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The Effects of Technological Progress in Innovative Regions on the Labor Markets of Lagging Regions: A Theoretical Perspective

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Abstract: The technological effects of innovative regions on lagging regions' labor markets have not been yet well understood, especially in the urban–rural context. I introduce a theoretical model that yields insight into the interactions between high-technology and lagging regions. While, through knowledge spillovers, urban technology can increase rural jobs, it can also reduce rural employment by raising the competitive advantage of urban firms over rural firms in product market competition. Progress in urban technology also exerts an ambiguous effect of a brain drain on the rural labor market.

Keywords: technological progress; knowledge spillovers; brain drain; product market competition

JEL Classification: J61; J64; R11; R23; O33

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1. Introduction

Due to the effect of knowledge spillovers, urban technology has been posited as a rescuer of the rural economy. However, urban technological progress can also have an adverse effect on the rural labor market through product market competition. The competition between urban and rural firms that produce identical or differentiated goods or services can decrease the demand for the outputs produced by rural firms. Therefore, progress in technology by urban firms, such as Amazon, can negatively affect the labor demand of rural firms, such as brick and mortar stores. In contrast, a brain drain can have an ambiguous influence on the rural labor market. On the one hand, urban technology can increase the outmigration from rural regions, through a brain drain; however, it can also create jobs in urban areas for unemployed workers living in rural regions.

In this paper, I introduce a theoretical framework that examines the technological effects of innovative regions on nearby labor markets in lagging regions. In doing so, I assume that innovative places are urban areas, while nearby lagging regions are rural. I incorporate the Hoselitz–Myrdal–Hirschman spread and backwash concepts with the endogenous growth theory to analyze three effects of urban technological progress: knowledge spillovers, a brain drain, and product market competition.

Surprisingly, to the best of my knowledge, no theoretical paper has yet systematically examined these effects of technological progress in innovative regions on the labor markets in lagging regions. The spillover effects of the technological progress of innovative regions have been documented in several studies. Hean and Partridge (2022) provide empirical evidence of the negative effect of urban technological progress on the rural labor market; they also provide suggestive evidence of the effects of urban technological progress, including knowledge spillovers, a rural brain drain, and product market competition. Previous studies have also found evidence of knowledge spillovers (Jaffe 1986; Jaffe et al. 1993), a brain drain (Agrawal et al. 2011; Artz 2003), and product market competition (Bloom et al. 2013). Others examine the effects of knowledge spillovers and trade in goods on wages, welfare, and economic growth across regions (Batabyal and Beladi 2015; Batabyal and Nijkamp 2019). Finally, several studies focus on technological changes and rational underdevelopment (Desmet 2002; Desmet and Ortín 2007). Under the Heckscher–Ohlin Theorem, Gumpert (2016) finds that financial transfers from innovative to technologically lagging regions could reduce the incentive for less-developed areas to adopt new technology; therefore, these transfers could potentially create an underdevelopment trap for lagging regions.

Another strand of the related literature concerns the determinants of migration. Several factors could affect migration patterns (Kourtit et al. 2021). Some of them include amenities, wages, and rents (Glaeser 2011; Lobao et al. 2021; Roback 1982), local minimum-wage laws (Hean and Deng forthcoming), institutional capacity (Lobao et al. 2021), social networks (Card 2001), and political and environmental conditions (Simpson 2022).

The relationship between the technological progress in innovative regions and lagging regions' economies is particularly significant for three reasons. First, although this research specifically analyzes the effects of technology in the urban–rural context, its implications could readily be extended to other regional (i.e., the impact of innovative European or U.S. regions on the labor markets of lagging regions) and international (i.e., the impact of innovative countries on the labor markets of developing countries) contexts. Second, without taking the negative effects of urban technology into account, any place-based policy aiming at increasing rural jobs through technological advancement could have adverse consequences. Third, given that the effects of technology are a pressing concern for academics and policymakers, this paper contributes by investigating three channels by which urban technology determines the performance of rural labor markets.

To counter the adverse effects of urban technological progress, governments should consider economic transfers, mobility assistance, and job training for rural residents (Hean and Partridge 2022). In addition, the COVID-19 pandemic has significantly affected consumers (Hean and Chairassamee 2022) and labor markets (Hean and Chairassamee Forthcoming); it could significantly change the geography of jobs. It is interesting to examine the effects of technology on the job landscape during and after the COVID-19 era.

