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The role of labor discrimination in spatial sorting: the USA as an example of ethnic groups staying apart

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Abstract

Despite the vast research about discrimination, there is little evidence about how space interacts with it. Our main hypothesis is that a discriminated group could have incentives to stay together, even if the location is less dynamic-avoiding areas where firms do not usually hire workers of their group. A virtuous and/or vicious circle emerges for each group, even in the long run. Using USA as an example, this article introduces a theoretical economic model to explain the incentives of ethnic groups in terms of location. We extend the well-known model of discrimination with imperfect information to a spatial framework. The results seem to indicate that the initial population distribution and the barriers to agglomerate activity (transport costs), as well as the behavior of employees, are key elements to determine the equilibrium. As a general conclusion, discrimination processes could clearly modify the location pattern of the population. Hence, the discriminated group could suffer from lower incentives to move from non-agglomerated areas to dynamic areas. These processes could help to explain why some populations prefer to maintain their traditional location in poor areas even if there are places with higher wages or better quality of life.

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1 Introduction

Spatial location of the activity has drawn the attention of many researchers in the field of regional economics. Multiple examples within the New Economic Geography framework discuss the incentives of firms or workers to locate across space. Some theoretical models can be found in Krugman (1991), Krugman and Venables (1995), Fujita and Krugman (1995) and Fujita et al. (1999) among others, as well as many empirical examples (like Ciccone and Hall 1996; Combes 2000; Ciccone 2002; Fernández-Vázquez and Rubiera-Morollón, 2013; or, more recently, Combes and Gobillon 2015). Economists in this framework have tried to understand the structure of activity and population across space with spatial and dynamic models. One of the most common incentives in this literature driving workers to move is the wage difference between areas—known as wage premium. A recent empirical analysis studying the causes of wage premium can be seen Matano and Naticchioni (2015). However, most of these models consider the population as a homogeneous group. Therefore, there is a lack of evidence about the influence of these dynamics on the integration of different groups (race, culture, religion, etc.) in a society.

At the same time, discrimination in labor markets has been widely studied by economists. Taste-based models of discrimination (see Becker 1957; Arrow 1973) are considered as one of the key references in this framework. In these models, the employer, customers or co-workers experience disutility from interacting with members of other groups. Hence, they would demand a higher wage or profit if they are forced to work with people from other groups. However, such discriminatory behavior would be very difficult to maintain in a context of perfect competition. Non-discriminatory firms would easily take advantage of their behavior, hiring equally productive, but cheaper workers and earning higher profits. In the long run, discriminatory firms would be driven out of the market. That is why many subsequent models are based on the idea of imperfect information (Arrow 1973, Phelps 1972 or Aigner and Cain 1977) or some kind of associated cost in hiring the discriminated group. For example, in Lang (1986) workers suffer an additional cost when they try to communicate ideas to co-workers of the other group because of language differences.

If employers believe that members of the minority group are less productive, they will behave similarly to employers who practice taste discrimination. Nonetheless and according to Lang and Spitzer (2020), if beliefs are incorrect, updating their information could change their behavior from a classical taste discrimination model.

As can be seen in Lippens et al. (2022), most of these theories do not consider an interaction between a discriminatory process in the labor market and the location preference of workers. As described in Lang and Spitzer (2020), empirical studies do not usually consider space or try to remove the location effect with controls. By this approach, they try to measure whether there is still a significant discrimination when location is considered.

However, through that approach, the interaction of both processes is not usually studied in detail, despite its possible consequences. Lang and Spitzer (2020) do briefly introduce this possibility. According to them, the labor market discrimination could contribute to residential segregation. Consequently, a discrimination suffered by a previous generation could still affect new generations, even without a proactive discrimination from their new employers.

In contrast to the previous literature, we show how a discriminatory behavior can reshape the location patterns of individuals. This interaction could be very interesting, because individuals may have strong incentives to move when they perceive discrimination. As such, if there is a location where members belonging to the discriminated group are not able to find a job, or an acceptable wage offer, they may move to a different region. This type of model would highlight the connection between groups and territories. As a result, this process might intensify the segregation of the population, because the discriminated group becomes even less common in the location of origin. The resulting process creates a barrier that, while not impossible to overcome, offers an additional explanation as to why discrimination and segregation disappears so slowly. It could also explain why spatial patterns in the distribution of groups may arise or be maintained. In addition, if both processes tend to interact, they should be seen as part of the same process. In an extreme case, if the minorities are always expelled to the most unproductive areas of a country, a traditional Oaxaca (1973) decomposition may easily link their lower salaries to their job in unproductive sectors or low-skill occupations. However, moving to more dynamic areas could be very difficult for these groups. Their concentration in non-agglomerated areas could be the consequence of the same discriminatory process we are trying to measure.

Some literature has already discussed the tendency of groups to concentrate in the space (see Cutler et al. 1999 or Topa 2001, among others). But there is a lack of understanding of how space and discrimination interact. In this regard, Selod and Zenou (2006) or Zenou (2009) could be considered as the most suitable models for this type of process. However, these models focus on the location of individuals within a city.

