. M. (2011). State Minimum Wages and Business Location: Evidence From a Refined Border Approach. *Journal of Urban Economics*, 69(1):103–117.

Samuelson, P. A. (1954). The Transfer Problem and Transport Costs, II: Analysis of Effects of Trade Impediments. *The Economic Journal*, 64(254):264–289.

Schmitt, J. (2015). Explaining the Small Employment Effects of the Minimum Wage in the United States. *Industrial Relations: A Journal of Economy and Society*, 54(4):547–581.

Strauss-Kahn, V. (2005). Firms' Location Decision Across Asymmetric Countries and Employment Inequality. *European Economic Review*, 49(2):299–320.

Takatsuka, H. (2011). Economic Geography of Firms and Skilled Labor. *Journal of Regional Science*, 51(4):784–803.

Appendix A The Presence of Agglomeration Forces

In the context of a symmetric exogenous minimum wage rate ($\underline{w}_1 = \underline{w}_2 \equiv \underline{w}$), we have the price indices,

$$\begin{aligned} G_1^{1-\sigma} &= \sigma \left(H_1 \underline{w}_1^{1-\sigma} + H_2 \underline{w}_2^{1-\sigma} \tau^{1-\sigma} \right) \\ G_2^{1-\sigma} &= \sigma \left(H_1 \underline{w}_1^{1-\sigma} \tau^{1-\sigma} + H_2 \underline{w}_1^{1-\sigma} \right) \end{aligned} \tag{A.1}$$

and the wage equations,

$$\begin{aligned} w_1 &= \mu \underline{w}_1^{1-\sigma} \left(Y_1 G_1^{\sigma-1} + Y_2 G_2^{\sigma-1} \tau^{1-\sigma} \right) \\ w_2 &= \mu \underline{w}_2^{1-\sigma} \left(Y_1 G_1^{\sigma-1} \tau^{1-\sigma} + Y_2 G_2^{\sigma-1} \right) \end{aligned} \tag{A.2}$$

within a two-region version of the economy. The symmetric solution for Equation (20) is then characterized by $H_1 = H_2 = \theta/2 \equiv H, Y_1 = Y_2 \equiv Y, G_1 = G_2 \equiv G$, and $w_1 = w_2 \equiv w$. Furthermore, it is straightforward to verify that the following relationships are satisfied.

$$1 + \tau^{1-\sigma} = \frac{1}{\sigma H} \left(\frac{G}{\underline{w}} \right)^{1-\sigma} = \frac{w}{\mu Y} \left(\frac{G}{\underline{w}} \right)^{1-\sigma} \tag{A.3}$$

We show the presence of agglomeration forces by examining them around the symmetric equilibrium. Around this point, an increase in a variable in one region is always accompanied by a corresponding decrease in the other region, with an equal absolute magnitude. Therefore, let $\mathrm{d}\Phi = \mathrm{d}\Phi_1 = -\mathrm{d}\Phi_2$, where $\Phi = \{H, Y, G, w, \underline{w}\}$.

(i) The *price index effect*

By differentiating the price indices (A.1), we obtain,

$$(1-\sigma)\frac{\mathrm{d}G}{G} = Z\left[\frac{\mathrm{d}H}{H} + (1-\sigma)\frac{\mathrm{d}\underline{w}}{\underline{w}}\right], \quad \text{where} \quad Z \equiv \frac{1-\tau^{1-\sigma}}{1+\tau^{1-\sigma}} \tag{A.4}$$

in which the new variable $Z \in (0, 1)$ serves as a measure of trade cost. In extreme cases, $Z = 0$ (when $\tau = 1$) indicates that trade is perfectly free, whereas $Z = 1$ (when $\tau = \infty$) indicates that trade is impossible. Given that $1 - \sigma < 0$ and $Z > 0$ and assuming $\mathrm{d}\underline{w} = 0$, Equation (A.4) implies that a change in the employment of skilled workers ($\mathrm{d}H/H$) has a negative effect on the price index of manufactured goods ($\mathrm{d}G/G$). This is the so-called *price index effect*, suggesting that the region with a larger manufacturing sector tends to have a lower price index.