The remaining sections are organized as follows. Section 2 describes a setup of the model that examines the three effects of technological progress in innovative regions, while Section 3 offers the equilibrium solutions of labor markets. Section 4 concludes the discussion.

2. Description of the Theoretical Model

The theoretical model in this paper builds on the endogenous growth theory of Romer (1990) and the concepts of spread and backwash in Hoselitz (1955); Myrdal (1957); Hirschman (1960).[1]

In this model, I add two important extensions to the Romer (1990) model. First, the analysis focuses on two regions, instead of one country. Second, the interactions between these regions are conducted through three channels: interregional knowledge spillovers, the mobility of labor, and trade in goods. In brief, three key mechanisms underlie the theoretical model of this paper. Knowledge spillovers from innovative regions improve the productivity of lagging regions, and therefore, the technology of innovative regions increases employment in lagging regions. Next, because technology can create jobs, technological progress in innovative regions can induce employed and unemployed residents to out-migrate from lagging regions. Such progress has an ambiguous effect on the labor markets of lagging regions. Finally, progress in technology can also raise the competitiveness of innovative regions at the expense of lagging regions.

The economy of each region can be described as follows. First, the manufacturing sector produces final goods using labor and capital. This market is competitive, so each manufacturing firm takes all prices as given. Second, the capital market is a monopolistic market, where each monopolist holds the right to a patent. A monopolist produces a capital good using raw materials and the monopolist's technology. The monopolist faces a downward-sloping demand curve. Third, the research and development sector produces new knowledge by using human capital, the existing knowledge in the region to which this sector belongs, and knowledge spillovers. In this sector, the existing knowledge in each region is a public good that everyone doing research in that region can use, and the final output is new knowledge that can be patented in that region. Fourth, agents choose whether to work, for which sector to work, and in which region to work. This decision is subject to differentials in wages, unemployment benefits, mobility costs, and the rigidity of the labor market.

In this model, there are two regions: one urban and one rural. These regions are denoted by "U" and "R", respectively. À la Romer (1990), three sectors are operating in the economy of each region. The first sector is a manufacturing sector that produces final goods. The goods produced in both regions are assumed to be substitutable to some degree. Specifically, I assume that consumers favor urban goods to rural goods because urban firms produce higher quality goods using better technology. This assumption follows the hypothesis of central place theory, which has proven to hold in many empirical studies. More details on this assumption and central place theory will be provided in Section 3.2. First, I solve the model by assuming that there is no trade between these two regions. Then, I explain how trade could affect the results of the model. To be specific, trade in the final outputs could give rise to product market competition.

At any time t, the maximization problem of the representative manufacturing firm in region $i \in \{U, R\}$ is given by,

$$\max_{L_{i,t},\ \{x_{i,t}(k)\}} Y_{i,t} \equiv L_{i,t}^{\alpha} \int_0^{A_{i,t}} [x_{i,t}(k)]^{1-\alpha} dk - (w_{i,t,L} L_{i,t} + \int_0^{A_{i,t}} x_{i,t}(k) p_{i,t}(k) dk). \quad (1)$$

I normalize the price of the final output produced in region i at time t to be one. $A_{i,t}$ is the available stock of knowledge up until time t in region i. $L_{i,t}$ is the amount of labor used in the manufacturing sector, and $\{x_{i,t}(k)\}$ are capital goods (i.e., intermediate inputs) employed to produce the final output.[2] Moreover, the final goods market is competitive, so the representative firm takes the prices of labor and capital goods (that is, $w_{i,t,L}$ and $p_{i,t}(k)$, respectively) as given.

Another sector is the capital-goods market. Each variety of capital goods in region i is produced by a monopolist who owns a patent acquired with the one-time price of $P_{A,i,t}(k)$.[3] For the time being, let us also assume that capital goods are not tradable across regions.[4] As in Jones (2005), it is safe to assume that one unit of a capital good (i.e., intermediate goods) can be produced by a unit of raw capital. At any time t, in region i, and for capital goods of variety k, a monopolist solves:

$$\max_{x_{i,t}(k)} \pi_{i,t}(k) \equiv x_{i,t}(k) p_{i,t}(k) - r x_{i,t}(k), \quad (2)$$

where $p_{i,t}(k)$ is the price of a capital good in region i at time t, and r is an exogenous interest rate on capital (that is, r might be determined by the federal government).