Using the USA for context, we propose a theoretical model inspired by the wellknown core–periphery model of Fujita et al. (1999). Using this model as a starting point to model the location incentives of workers, a discriminatory process is introduced. The model is heavily inspired by the discrimination framework with imperfect information—as in Becker (1957), Arrow (1973) or more recently Bagues and Perez-villadoniga (2013) as well as urban models such as Selod and Zenou (2006) or Zenou (2009). We demonstrate that, even without the usual incentives toward concentration, minority workers could tend to avoid locations where the other group is abundant.

The results suggest discrimination seems to work pulling workers of each ethnic group to the same location and away from the main location of other groups. Dividing the population in a minority group and a majority group for simplicity, this incentive is much greater in the minority group. This force can be so intense, that using the same parameters of the core–periphery model in Fujita et al. (1999) where the population tends to disseminate, we could still find a clear concentration pattern for the minority group. Given the weight of the majority group, the minorities must concentrate in the non-agglomerated area—and less productive—of the model. The rest of the paper is organized as follows: Section 2 explains key stylized facts. Section 3 presents a summary of the necessary definitions. In Sect. 4, we explain the proposed theoretical model linking space and discrimination. Then, Sect. 5 presents a replicable calibration of the model. An explanation of the policy implications and main conclusions is given in Sect. 6.

2 Stylized facts about ethnics and location

Nowadays we live in a world where it is possible to work remotely, and communication infrastructure allows any worker to move easily between territories. Unless there is a legislative barrier—like country borders—or recent conflicts—like in Bosnia and Herzegovina—workers could travel to any other location in a matter of hours or days, at most. In a scenario like that, we could think the location of workers should change swiftly. Therefore, economic incentives should easily mix cultural, religious or ethnic groups. Because of this process, we should detect the same spatial distribution of workers, regardless of their group. If a place pays higher wages, workers should be attracted to that location, no matter the group. However, it is not uncommon to find spatial patterns within countries. Some examples of these patterns are the USA, Canada, Australia or Brazil among others.

The USA scenario is very interesting case to illustrate our theory. The USA is well known for its high mobility—compared to the European Union at least—as stated in the Blanchard et al. (2017). Therefore, we could consider the USA as a unified labor market. Certainly, spatial sorting is expected to be even more significant if we consider groups of countries or continents. Nonetheless, we understand other barriers could be in place, like language, regulation or immigration polices (in the case of continents) and not individual decisions. Having a labor market with few barriers is essential for our example, given that our model is going to assume free movement of people. With this characteristic, we could expected a similar distribution in all the ethnic groups. However, their distribution are quite different in the USA.

Figure 1 shows the spatial distribution of African-Americans, Hispanics, American and Alaskan Natives (hereinafter Natives), and Whites, according to the 2020 US Census. In general, African-American population concentrates in the southeast, Hispanic in the southwest, and Natives in the west and center, while the White population is located in the north and northeast.

Of course, this is not an extreme distribution. It is perfectly possible to find people of different groups in most of the states. Nonetheless, it is easy to find a location preference within each group. It could be argued that these locations are the consequence of historical reasons. For example, Black population tends to be located in the southeast, such as Florida, Georgia or South Carolina due to their history of slavery. This argument could be reasonable to explain the distribution of the population in a labor market with little communication infrastructure, legal barriers or intense racial conflicts. But, over time, market incentives should easily dismantle this distribution in a unified labor market.



Fig. 1 Race or ethnics (%) by state, 2020 Data source: United States Census Bureau

Although USA could be considered one of the most suitable cases for our research, other countries could experience similar behaviors. For example, the native population of Brazil or Ecuador, located in the poor inland of the country, could be another cases of a similar behavior. Traditions are usually considered the main reason for this pattern. Consequently, these population groups would be immune to the basic economic incentives of the labor market. They would rather stay in less developed areas because they have a higher preference toward them. As a result, they prefer to stay there despite the possibility of earning higher wages in other places. Although this is possible, our hypothesis is that there is a more rational economic behavior behind it. They prefer to stay in those areas, because their ethnic or racial group is more frequent there. That means an advantage when they try to find a job in that area, because employers have more information about their group.

This example does not try to prove that ethnic or racial groups are always going to concentrate in different locations in every single country. Cultural differences in a specific context could be irrelevant in another. As such, those groups would tend to merge, creating a similar spatial pattern. The objective of this research is to understand why segregation patterns may arise and why they may be so difficult to eradicate.

3 Previous literature, concepts and definitions

The methodology in this paper is inspired on a combination of discrimination theories of Labor Economics and the New Economic Geography of Regional Economics. One of the main topics of discussion in the discrimination theories is whether this behavior is rational or not. As explained in Becker (1957) and later in Arrow (1973), the first idea about this topic was a preference of employers, other employees or even clients against a certain race. Given that most citizens avoid any contact with the minority, anyone willing to work with them would receive higher earnings in compensation. This is what is called a taste-based discrimination.

The main problem of this type of discrimination is that unless there is any additional cost associated to the discriminated group, firms without discriminatory behavior would have an economic advantage—see Lang and Spitzer (2020). In the long run, it is expected discrimination in firms would tend to disappear. They behavior would push these firms toward bankruptcy due to competition in the market of goods and inputs.

It is still possible to find some other reasons in this framework to think that it is not just a matter of taste. For example, Lang (1986) explains workers may have similar communication codes when they work with people from their group. As a result, they would face an additional cost in their daily work when they have to interact with individuals from the other group. In this case, firms would tend to specialize in one type of worker. This reasoning is quite interesting because it already shows segregation is a logical outcome when workers react to discriminatory behaviors. Unless they are forced to stay in discriminatory firms, they would have an incentive to leave. This is a process we try to reflect in the model, but in a spatial context.