(ii) The *home market effect*

By differentiating the wage equations (A.2), we derive,

$$\frac{\mathrm{d}w}{w} = (1-\sigma)\frac{\mathrm{d}\underline{w}}{\underline{w}} + Z\left[\frac{\mathrm{d}Y}{Y} - (1-\sigma)\frac{\mathrm{d}G}{G}\right] \tag{A.5}$$

and substituting (A.4) into (A.5) gives:

$$\frac{1}{Z}\frac{\mathrm{d}w}{w} + \left[\frac{\sigma-1}{Z} + Z(1-\sigma)\right]\frac{\mathrm{d}\underline{w}}{\underline{w}} + Z\frac{\mathrm{d}H}{H} = \frac{\mathrm{d}Y}{Y} \tag{A.6}$$

Suppose that there is a perfectly elastic supply of skilled workers to manufacturing and the symmetric minimum wage rate is constant, i.e., $\mathrm{d}w = 0$ and $\mathrm{d}\underline{w} = 0$. Then (A.6) tells that a 1 percent change in the demand for manufactures ($\mathrm{d}Y/Y$) results in a $1/Z$ (> 1) percent change in the employment of skilled workers ($\mathrm{d}H/H$). This relationship is known as the *home market effect*. Other things being equal, the region with a larger home market has a more than proportionately larger manufacturing sector, which is associated with a lower price index. The cumulative causation as analogous to that in Fujita et al. (1999, Chapter 4.5) forms the agglomeration.

Furthermore, the impact of a symmetric minimum wage rate on the *price index effect* and the *home market effect* can be confirmed. That is to say, an increase in the minimum wage ($\mathrm{d}\underline{w}/\underline{w}$) raises the price index and expands the home market, as shown in (A.4) and (A.6), respectively. The minimum wage serves as both a dispersion force and an agglomeration force in our model.

Appendix B Proof of Equation (21)

First, we rewrite the eight equations in Equation (20) under the core-periphery pattern with $\lambda = 1$.

$$\begin{aligned} Y_1 &= \left(\sigma - \frac{\sigma-1}{\underline{w}_1}\right)\theta w_1 + \frac{1-\theta}{2} \\ Y_2 &= \frac{1-\theta}{2} \end{aligned} \tag{B.1}$$

$$\begin{aligned} G_1^{1-\sigma} &= \sigma\theta \underline{w}_1^{1-\sigma} \\ G_2^{1-\sigma} &= \sigma\theta \underline{w}_1^{1-\sigma}\tau^{1-\sigma} \end{aligned} \tag{B.2}$$

$$\begin{aligned} w_1 &= \mu \underline{w}_1^{1-\sigma} G_1^{\sigma-1}(Y_1 + Y_2) \\ w_2 &= \mu \underline{w}_2^{1-\sigma} G_1^{\sigma-1}\left(Y_1\tau^{1-\sigma} + Y_2\tau^{\sigma-1}\right) \end{aligned} \tag{B.3}$$

$$\begin{aligned} \omega_1 &= w_1 G_1^{-\mu} \\ \omega_2 &= w_2 G_2^{-\mu} \end{aligned} \tag{B.4}$$

Equation (B.1) indicates that income in Region 1 is greater than in Region 2 because Region 1 benefits from all the income generated by employment in manufacturing, and Equation (B.2) indicates that the price index is greater in Region 2 than in Region 1 ($G_2 = \tau G_1, \tau > 1$) because Region 2 has to import all its manufactured goods.

Second, substituting (B.2) and (B.3) into (B.4) and performing calculations, it is helpful to rewrite the sustain condition ($\omega_1 \geq \omega_2$) in the form

$$\begin{aligned} \underline{w}_1^{1-\sigma}(Y_1 + Y_2) \ &\geq \ \tau^{-\mu}\underline{w}_2^{1-\sigma}\left(Y_1\tau^{1-\sigma} + Y_2\tau^{\sigma-1}\right); \\ \text{or} \quad Y_1 \ &\geq \ \frac{\tau^{\sigma-1-\mu} - \widetilde{\underline{w}}}{\widetilde{\underline{w}} - \tau^{1-\sigma-\mu}}\, Y_2, \quad \text{where} \quad \widetilde{\underline{w}} \equiv \left(\frac{\underline{w}_1}{\underline{w}_2}\right)^{1-\sigma} \end{aligned} \tag{B.5}$$