The third sector is a research and development sector. Following Romer (1990), I maintain the linearity assumption for the growth rate of technology. Specifically, I assume that

$$\frac{\dot{A}_{i,t}}{A_{i,t}} = \delta_i H_{i,t} \phi_i, \quad (3)$$

where δ_i is the productivity parameter of region i, and $H_{i,t}$ is the human capital employed in the research and development sector. ϕ_i is the absorptive capacity of region i in capturing interregional knowledge spillovers; I assume that it is constant and greater than or equal to one. The assumptions imposed on ϕ_i are by no means able to successfully reflect the nature of knowledge spillovers across regions. These assumptions are maintained only for analytical convenience.[5] ϕ_i equals 1, meaning that the growth rate of technology in region i only depends on local productivity and local human capital. The greater ϕ_i implies that region i's technology can grow faster by absorbing knowledge from the neighboring region. Finally, as in Romer (1990), the market for patents, which are the products of the R&D sector, is assumed to be competitive.

Regarding the labor market, the total population in both regions sums up to a constant. For simplicity, let us assume that everyone is endowed with a unit of labor. For simplicity, I assume that each person can either supply either a unit or none of his or her labor to the market.

Let m and n be positive real numbers, then define $f(m,n)$ and $d(m,n)$ as follows:

$$f(m,n) = \frac{m-n}{m+n} \tag{4}$$

$$\begin{cases} d(m,n) = 1 & if\ m > n \\ d(m,n) = 0, & otherwise \end{cases}. \tag{5}$$

For $m, n > 0$, it is straightforward to show that $(m,n) = -f(n,m)$, $f(m,n) \in (-1,1)$, $\frac{\partial f(m,n)}{\partial m} > 0$, and $\frac{\partial f(m,n)}{\partial n} < 0$. One can also establish that $f(m,m) = 0$; $\lim_{n \to 0} f(m,n) = \lim_{m \to 0} -f(m,n) = 1$, and $\lim_{m \to \infty} f(m,n) = \lim_{n \to \infty} -f(m,n) = 1$. Furthermore, for $m < m'$, $n < n'$, and $|m-n| = |m'-n'| \neq 0$, we have $|f(m,n)| < |f(m',n')|$. In what follows, I use $f(m,n)$ to capture the flow rate of labor into and out of the labor market. Specifically, if m, n are wages in regions i and j, respectively, and if $m > n$, the flow of the labor force from j to i is proportional to the difference between these wages (the numerator of $f(m,n)$). The rate is between zero and one. The rate approaches one when the wage in region j approaches zero or when the wage in region i approaches infinity. Finally, it gets harder to attract more labor from region j as both wages grow higher, given that the difference between these wages is constant over time.

For the sake of model tractability, I specify the change in population in each region as follows:

i. The change in total unemployment in region i at time t that is due to the labor participation or the quitting of jobs by agents living in region i at time t:

$$\dot{Pop}_{ue,i,t} = f(w_{ue,i}, w_{e,i,t})\left[d(w_{e,i,t}, w_{ue,t})(Pop_{i,t} - Pop_{e,i,t}) + d(w_{ue,t}, w_{e,i,t})Pop_{e,i,t}\right] \tag{6}$$

$\dot{Pop}_{ue,i,t}$ is the change in total unemployment in region i at time t. $w_{e,i,t}$ is the highest wage offered in region i at time t; $w_{ue,t}$ is the unemployment benefit in both regions. Assume that the unemployment benefit grows at a constant rate, such that $w_{ue,t} = (\gamma_{ue})^t w_{ue,0}$, where $w_{ue,0}$ is a given unemployment benefit at the beginning of time. The growing unemployment benefit encompasses the idea that the unemployed agents have received higher unemployment benefits over time. $Pop_{i,t}$ and $Pop_{e,i,t}$ are the total population and total employment in region i at time t.