The other approach to this matter comes from imperfect information theories see Arrow 1973, Phelps 1972 or Aigner and Cain 1977.¹ Their idea is that employers do not really dislike any of the group, but they take group characteristics to evaluate their candidates. This behavior is the consequence of their lack of information about the candidate future or past performance. In addition, given that they have more information about the predominant group, they tend to hire workers from this group. This process creates a vicious circle which avoids firms from giving the minority a chance to prove them wrong.

For example, in the natural experiment carried out in Castillo and Petrie (2010), the outcome of participants requires the collaboration with other participants in a finitely repeated game. In the absence of information, the participants avoided the Black race, while it was not significant when they had information about their past performance.

Among this literature, the obvious conclusion is that employers could solve this issue with additional information (see Lang and Spitzer 2020). In general terms, this theory stablishes this is the main solution to the problem, although there are some exceptions. In the recent article of Cavounidis et al. (2023), an economic model is

¹ For a detailed summary of the empirical evidence on discrimination theories applied in this paper, Lippens et al. (2022) very well structured the systematic review on the topic.

used to explain the shorter employment duration of the Black population. Given that firms are using race to infer their ability, employers tend to monitor much more this group, allowing them less errors before being fired.

However, even in this framework we could assume firms will tend obtain this information sooner or later. If they updated their information, they would obtain higher earnings, because of the low wage of the discriminated group. Our hypothesis is that the information employers obtain, consciously or unconsciously, is obtained from their surroundings, from their local environment. If that is the case, their information or ability to judge the groups is going to be heavily influenced by the location of the groups.

The spatial framework we apply in this model begins with the concept of agglomeration economies of Marshall (1890) and continues to this day within the framework of the New Economic Geography—see Fujita et al. (1999). As explained in Parr (2002a) and Parr (2002b), this concept stablishes firms generate positive externalities or gains of productivity when they are in the same area. This difference in productivity allows firms to pay higher wages—see Matano and Naticchioni (2015). Some of the ideas behind this idea justify agglomeration economies through a pool of specialized workers, providers or shared knowledge—known as spillovers. Following this idea, there is a whole framework that continues even in recent empirical research such as Combes et al. (2011), Combes and Gobillon (2015). This framework is extremely relevant for our modeling because it formulates that citizens have incentives to concentrate in a few locations. When they concentrate, they earn higher wages, shaping the location pattern of the population.

If we used this framework alone, we would think racial groups tend to have the same spatial distribution because they are influenced by the same market incentives. However, in combination with the discrimination ideas, as in Lang and Spitzer (2020), we hypothesize minorities will tend to concentrate, but in different places. Minorities will suffer less discrimination in other locations. Hence, they suffer from a negative (positive) externality in locations dominated by the predominant (minority) group. Even if the location is less dynamic, it could still compensate them to concentrate away from the other group.

Before we begin with the economic model, we first need to define some assumptions and concepts taken from previous models. Our model takes inspiration from the core–periphery model in chapter 5 of Fujita et al. (1999), the benchmark model of the New Economic Geography. It is our intention to make our results as comparable as possible with these models. With this aim in mind, this section briefly summarizes the core–periphery model to expand it into a discriminatory reality in the next section—for a further explanation, see chapters 5–7 of Fujita et al. (1999). The core–periphery model is based on the Dixit–Stiglitz model of monopolistic competition (see Dixit and Stiglitz 1977). Though the assumptions of Dixit–Stiglitz are similar in terms of imperfect markets, the core–periphery model summarizes the incentives of a dynamic sector to locate in a certain region through increasing returns, reduced transport costs and mobility of workers.

In this model, it is assumed there are only two sectors in the economy: manufacturing and agriculture. In more general terms, they could be considered as a dynamic sector and a traditional one. The distribution of resources is endogenous in the dynamic sector, while it is exogenous in the traditional one. The manufacturing sector operates under monopolistic competition with increasing returns. The labor force in this sector can freely move between regions. On the other hand, the traditional sector is highly competitive with a fixed number of workers in each region. Choosing the suitable units and without losing generality, the total workforce in the dynamic sector is defined by μ and in the traditional sector by $(1 - \mu)$.

Transport costs in the dynamic sector follow an iceberg shape. Hence, from any good sent from one region to another, only 1/T arrives. As in Fujita et al. (1999), no cost is assumed for the traditional sector.² Given that the traditional sector is assumed to have constant returns and no transport costs, its wage is the same in both regions and can be used as numeraire.

The core-periphery model divides the territory into two regions, where the agricultural sector is equally distributed between them. λ would represent the proportion of employment of the dynamic sector in region 1, while $(1 - \lambda)$ is assigned to region 2. A total of 8 equations—4 in each region—determines the equilibrium. These equations represent the income, the price level, the nominal wage and the real wage in each region. With all these assumptions, the income function (Y_i) in each *i* region can be written as in the set of equations:

$$Y_{1} = \mu \lambda w_{1} + \frac{1 - \mu}{2},$$

$$Y_{2} = \mu (1 - \lambda) w_{2} + \frac{1 - \mu}{2},$$
 (1)

where income in region 1 is defined by the number of dynamic workers $\mu\lambda$ multiplied by wage in this sector (w_1) and the number of traditional workers $\frac{1-\mu}{2}$ multiplied by their wage, the numeraire. The income in region 2 follows the same pattern, but with its proportion of the dynamic sector $(1 - \lambda)$.