Finally, the expression for Y_1 can be easily derived by substituting (B.3) into (B.1),

$$Y_1 = \frac{1-\theta}{2}\,\frac{(1+\mu)\sigma\underline{w}_1 - \mu(\sigma-1)}{(1-\mu)\sigma\underline{w}_1 + \mu(\sigma-1)} \tag{B.6}$$

and the condition on (B.5) becomes,

$$\frac{(1+\mu)\sigma\underline{w}_1 - \mu(\sigma-1)}{(1-\mu)\sigma\underline{w}_1 + \mu(\sigma-1)} \ \geq \ \frac{\tau^{\sigma-1-\mu} - \widetilde{\underline{w}}}{\widetilde{\underline{w}} - \tau^{1-\sigma-\mu}} \tag{B.7}$$

which shows the critical condition that the core-periphery pattern with all manufacturing firms located in Region 1 is sustainable.

Appendix C Proof of Equation (22)

(i) Nominal wage in Region 1

Substituting Equation (B.6) into (B.3), the expression for the nominal wage that skilled workers received in Region 1 can be rewritten as follows:

$$w_1 = \frac{1-\theta}{\theta} \frac{\mu \underline{w}_1}{(1-\mu)\sigma \underline{w}_1 + \mu(\sigma - 1)} \tag{C.1}$$

Then differentiating it with respect to $\underline{w}_1$ yields:

$$\frac{\partial w_1}{\partial \underline{w}_1} = \frac{1-\theta}{\theta} \frac{\mu^2(\sigma-1)}{[(1-\mu)\sigma \underline{w}_1 + \mu(\sigma-1)]^2} > 0 \tag{C.2}$$

The rewriting of (C.1) for the ratio of two wage rates between skilled and unskilled workers in the manufacturing sector, and its differentiation with respect to $\underline{w}_1$, reveals the following result regarding the minimum wage effect on wage inequality:

$$\frac{\partial (w_1/\underline{w}_1)}{\partial \underline{w}_1} = -\frac{1-\theta}{\theta} \frac{\mu(1-\mu)\sigma}{[(1-\mu)\sigma \underline{w}_1 + \mu(\sigma-1)]^2} < 0 \tag{C.3}$$

(ii) Total income in Region 1

Differentiating Equation (B.6) with respect to $\underline{w}_1$ gives:

$$\frac{\partial Y_1}{\partial \underline{w}_1} = \frac{\mu\sigma(\sigma-1)(1-\theta)}{[(1-\mu)\sigma \underline{w}_1 + \mu(\sigma-1)]^2} > 0 \tag{C.4}$$

(iii) Employment of unskilled workers in Region 1's two sectors

Recall that the equilibrium numbers of unskilled workers employed in the agricultural and manufacturing sectors are defined in Equation (15). In the core-periphery pattern with $\lambda = 1$ (also means $H_1 = \theta$), making use of (C.1), we characterize the employment of unskilled workers in Region 1's two sectors as follows:

$$\begin{aligned} L_1^M &= (\sigma-1)\frac{w_1}{\underline{w}_1} H_1 = \frac{\mu(\sigma-1)(1-\theta)}{(1-\mu)\sigma \underline{w}_1 + \mu(\sigma-1)} \\ L_1^A &= \frac{1-\theta}{2} - L_1^M \end{aligned} \tag{C.5}$$

Differentiating them with respect to $\underline{w}_1$ gives:

$$\begin{aligned} \frac{\partial L_1^M}{\partial \underline{w}_1} &= -\frac{\mu\sigma(\sigma-1)(1-\theta)(1-\mu)}{[(1-\mu)\sigma \underline{w}_1 + \mu(\sigma-1)]^2} < 0 \\ \frac{\partial L_1^A}{\partial \underline{w}_1} &= -\frac{\partial L_1^M}{\partial \underline{w}_1} > 0 \end{aligned} \tag{C.6}$$