Equation (6) states that a change in the total unemployment in region i at time t is proportional to the difference between the unemployment benefits and the highest wage offered. If the wage is greater than the unemployment benefits, a fraction of the people unemployed will be employed in the next period. If the wage is less than the unemployment benefits, some workers will quit their jobs. Otherwise, there is no change in total unemployment. This condition, which is imposed by setting $f(m,n) \in (-1,1)$, reflects rigidity or friction in the labor market, which cannot fully adjust in response to changes in wage and unemployment benefits.[6] It also captures the idea that workers have heterogeneous responses to changes in labor conditions. That is, workers might have idiosyncratic unemployment benefits.

ii The change in total unemployment in region i at time t that is due to the out-migration of unemployed agents to region j:

$$\dot{Pop'}_{ue,i,t} = M_{ue,i} d(w_{e,j,t}, w_{e,i,t}) d(w_{e,j,t}, w_{ue,t}) f(w_{ue,t}, w_{ue,j,t})\left[Pop_{i,t} - Pop_{e,i,t}\right] \tag{7}$$

This condition says that unemployed agents living in region i will move to work in region j whenever the highest wage offered in region j is higher than the highest wage offered in region i. The mobility of migrants is restricted by the ease of mobility captured by $M_{ue} \in (0,1)$. That is, $(1 - M_{ue,i})$ are mobility costs, such as travel distance, sociopsychological costs, and amenity values, that migrants living in region i incur when they decide to work in region j. The low M_{ue} reflects a case where the costs of the labor mobility of unemployed migrants are very high, and therefore, the flow of unemployed migrants is very low.

iii The change in total employment in region i at time t that is due to migration by the employed workers in region j at time t:

$$\dot{Pop}_{e,i,t} = f(w_{e,i,t}, w_{e,j,t})\left[M_{e,j}d(w_{e,i,t}, w_{e,j,t})Pop_{e,j,t} + M_{e,i}d(w_{e,j,t}, w_{e,i,t})Pop_{e,i,t}\right] \quad (8)$$

Equation (8) requires a fraction of the employed agents living in region j to work in region i, when the highest wage offered in region i is higher than the highest wage offered in region j. Equation (8) also requires the number of workers gained by region i to be equal to the number of employed agents leaving region j. The mobility of migrants is restricted by the ease of mobility, $M_e \in (0,1)$. That is, $(1 - M_{e,j})$ captures a variety of costs, such as travel distance, social costs, and amenity values for migrants who are employed and living in region j at time t. The low M_e corresponds to a situation in which the costs of the labor mobility of employed migrants is very high, and therefore, the flow of employed migrants is very low.

Heretofore, I have ignored the situation where there is job mobility across sectors within any region. That is, workers can switch from the manufacturing sector to the R&D sector. For this model, such a situation is not necessary for the analysis, for two reasons. First, job mobility across the sectors within a region does not affect the unemployment rate in that region. Second, it turns out that there is no job mobility in this model when both sectors are operating. This is because the wages offered in both sectors are equal in an equilibrium. This condition is discussed in more detail in Section 3.

3. Equilibrium of the Labor Market

3.1. Equilibrium of the Labor Market with No Trade in Goods

I drop unnecessary subscripts to avoid cluttering notations. With no trades, the analysis of this model is straightforward, as in the analyses in Romer (1990) and Aghion and Howitt (1998c). One can prove the following conditions in an equilibrium:

i. There is no arbitrage between workers employed in the manufacturing sector and the R&D sector in each region at any time if both sectors are to operate:

$$w_{L,i,t} = w_{H,i,t}, \quad (9)$$

where $w_{L,i,t}$ and $w_{H,i,t}$ are wages offered to employees working in the manufacturing goods and R&D sectors in region i at time t, respectively.

ii. Due to the symmetry of all capital goods, in region i at time t, we have:

$$x_{i,t}(k) = x_{i,t}, \quad (10)$$

$$P_{A,i,t}(k) = P_{A,i,t}. \quad (11)$$

iii. Since the existing knowledge is available for everyone in the R&D sector to use, in region i at time t, we have the following condition:

$$w_{H,i,t} = P_{A,i,t}\delta_i\phi A_{i,t}. \quad (12)$$

iv. The total workers in region i at time t is

$$Pop_{e,i,t} = L_{i,t} + H_{i,t}. \quad (13)$$

v. The total employment in the sector producing manufacturing goods in region i at time t is constant. Hence,