The product price function (G_i) in the dynamic sector in each region is expressed as in Eq. (2). This expression is derived from the model of monopolistic competition in Dixit and Stiglitz (1977).

$$G_{1} = \left[\lambda w_{1}^{1-\sigma} + (1-\lambda)(w_{2}T)^{1-\sigma}\right]^{1/1-\sigma},$$

$$G_{2} = \left[\lambda (w_{1}T)^{1-\sigma} + (1-\lambda)w_{2}^{1-\sigma}\right]^{1/1-\sigma}.$$
(2)

In these expressions, σ represents the elasticity of substitution between any two goods in the dynamic sector. As stated in these equations, the aggregate prices in a region tend to be reduced when the products are manufactured in that region. That is because bringing products from other regions implies an additional transport cost.

 $^{^2}$ This assumption can be dropped. In this case, its influence in the agglomeration process can be seen in chapter 7 of Fujita et al. (1999).

Nominal wage in both regions is defined as in (3). In these equations, the higher the nominal wage, the greater the income in the same region—or in close regions in a more general context. This equation represents the wage in which firms obtain a normal profit. From a spatial perspective, this equation shows firms can pay higher wages when there is a good access to the market.

$$w_{1} = \left[Y_{1}G_{1}^{\sigma-1} + Y_{2}G_{2}^{\sigma-1}T^{1-\sigma}\right]^{1/\sigma},$$

$$w_{2} = \left[Y_{1}G_{1}^{\sigma-1}T^{1-\sigma} + Y_{2}G_{2}^{\sigma-1}\right]^{1/\sigma}.$$
(3)

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Nominal wages in Eq. (3) are transformed to real wages as in Eq. (4) thanks to the price index in Eq. (2):

$$\omega_1 = w_1 G_1^{-\mu},$$

$$\omega_2 = w_2 G_2^{-\mu}.$$
(4)

Given the difficulty of obtaining an equilibrium with a set of 4 equations for each region, a calibration exercise is necessary. According to the Fujita et al. (1999), when transport costs are low enough, the homogeneous distribution of the dynamic sector ($\lambda = 0.5$) defines an unstable equilibrium.

As shown in Fig. 2,³ any value of λ above 0.5 will easily create a positive real wage gap between regions. As a result, λ will tend to increase even more. Just the opposite would happen for values of λ lower than 0.5. In Fig. 7 and 8 in appendix, we show this pattern is the opposite when the transport costs are high enough. This result is very remarkable, because it indicates that regions need to be prepared to compete in a wider and more dynamic environment when the communications improve.

Since this model was developed to understand the incentives of the activity to concentrate, all workers are considered as homogeneous. To study the interaction with discrimination, the model needs to be extended to consider different groups of workers and an explicit reason behind the discrimination. While introducing discrimination in our model is likely to create a higher level of complexity, it is our purpose to show, as simple as possible, the implications of a spatial sorting process when there is a discriminatory behavior in the labor market.

³ All the necessary codes to replicate these figures can be found in https://doi.org/10.6084/m9.figshare. 24782775.



Fig. 2 Real wage gap (T=1.5)

4 The theoretical model

We propose a model of discrimination inspired in the well-known imperfect information model (see Becker 1957 and Arrow 1973) in a context of the core–periphery model. Of course, there are other well-known discrimination models, such as the taste discrimination model in Becker (1957) or the statistical discrimination in Aigner and Cain (1977) or more recently Cavounidis et al. (2023). The choice of this framework does not mean that other discrimination processes are not possible. However, the discrimination mechanism described in Arrow (1973) seems remarkably similar to the mechanism of the core–periphery model. In both models, the concentration of workers in a certain place (core–periphery model) or in a certain type of job (Arrow discrimination model) is crucial to explain wages. Therefore, both models are expressed in almost identical terms. In addition, the core–periphery model already has 4 equations for each region. Hence, keeping it as simple as possible is critical. In that regard, the Arrow's model is extremely efficient, given that it can be summarized in two simple equations.

According to this model, there are two types of jobs: skilled and unskilled. While all workers are qualified to perform the unskilled job, only some are qualified to perform the skilled job. Moreover, employers must make a personnel investment when hiring workers for the qualified job.

However, information about the performance of a candidate is only available for the employer after a certain time in the firm. Given the lack of information, employers tend to evaluate workers using the group as proxy. As a result, they expect workers from the minority group (discriminated) would perform the job required with a probability of P_D and the majority group (non-discriminated) with P_N . These probabilities are calculated according to the proportion of workers of that group in the sector.

In this model, the employer receives a constant expected return per worker in a qualified job of r. The incentives for the employer to make personnel investments are the following: If a discriminated employee is suitable for the job, the employer would obtain the marginal productivity MP_s net of the wage (w_D) and nothing if the worker turns out to be unskilled. The same principle is applied to determine the wage of the non-discriminated group w_N. The expected returns of the described process can be defined as in Eq. (5):

$$r = (MP_s - w_D)P_D,$$

$$r = (MP_s - w_N)P_N,$$
(5)

where the gains are weighted by the proxy variable of each group— P_D or P_N —and the wage of the group would be endogenously determined. Firms would expect the same returns from both groups. Given that the employers have more interactions with the non-discriminated group, P_N tends to be higher than P_D . Hence, the same return per worker can only be achieved if the discriminated group earns a lower salary than the non-discriminated group. Hence, assuming firms only hire a worker if the expected return is equal to r, the equilibrium would tend to generate a difference in salary between the groups.

Of course, it is possible to find a non-discriminatory solution where wages and probabilities in both groups are the same. Why would an employer perceive a different probability of being qualified between groups? Certainly, one group may not be traditionally found in a specific sector. But, as soon as that group is incorporated to the labor pool, the gap should quickly disappear if employers gain more information. Our proposal in this paper is that an important reason behind a possible gap in the probabilities could be caused by the spatial distribution of the groups, because employers obtain information about workers in their local environment. Spatial sorting could clearly result in a heterogeneous distribution of groups, leading to significant imbalances in the probability of finding qualified workers from a specific group. Compared to the previous case, these endogenous imbalances could easily persist over time.

In our proposal, the accuracy of employers' information depends on the lack or abundance of each group in the territory. According to this assumption, a firm could perceive individuals from an uncommon group in the area as a possible risk. This perception of risk does not have to be necessarily connected with the employer's preferences; it could also be related to the degree of integration of those individuals in the firm, as in Lang (1986). Therefore, a competitive market would tend to minimize these costs with segregation. Cultural differences are not restricted to language. Individuals from each group could develop codes or routines that are common within their own group, but not prevalent in another group. For example, there may be group differences regarding formality between workers, time after work or relationships. These differences could also affect how workers present their ideas to a superior, correct the behavior of a co-worker, etc. Most of these interactions could be much easier when the two individuals share the same codes, while otherwise it could be seen as impolite, counterproductive or odd. As a result, employers could perceive workers from the most abundant group in the region as those with higher probabilities to fit in the firm.

Not only the spatial distribution of workers influences firms, the behavior of the firms also influences the population distribution. For example, workers could move to those regions where their group is more abundant. Consequently, both incentives should be modeled together to understand the consequences of their interaction.

The analysis of discrimination in this section departs from the well-stablished core-periphery model explained above, which does not include any explicit difference between groups. In the original model, the only difference between workers is given by the location or the sector.

Our model is enhanced through the definition of λ_N as the proportion of non-discriminated qualified workers (*N*) in region 1, while λ_D stands for the discriminated qualified workers (*D*). Consequently, the core–periphery model can be seen as a specific case of this model. The total proportion of qualified workers can be obtained as a weighted average of qualified workers in each group, as in Eq. (6):

$$\lambda = \lambda_N \frac{N}{N+D} + \lambda_D \frac{D}{N+D}.$$
(6)

The average nominal wage in each region $(w_1 \text{ and } w_2)$ can also be obtained as the weighted mean of both groups in each region as in:

$$w_{1} = \frac{w_{1N}N_{1} + w_{1D}D_{1}}{N_{1} + D_{1}},$$

$$w_{2} = \frac{w_{2N}N_{2} + w_{2D}D_{2}}{N_{2} + D_{2}}.$$
(7)

To establish the discrimination process, we use the same assumptions of imperfect information in Becker (1957) or Arrow (1973). Firms in each region expect to obtain a net gain that is the difference between the wage of the group in the region $(w_{1D}, w_{1N}, w_{2D}, w_{2N})$ and the productivity in each region (MP_{s1} and MP_{s2}). Once a worker is hired, the firm would obtain this return if and only if the worker is qualified enough or zero otherwise. This information problem leads firms to weigh the gains according to the observed probability of finding a qualified worker in the group and region ($P_{1D}, P_{1N}, P_{2D}, P_{2N}$).

$$r = (MP_{s1} - w_{1D})P_{1D}; P_{1D} = \frac{(D_1 + D_2)}{L}\frac{\lambda_D}{\lambda},$$
$$r = (MP_{s1} - w_{1N})P_{1N}; P_{1N} = \frac{(N_1 + N_2)}{L}\frac{\lambda_N}{\lambda},$$

$$r = (MP_{s2} - w_{2D})P_{2D}; P_{2D} = \frac{(D_1 + D_2)}{L} \frac{(1 - \lambda_D)}{(1 - \lambda)},$$

$$r = (MP_{s2} - w_{2N})P_{2N}; P_{2N} = \frac{(N_1 + N_2)}{L} \frac{(1 - \lambda_N)}{(1 - \lambda)},$$

$$MP_{s1} = [Y_1 G_1^{\sigma - 1} + Y_2 G_2^{\sigma - 1} T^{1 - \sigma}]^{1/\sigma},$$

$$MP_{s2} = [Y_1 G_1^{\sigma - 1} T^{1 - \sigma} + Y_2 G_2^{\sigma - 1}]^{1/\sigma}.$$
(9)