$$L_{i,t} = \frac{r}{(1-\alpha)\delta\phi_i}. \tag{14}$$

vi. The competitive market in the manufacturing sector will equalize the labor wage and the marginal productivity of labor. That is,

$$w_L = \alpha L^{\alpha-1} A x^{1-\alpha}. \tag{15}$$

vii. The price of each capital good must be equal to the marginal product of each capital good in the manufacturing sector. Therefore,

$$p(x) = (1-\alpha) L^{\alpha} x^{-\alpha}. \tag{16}$$

Corollary 1. *Progress in technology leads to high wage.*

Proof. By substituting (12) into (2) and solving for x, the solution to a monopolistic optimization problem will be:

$$x = \left[\frac{r}{(1-\alpha)^2}\right]^{-1/\alpha} L. \tag{17}$$

Then, using (5), (9), and (11), we can derive the following condition,

$$P_A = \frac{\alpha}{\delta\phi_i} L^{\alpha-1} x^{1-\alpha}. \tag{18}$$

Next, we can derive the following condition:

$$P_A = \frac{\alpha}{\delta\phi_i}\left[\frac{r}{(1-\alpha)^2}\right]^{-1/\alpha}. \tag{19}$$

Now, by substituting the value of P_A into (12), we can solve for w_H such that,

$$w_H = \alpha\left[\frac{r}{(1-\alpha)^2}\right]^{-1/\alpha} A. \tag{20}$$

Equation (20) is the regional wage equation. It states that raising the technological stock in region i and at any time t will increase wages.[7] This is because technology increases the productivity of human capital (both in the R&D and manufacturing sectors). □

Proposition 1. *The growth rate of wages increases with the technological progress rate, which depends on the degree of knowledge spillovers or the absorptive capacity.*

Proof. Taking logs and the time derivative of (20) gives us the following condition,

$$\frac{\dot{w}_H}{w_H} = \frac{\dot{A}}{A} - \frac{\dot{r}}{\alpha r} = \delta H\phi - \frac{\dot{r}}{\alpha r}. \tag{21}$$

□

Corollary (1) shows that the growth rate of wages in a region increases with the growth rate of the technological stock in that region. From this corollary, urban technology can lead to progress in rural technology through interregional knowledge spillovers (that is,

ϕ_R). Knowledge spillovers increase the growth rate of rural technology (that is, $\frac{\dot{A}}{A}$), and so they raise the knowledge stock of the rural region. By raising the rural knowledge stock, urban knowledge spillovers increase the wages of rural workers, limit the outflow of human capital, and raise the labor participation rate. Precisely by raising wages, urban technology effectively reduces the rural unemployment rate through two channels: first, by increasing the wage growth in the next period ($\frac{\partial}{\partial H_{R,t}}\left(\frac{\dot{A}}{A}\right) > 0$), and second, by increasing the participation of unemployed agents in the rural labor market ($\frac{\partial \dot{Pop}_{ue,R,t}}{\partial w_{e,R,t}} > 0$).[8] However, urban technology can also give rise to a brain drain, which has an ambiguous net effect on rural labor.

Proposition 2. *Given that $A_U > A_R$ and $w_{e,U,t} > w_{ue,t}$, the brain drain caused by the progress of urban technology has an ambiguous effect on the unemployment rate in the rural region.*

Proof. If $A_U > A_R$ and $w_{H,U,t} > w_{ue,t}$, by Corollary 1, Equation (6) becomes

$$\dot{Pop}'_{ue,R,t} = M_{ue,R} f(w_{ue,t}, w_{H,U,t})[Pop_{R,t} - Pop_{e,R,t}] < 0. \tag{22}$$

Equation (22) states that a fraction of unemployed agents will move to work in the urban area. Take the derivative of (22) with respect to A_U,

$$\frac{\partial}{\partial A_U}\left(\dot{Pop}'_{ue,R,t}\right) = \frac{\partial f(.)}{\partial w_{H,U,t}} \cdot \frac{\partial w_{H,U,t}}{\partial A_U}[M_{ue,R}(Pop_{R,t} - Pop_{e,R,t})] < 0. \tag{23}$$

That is, progress in urban technology can reduce the total number of unemployed. Yet given that $A_U > A_R$, by Corollary 1, Equation (8) can be written as

$$\dot{Pop}_{e,R,t} = f(w_{H,R,t}, w_{H,U,t})(M_{e,R} \cdot Pop_{e,R,t}) < 0. \tag{24}$$

As urban technology progresses faster than rural technology, wages offered in the urban area exceed wages in the rural area. In response, rural workers move to work in the urban area. Take the derivative of (30) with respect to A_u,

$$\frac{\partial}{\partial A_U}\left(\dot{Pop}_{e,R,t}\right) = \frac{\partial f(.)}{\partial w_{H,U,t}} \cdot \frac{\partial w_{H,U,t}}{\partial A_U}(M_{e,R} \cdot Pop_{e,R,t}) < 0. \tag{25}$$

Equation (25) indicates that a rise in urban technological stock can reduce the total rural employment in the R&D sector, through raising the wages offered in the urban region. As shown in Proposition 1, a reduction in employment in the R&D sector can slow the growth of rural wages. In addition, given that the unemployment benefits grow over time, and the change in total unemployment is an increasing function of unemployment benefit ($\frac{\partial \dot{Pop}_{ue,i,t}}{\partial w_{ue,,t}} > 0$), the decline in wage growth in the rural area can lead to an increase in the total unemployment in this area. □

Intuitively, its ample technological stock (that is, $A_U > A_R$) leads to higher wages in the urban region. Therefore, the urban region can attract rural workers by offering higher wages. This phenomenon will reduce the availability of human capital in the rural area and, therefore, reduce the growth rate of rural technology. Through this mechanism, it reduces the growth rate in the labor wage and manufacturing output in the rural region.

In an extreme situation, a brain drain could also reduce labor availability for the rural manufacturing sector, and therefore, urban technology will reduce the rural manufacturing outputs.[9] Nevertheless, the brain drain effect can also reduce the unemployment rate in the rural region, because urban technology can create jobs for those who are unemployed and have sufficiently low mobility costs.[10]

To sum up, progress in urban technology can reduce total unemployment in the rural area by creating jobs for unemployed agents. However, it can also increase the rural unemployment rate by slowing wage growth in the rural region. Therefore, the brain drain of urban technology has a net ambiguous effect on rural labor market performance.

3.2. Equilibrium of the Labor Market with Trade in Goods

By relaxing the assumption of no trade in the previous subsection, we are able to derive the product market competition effect. Let us consider a situation where the manufacturing output can be traded across the regions, with no transportation cost. Let us also assume that the final outputs of both regions are perfectly substitutable.

I follow central place theory, which hypothesizes that successively high orders of services and goods are first available at the upper tiers of regional centers in the urban hierarchy. Specifically, I assume that urban goods are more desirable to all consumers than are rural goods. There is strong empirical evidence supporting this assumption (Partridge et al. 2008, 2009). Since the urban region is the technological leader and is likely to have more human capital (due to higher wages offered by firms), it is very likely that urban regions can produce a higher quantity (and more varieties) of good and services than can rural areas. Consequently, urban goods and services are in higher demand in both regions.[11]

Let us assume that unemployed agents only consume what comes from the unemployment benefit, whose price is measured in terms of the urban manufacturing output price. Therefore, manufacturing goods will be consumed only by employed workers. To meet the aforementioned assumptions of the demand function of manufacturing goods and for an expositional purpose, I specify the inverse demand functions of both regions as follows:

$$p_{R,t,q} = \gamma_{t,q}(A_U, A_R) \cdot p_{U,t,q} = p_{t,q}(Pop_{e,R,t} + Pop_{e,U,t}, Y_{R,t}, Y_{U,t}), \tag{26}$$

where $\frac{\partial p_{t,q}}{\partial (Pop_{R,t} + Pop_{U,t})} > 0$ and $\frac{\partial p_{t,q}}{\partial Y_{R,t}}, \frac{\partial p_{t,q}}{\partial Y_{U,t}} < 0$. $p_{R,t,q}$ and $p_{U,t,q}$ are the prices of manufacturing goods for rural and urban products, respectively. $Y_{R,t}$ and $Y_{U,t}$ are the final outputs produced in rural and urban regions, respectively.