In the equilibrium, all these expected gains are equal to a constant return (r). Therefore, wages of each group and region would be set endogenously. The rest of the equations of the core-periphery model have been adapted to fit with these equations. As such, the income and price equations are defined by:

$$Y_{1} = \mu \lambda M P_{s1} + \frac{1-\mu}{2},$$

$$Y_{2} = \mu (1-\lambda) M P_{s2} + \frac{1-\mu}{2},$$

$$G_{1} = \left[\lambda M P_{s1}^{1-\sigma} + (1-\lambda) \left(M P_{s2} T \right)^{1-\sigma} \right]^{1/1 - \sigma},$$

$$G_{2} = \left[\lambda (M P_{s1} T)^{1-\sigma} + (1-\lambda) M P_{s2}^{1-\sigma} \right]^{1/1 - \sigma},$$
(11)

where income and prices are a function of the productivity of the workers in the region. This step is necessary, given that the original formulation of Krugman does not include any difference between productivity and wages. However, all the incentives modeled in the original formulation remain. In these equations—as in Fujita et al. (1999)—the real wage discounts the regional prices from the nominal wages as in:

$$\omega_1 = w_1 G_1^{-\mu},$$

$$\omega_2 = w_2 G_2^{-\mu}.$$
(12)

Although this model is not easy to solve given the number of equations, the incentives are very clear. On the one hand, the same agglomeration principles of the core–periphery model can be found in this model, with the transport costs as the main barrier. On the other hand, if there is a discrimination process, the incentives of workers from the minority group might not be so clear. Consequently, a

calibration exercise is necessary to understand the incentives of these workers and the equilibrium of the model.

5 Results

The calibration exercise of this model has been set considering Fujita et al. (1999) as the benchmark model. To allow the comparison of the results, it has been made the same parameters, $\sigma = 5$, $\mu = 0.4$. Transport costs have also been set to the same three values (1.5, 1.7 and 2.1). This variability in transport costs should allow to compare the results under three different scenarios of communication infrastructure—low, medium and high costs.

In terms of the labor market, the behavior of the model is analyzed for a situation with a clear majority of one group $\frac{N_1+N_2}{L}=0.9$. This imbalance between the groups allows us to clearly establish a differential pattern depending on the weight of the group. However, it could easily be modified to represent the specific situation of any country. This parameter can be considered as a sensitivity parameter, but similar processes would appear even if it was set to 0.5. In this case, both groups would have identical incentives and can be seen as an intermediate case of the extreme cases presented here. That is because the patterns of this model are created by the discrimination process, not only by the weight of the groups. Without a loss of generality and to simplify the computation, it is assumed firms expect to obtain an arbitrary return of 0.2 for each qualified worker.

Workers would move to the region paying a higher salary for their group. The solution of the model is estimated for each pair of (λ_N, λ_D) using the Broyden–Newton algorithm.⁴ The algorithm finds the vector of values that minimizes the differences of all the equations in (8) to the fixed value of *r*. The process will continue changing the values of the endogenous variables (income, prices and salaries) until convergence is achieved.

Once a solution is found for a pair (λ_N, λ_D) , we can analyze the incentives of each group to move—in a similar way to Fig. 2.⁵ Figure 3 shows the results of the model in a case with low transport costs (T = 1.5) for the minority group. This figure would represent the incentives of the minority group given different situations of the majority. In our example, the solid line would indicate the incentives of the minorities to locate the northeast, while the dotted line would indicate the incentives, south (Black) or the inland (Natives).

To easily understand the incentives of the minority group, Fig. 3 shows its real wage gap between region 1 and 2. When the real wage gap is higher than zero, the salaries of the minority in the dynamic sector are higher in region 1 than in region 2—creating an incentive to move to that region. Each line represents these

⁴ Available in the R package *nleqslv*.

⁵ Just like in the core–periphery model, all the necessary codes to replicate these figures can be found in https://doi.org/10.6084/m9.figshare.24782775.

incentives for different values the proportion of the majority group in region 1 (λ_N). For example, the solid line illustrates the incentives of the minority group when the majority group already dominates the dynamic sector in region 1—as in the northeast of USA. In the same way, the dotted line represents the incentives of the minority group to move when the majority group is not as present in that region—as in the southeast. The dashed line represents the incentives of the minority when the majority is equally distributed in both regions.

For example, if we think in the incentives of any Hispanic individual in Fig. 1, they could stay in the southwest or move to the northeast. Since the northeast is the prevalent location of the White population, their incentives would be represented by the solid line. The real wage increment that they would perceive if they moved to the northeast would be negative—unless most of the Hispanic workers would also be in this region as well. In comparison, and according to the dotted line, any Hispanic living in the northeast would have a high incentive to move to the southwest—where the majority group is not very predominant. He would be moving from a place where his group is not common, to another where the majority group would tend to create their own agglomeration effect in the south, even if it is not so as high as in the northeast. The same idea would be applied to the Black population—locating in the southeast—or the Natives—in the center.

When the majority group is evenly distributed in the two regions, the minority group will tend to agglomerate in either region, just like in Fig. 2-describing an unstable equilibrium in $\lambda_D = 0.5$. This behavior changes when the majority group is already established in any of the regions. As shown in Fig. 3, when the majority group already dominates the dynamic sector in region 1-like the northeast of USA—the real wage gap is lower in that region for every value of λ_D . Unless the minority group is already extremely agglomerated in that region, the wage gap will tend to reduce λ_D and increase $(1 - \lambda_D)$. This behavior would be the opposite if the majority group were agglomerated in region 2. To have a complete picture of the mechanism, we also need to understand the incentives of the majority group. With the analysis of this group, we can stablish how probable is to find $\lambda_D = 0.5$ or an agglomeration of the majority group. In addition, if the majority also tends to concentrate in the same region as the minority, they could easily compensate the previous incentive toward segregation, at least, in relative terms. In that case, if the White population tends to follow the Hispanic to the southwest the spatial sorting would tend to disappear. Figure 4 presents the incentives of this group in the same way as in Fig. 3.

As shown in Fig. 4, the majority group has the same incentive as the minority group. If the minority is very dominant in the dynamic sector of one region—such as the south or southwest—there would be a real wage gap toward the northeast—unless the majority group is already well established in that same region. If the minority group is equally distributed in both regions, the majority group will also have incentives to agglomerate in either region.

There is, however, an interesting difference between Figs. 3 and 4: the sensitivity. Although the shape of the graph is similar, the scale is certainly not the same. With the parameters of our calibration, the signal in terms of real wage gap is five times higher in Fig. 4 than in Fig. 3. This difference indicates, in case of discrimination,





Fig. 3 Real wage gap by group (T = 1.5)—Minority group

there is a strong incentive for the minority to try to compensate for this effect by agglomerating in a different location. That incentive is the same for the majority group, but it is much less intense. As a result, the incentive for the minority group to find a place with workers of the same group is greater. Given that the White population has an incentive to agglomerate whether is avoiding minorities or not, this would easily push away the minorities out of the chosen place of the majority because minorities much more sensitive to the location of the other group.

As in Fujita et al. (1999), one of the barriers to agglomerate is given by the importance of transport costs. As explained above, the original formulation of the model shows a pattern toward a homogeneous distribution of the dynamic sector ($\lambda = 0.5$) when the transport costs are high enough—see Fig. 7 in appendix. Given the lack of incentives toward an agglomerated economy, the pattern of each group could easily vary. To test this possibility, we have set the parameter *T* to 2.1, just like in Fujita et al. (1999). Therefore, the results in Fig. 5 should be immediately comparable with Fig. 7.

In comparison with Fujita et al. (1999), the incentives of each group when transport costs are high do not follow the same pattern. On the one hand, the minority group still has a similar incentive to agglomerate out of the northeast. For example, according to the dotted line, workers of the minority group have a positive real wage gap toward moving to a region 1—increasing λ_D —when the proportion of majority workers in the dynamic sector in that region is low—as in the south or southeast. Consequently, despite the lack of a general advantage in terms of transport cost to agglomerate, this group still has high incentives to locate in the same place and away from the predominant location of the majority group. This result is quite reasonable: in a context of discrimination, information works as an additional centripetal force

Mayority group real wage gap (T=1.5)



Fig. 4 Real wage gap by group (T=1.5)—Majority group

within the group and as a centrifugal force between them. In this context, the market sends a sign in terms of salary to the minority group to remain in the same place and away from the other. With this spatial configuration, firms are more likely to accurately evaluate their skills—optimizing P_{1D} or P_{2D} , but not both.

On the other hand, the incentives for the majority group are completely different in a scenario of high transportation costs. As this group does not usually have to deal with a problem of discrimination, $\lambda_N = 0.5$ remains as a stable equilibrium just as in Fig. 7. However, when λ_N is already close to 1 or 0, an incentive toward concentration could emerge. In this regard, the White population would only avoid a territory, such as the south or southwest if a minority is extremely concentrated in that area. If not, as in Fujita et al. (1999), they would distribute evenly between the northeast and other regions. This mechanism seems rational, since majority workers will suffer from discrimination if they try to locate in a region where there are almost no workers from their group. The result for the majority group looks very similar to the case with intermediate costs of transport (T = 1.7) of the benchmark model-see Fig. 8 in appendix. The homogeneous distribution can be maintained if there is not a clear pattern of concentration. The result of the model seems to indicate in this case, the minorities would tend to agglomerate first, and then, the majority would only start to concentrate if the concentration of that group is extremely obvious. If not, they would distribute among both territories.

Finally, we consider a scenario with intermediate costs of transport (T = 1.7). Applying the same parameters, the results of the model are shown in Fig. 6 for both the majority and the minority group.

The incentives of the intermediate case also show an interesting change with respect to the core-periphery model. The stability of a homogeneous distribution,



Fig. 5 Real wage gap by group (T=2.1)



Fig. 6 Real wage gap by group (T=1.7)

 $\lambda_N = 0.5$ or $\lambda_D = 0.5$, is completely lost for the minority group and is only found in the majority group when the minority group is homogeneously distributed across space. Even in this case, the pattern is barely visible. Each group would avoid a region where the other group is concentrated. Consequently, unless an extreme initial value prevents this—generating just one agglomeration—both groups will tend to agglomerate in different regions. Given the higher incentives of the minority group in terms of real wage gap, it is reasonable to think this group would tend to move faster than the majority.

This result is very remarkable, because it clearly shows how discrimination operates as an incentive very similar to the centripetal forces of the core–periphery model within groups but as a centrifugal force between them. In that sense, the effect is similar to a reduction in transport costs. As soon as an ethnic group is clearly established in one region, the other group will try to avoid that region. Given the high incentives for the minority group, it is much more likely they would be the ones avoiding that area. In our example, Natives, Hispanic and Black groups would tend to avoid the northeast, even in the intermediate case of the Fujita et al. (1999) model. Once the minorities have already established themselves in a location and λ_D becomes significantly different from 0.5, even the majority group will tend to avoid that area.