$\gamma_{t,q}(A_U, A_R) \in (0, 1)$ captures the concept of central place theory, which postulates that consumers favor urban goods and services. The taste parameter adjusts the prices of goods to the quality improvement provided by technology. I assume that $\frac{\partial \gamma_{t,q}}{\partial A_U} = -\frac{\partial \gamma_{t,q}}{\partial A_R} < 0$ for $\forall A_U, A_R \geq 0$. That is to say, an increase in urban technology makes urban goods and services more attractive to consumers. To put it in another way, progress in rural technology makes urban goods and services less attractive. One can think of this assumption as suggesting that an improvement in the technology of a region leads to an improvement in the quality of the products of that region. Consequently, if the change in urban technology is greater than the change in rural technological stock ($\dot{A}_{t,U} > \dot{A}_{t,R}$), the change in the taste parameter is negative, $\dot{\gamma}_{t,q} < 0$.[12] In other words, urban goods and services become more attractive over time when urban technology advances faster than does rural technology.

Equation (26) requires prices to be high when the world demand is high and low when the supply of goods is plentiful. By assuming perfect substitutability between these goods, I intentionally ignore complementarity between some goods and services offered in both regions.

Proposition 3. *Through product market competition, the progress of urban technology decreases the wages offered to workers in the rural region.*

Proof. Given that the price of the rural manufacturing of goods is $p_{R,t,q}$, from Corollary 1, we can rewrite the wages offered to employees in the rural region as,

$$w_{H,R,t} = \alpha \left[\frac{r}{(1-\alpha)^2} \right]^{-1/\alpha} A_{R,t} p_{R,t,q}. \tag{27}$$

Take the derivative of (27) with respect to $A_{U,t}$,

$$\frac{\partial w_{H,R,t}}{\partial A_{U,t}} = \alpha \left[\frac{r}{(1-\alpha)^2} \right]^{-1/\alpha} A_{R,t} \cdot \left(\frac{\partial p_{R,t,q}}{\partial Y_{U,t}} \right) \left(\frac{\partial Y_{U,t}}{\partial A_{U,t}} \right) < 0. \tag{28}$$

□

Technological development in the urban region could translate into an excessive distribution of urban manufactured goods into the world. Urban technological progress also raises the demand for urban goods and services, due to an improvement in quality. Per Equation (28), this situation reduces the output price of rural products relative to the output price of urban products. This reduction in output price leads to a reduction in wages in the rural region. Therefore, urban technology could enhance the effects of a brain drain. A reduction in wages in the rural region can also lead to an increase in total unemployment whenever wages fall below the level of unemployment benefits.[13] In short, urban technology could harm firms operating in the rural area, and so product market competition could increase the rural unemployment rate.

It is noteworthy to mention that the price of urban manufacturing goods is shielded from the adverse effects of technological progress by an increase in wages due to urban technological progress and a consumer preference for urban goods. It is also important to note that we have only differentiated goods in this model, and therefore, urban technology might be able to overwhelm rural production completely. However, in the real world, there are goods and services that are mainly produced in rural regions, not in urban areas (one possible cause is the different factors of endowment). So, rural firms that produce those goods and services do not compete directly with urban firms. Therefore, the progress of urban technology is more likely to lead each region to specialize in producing different goods and services.

Let us suppose that trade in capital goods is also allowed. As shown in Aghion and Howitt (1998a), the trade in capital goods in this type of model will lead to higher wages for workers. That is because increasing the variety of capital goods will enhance the productivity of labor in the manufacturing sector. However, the trade in capital goods generally also increases the competition faced by each producer (Grossman and Helpman 1991a; Aghion and Howitt 1998a). Unfortunately, the type of model presented here cannot yield this competitive effect (that is, the product market competition effect in capital goods), because the manufacturing technology is additively separable in capital goods (Aghion and Howitt 1998a).

To recapitulate, while knowledge spillover can improve the performance of the rural labor market, product market competition can adversely affect this market. On the other hand, the effect of a brain drain is ambiguous. Therefore, the net effect of urban technology on the rural labor market is theoretically ambiguous. An empirical study is needed to identify this net effect.

4. Conclusions

This article introduces a theoretical model that combines insights from the endogenous growth theory and the spread-backwash concept to systemically analyze the technological effects of innovative regions on lagging regions' labor markets, particularly in the urban–rural context. While urban technological progress has a positive impact on rural labor market performance through knowledge spillovers, urban technology also exerts the product market competition effect on the rural labor market. On the other hand, a brain drain has an ambiguous effect on rural labor performance.