6 Conclusions and policy implications

The results of the economic model seem to indicate minorities such as Black, Hispanic or Natives have strong incentives to concentrate away from the White population. Of course, races and groups could easily change in other economies. These incentives remain even under the conditions where the core–periphery model in Fujita et al. (1999) leads to an homogeneous distribution of the population. Given that the discrimination mechanism of the population in our model is based on the relative abundance of each group, even White workers will tend to avoid places dominated by minorities. However, given their weight in the general population, their incentive to move away from the other races is lower. In practical terms, minorities are expected to move away faster than the predominant group.

This research points to the spatial interaction as a possible key element to understand why discrimination processes persist over time. In summary, discrimination can easily give incentives to individuals to sort across space according to their group—ethnic, culture, religion, etc. While many economic models suggest discrimination should disappear over time, it is not the case in this one. If this pattern emerges, the model indicates it is far from being an unstable equilibrium, doomed to disappear over time. An equilibrium with agglomerations dominated by just one group (minority or majority) is reinforced by further agglomeration and a clear difficulty for the other races to find a job there.

Our model shows minorities, such as Afro-American, Hispanic or Natives, have a strong incentive to move away from the location chosen by the majority group, such as the northeast of USA. Given the weight of the majority group, the White population will tend to take advantage of higher agglomeration economies. Despite the dynamism of these areas, the minorities have a strong incentive to stay away from

them. In the end, they choose less agglomerated areas, where their group is more abundant, and employers have more information about their group. In addition, if the minority group is big enough, they could create their own agglomeration economies, even if they are not as significant as in the area of the majority group.

This is especially relevant for empirical studies in labor discrimination analysis. We believe this process could easily be misidentified as a non-discriminatory process but rather as the fair consequence of workers linked to less productive sectors, firms or areas. It is very common to use these variables as controls in an Oaxaca (1973) decomposition, as can be seen in Lippens et al. (2022). However, their stagnation in these less productive places would not be an exogenous process. It would be an additional outcome of the discriminatory behavior in a society. From an empirical perspective, this result involves an additional challenge. Being able to distinguish the propensity to locate in an area caused by the group category can be quite difficult, given that many other factors—like friends or family—could also condition their decision. This choice could have already been taken even in a previous generation of workers, as stated in Lang and Spitzer (2020). Nonetheless, the results imply this behavior should be considered as an additional consequence of discrimination, or at least, evidence of the lack of integration between groups.

Of course, we do not claim this pattern should always emerge. First, if there is already a place where the groups coexist— λ_N and λ_D close to one—the model considers that situation as a stable equilibrium. However, given another initial distribution, this pattern could easily emerge. In addition, if firms can clearly identify the characteristics of minority workers, this pattern will easily disappear as well. This second case would indicate both groups share a common ground of values or habits, which facilitates their integration with the other group. That is why these spatial patterns are not created in many countries, while they are quite evident in others. This pattern may even emerge for a specific minority in a country, but not for other minorities.

The consequences of this model are crucial in terms of territorial integration. A conflict that is usually categorized as an internal problem of the firms ends up modifying the spatial configuration in the territory. Whether this is optimal depends on the strength of the assumptions. If the discrimination process could disappear, the original core–periphery model would be the optimal. However, whether this possibility is feasible or not will depend on the country of analysis. The equilibrium in this model would tend to appear as a sub-optimal solution when this restriction is strong enough. Active policies aimed at moving people from one region to another could seem the solution to the problem. But, unless additional measures in terms of wages and/or employability were applied, this situation could easily be considered as inferior in terms of Pareto optimality. Then, the incentives of the model will push workers back to the equilibrium with the spatial sorting of groups.

This situation points to an additional issue. A spatial sorting of the population can be a sub-optimal market solution, but it also presents extra challenges in terms of territorial integration. Rivalries between communities could easily emerge, especially when there is a physical distance between them. As a result, there could be a higher risk of potential conflicts between regions—with political confrontation between those areas. Of course, spatial sorting of the population does not always have to end in a confrontation, but it could be a key determinant unless is properly addressed. This result is surprising because market incentives usually tend to reduce the incentives toward conflicts. In the end, citizens have to fulfill each other's needs to earn a reward. This is the most basic principle of a market economy. Consequently, market incentives should reduce the tension between individuals over time. However, in our case, given the right conditions, the market incentives tend to transform the discrimination problem in the labor market incentives, each group tends to isolate itself rather than integrate with the other group.

Being able to change the behavior of firms or the location of individuals through integration policies before this pattern is completely defined seems the most reasonable action. However, if the spatial structure is fully formed, changing the spatial configuration will prove especially difficult. In this case, trade between communities and other social linkages, such as exchange of students, firms operating in both regions and infrastructures of communication, has proved to be useful to connect different communities. Trying to make both communities to cooperate and bring products and services to the other through the market mechanisms could be particularly useful to reduce the necessity of both groups to live apart.

There are plenty of research questions following this paper. For example, many other patterns of discrimination could arise. Yet, we hope this article serves as a possible way of understanding spatial sorting of groups and why some conflicts could arise within the countries.

Appendix

See Figs. 7 and 8.



Fig. 7 Real wage gap by group (T=2.1)



Fig. 8 Real wage gap by group (T=1.7)

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