Unfortunately, these facts have not yet received full attention in academic and political arenas. Without taking these negative effects into full account, any place-based policy aiming to increase local and regional jobs by improving technology might have unintended consequences. To maintain rural dwellers' well-being in the presence of strong urban technological progress, rural income transfers, rural job training, and rural mobility should be considered. For rural residents, policies that increase the accessibility and affordability of new technologies, as well as enhancing urban-rural knowledge spillovers, could offset the negative impact of urban technological progress.

While this article attempts to capture the relationship between technological progress in urban regions and rural labor markets, the model in the paper might not perfectly capture several features in urban-rural interactions in developing countries. For example, foreign direct investments could transform rural areas in these countries into urban areas. Moreover, unemployment benefits might not be available in these places. Future research should focus on these issues.

Another issue is the heterogeneous effects of urban technology on rural labor markets. Urban technological progress may perhaps have a relatively more substantial impact on less-rural regions because these regions offer skilled workers that are compatible with the urban labor demand. On the other hand, remote rural areas do not have skill compositions suitable for the urban labor demand.

Finally, it is interesting to analyze the impact of digital technology on labor markets. Digital technology could foster remote work; however, due to agglomeration effects, this technological change does not make cities obsolete (Glaeser 2011). In addition, the adoption of digital technology in rural areas is slow; rural residents still lack access to high-speed broadband, even in developed countries such as the United States. Future studies could focus on this issue, especially during and after the COVID-19 pandemic.

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Notes

1. There are two generations of endogenous growth models. In addition to Romer (1990), other notable first-generation works include Aghion and Howitt (1992) and Grossman and Helpman (1991b). Key second-generation works follow Jones (1995a, 1995b); Kortum (1997); Segerstrom (1998); Aghion and Howitt (1998b); For a comprehensive discussion of the spread and backwash concepts, see Gaile (1980).
2. A specific variety of capital goods is denoted by k, and $\{x_{i,t}(k)\}$ denotes a vector of capital goods (i.e., intermediate goods) in i at time t.
3. That is, $P_{A,i,t}(k)$ is a sunk cost that a monopolist has to pay for when it enters the capital market.
4. Formal treatment of these models can be found in the works of Grossman and Helpman (1991b, 1996).
5. For a comprehensive review of the knowledge-transfer function, see Sarkar (1998). For empirical studies on the relationship between knowledge spillovers and the absorptive capacity, see Girma (2005); Girma and Görg (2005); Falvey et al. (2007); For an in-depth treatment of a knowledge production function, see Griliches (1979).
6. This condition is in the spirit of Burdett and Mortensen (1998).
7. Since $w_L = w_H$, technology also raises the wages for workers employed in the manufacturing sectors.
8. Knowledge spillovers could also prevent the outflow of unemployed agents living in the rural region, whenever $A_R \geq A_U$. This phenomenon would increase the unemployment rate in the rural region. However, this condition should not hold empirically because most urban regions are technological leaders.
9. That is, the optimal solution of labor input for the manufacturing sector is more than the number of available workers in a region.
10. A decision to work in another region depends on the mobility cost, the outside wage, and current and future wage differentials. Historically, given that rural–urban wage differentials have been growing over time, the brain drain effect could have a significant impact on the rural labor market.
11. In this analysis, I have ignored the complementary effect between urban and rural goods. In the next section, I show that there is suggestive evidence that the product market competition effect dominates the complementary effect.

12 $\dot{\gamma}_{t,q} = \frac{\partial \gamma}{\partial A_U} \dot{A}_{t,U} + \frac{\partial \gamma}{\partial A_R} \dot{A}_{t,R}$. Hence, if $\dot{A}_{t,U} > \dot{A}_{t,R}$, we have $\dot{\gamma}_{t,q} < 0$.

13 The unemployment benefit is measured relative to the urban output price. If urban technological progress deflates the price of urban products, the unemployment benefit also decreases over time. However, the price of urban goods is protected by the preference of consumers for urban goods, and therefore, the price of urban goods and the unemployment benefit might not necessarily decline over time.

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