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Economic Geography, Endogenous Fertility, and Agglomeration

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Economic Geography, Endogenous Fertility, and Agglomeration*

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Abstract

In this study, we construct an interregional trade model that includes endogenous fertility rates. The presented model shows that the agglomeration of manufacturing firms in a large region causes fertility rates to become lower than that in a small region. The agglomeration of firms in a region lowers the price of manufactured goods relative to child rearing costs, which reduces fertility rates.

We also find that a decrease in transportation costs results in the agglomeration of manufacturing firms, which lowers fertility rates in both large and small regions. We then extend our two-region model to a multi-region model and find that the number of manufacturing firms in larger regions is always greater than that in smaller regions. Therefore, fertility rates in larger regions are always lower than in smaller regions.

Keywords: Agglomeration, Fertility rates, Transportation costs, Consumerism
JEL classification: J13, R10

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1 Introduction

Two trends regarding fertility rates are relevant to this study. First, fertility rates in regions with a high population density are known to be lower than those in regions with a low population density. Second, fertility rates have decreased in developed countries.

With regard to the first point, there are interregional differences in fertility rates within the same country. For example, Figure 1 plots the relationship between Japanese prefectural-level total fertility rates and population density at 2009. [1] The straight line in Figure 1 is the regression line. This figure shows that the fertility rates become low in the prefectures with high population densities, while prefectures with low population densities has relatively high fertility rates. From Figure 1, fertility rates in regions with a high population regoins are lower than those in regions with a low population density. Figure 2 plots the relationship between population density and number of establishments in Japanese prefectures in 2009. This figure shows that in the high population density prefectures, the number of establishment is large. Therefore, Figures 1 and 2 show that in Japanese prefectures with high population density, fertility rates are low and there are many firms. We see a similar trend in data that show the difference in fertility rates across countries.[2] Figure 3 plots the relationship between fertility rates and population density in EU countries in 2010, based on data from Eurostat. Figure 3 highlights that fertility rates are lower in the more densely populated EU countries. Once again, we see that fertility rates in more densely populated regions (countries) are lower than in less populated regions (countries). In addition, Figure 4 shows that in the high population density countries, the number of enterprise is large. Thus, in the countries with high population density, fertility rates are low, and many firms agglomerate. This study examines the driving forces behind these trends, that is 1. higher population density regions has lower fertility rates, 2. higher population density regions has greater number of firms. [3] Our study constructs an interregional trade model with endogenous fertility, and presents a mechanism that could explain the regional fertility variation.

With regard to the second point, fertility rates have decreased in developed countries to the point that a low fertility rate is a characteristic of a modern developed economy. Table 1 shows the decrease in fertility rates in some OECD countries. For example, from 1960 to 2000, the total fertility rate decreased from 2.00 to 1.36 in Japan, and from 3.64 to 2.06 in the US (Cabinet Office, Government of Japan (2004)). Table 1 shows that similar trends have occurred in the UK, Germany, France, and Sweden. We can also observe that the decrease

[1] Murphy, Simon, and Tamura (2008) and Tamura, Simon, and Murphy (2012) show that in U.S. we can observe the similar tredns. They show that a decrease in population density brings about a baby boom in states in the US.

[2] Simon and Tamura (2009) find a strong negative relationship between population density and fertility rates in both European countries and Canada.

[3] Generally, there is less international migration than interregional migration. The facts presented here show that fertility rates are lower in more densely populated regions, irrespective of whether there is migration among regions.

in transportation costs is also a feature of the modern economy. Combes et al. (2008) show that maritime transportation costs decreased by 70% between 1920 and 1990, and that air transportation costs decreased by 85% between 1930 and 1990. In addition, the average tariff rates in the US decreased from 7.3% in 1960 to 1.6% in 2000, and then to 1.3% in 2010. In this paper, we present that the decline in transportation costs is one candidate for a mechanism that explains the recent decrease in fertility rates.

Here, we present "consumerism" in an effort to capture the mechanisms behind above two aforementioned trends (interregional variation in fertility rates and the decrease in fertility rates in developed countries). Some researchers have stated that, in modern industrialized countries, parents prefer to consume goods rather than bear children. For instance, Lutz (1996) points out that consumerism is the basis for the decrease in fertility rates in modern developed countries:

"Commentators often mention the increase in consumerism as a basic underlying cause for the recent fertility decline. The argument is that people would rather invest in pleasures for themselves than in children; they would rather buy a new car than have another child; they would rather spend their time watching TV than changing diapers." (p. 273)

In this paper, we propose a model in which consumerism causes lower fertility rates. Here, we define consumerism as that agents increase the ratio of their consumption of differentiated goods to their income, and allocate more time to working than rearing children. As a result, agents have fewer children. For example, in Japan, the share of expenses spent on child rearing decreased from 33.4% in 1993 to 26.2% in 2007 (Nomura holdings, 2007). Therefore, the share of general expenses increased, while the share of child rearing decreased. In this way, we see the progress of consumerism in Japan, with agents decreasing their consumption related to rearing children, which reduces the number of children. We find that: (i) fertility rates in the large region, which houses more manufacturing firms, become lower than in the small region; and (ii) a decrease in transportation costs results in the agglomeration of manufacturing firms in the large region, which subsequently lowers the fertility rates in both the small and large regions. In this study, we show that point (i) explains the interregional fertility variation, and point (ii) explains the recent decrease in the fertility rate in developed countries. Consumerism is proxied by the agglomeration of manufacturing firms in a large region and the decrease in transportation costs of manufactured goods

In the presented analysis, we assume that parents receive utility from both their children and their consumption of differentiated goods.[4] Parents allocate their fixed time to working or to rearing children. Thus, there is a trade-off between nominal income and children. [5] If consumerism progresses, agents

[4] Becker, Murphy, and Tamura (1990), Eckstein and Wolpin (1985), and Galor and Weil (1996, 2000), among others, assume that parents receive utility from their children.

[5] Strulik and Weisdorf (2008) also assume that children and consumption goods are substitute with each other. They constructed a model in which there is a trade-off between consumption for manufactured goods and food goods, while number of children increases with

raise their share of consumption for differentiated goods and reduce the number of children. In our model, the agglomeration of manufacturing firms in a large region lowers the relative price of the differentiated goods in this region, since consumers can buy a variety of manufactured goods without incurring transportation costs. Thus, the agglomeration of manufacturing firms induces parents to extend their expenditure share on differentiated goods. In other words, consumerism is relatively advanced in the large region. Through this mechanism, parents in the large region have fewer children, which explains why fertility rates are lower in large regions than in small regions.

In addition, the decrease in transportation costs actually lowers fertility rates in all regions in our model. A decrease in transportation costs lowers the relative price of differentiated goods in all regions, since consumers can purchase manufactured goods produced in other regions at lower prices. This allows parents to extend their expenditure share on differentiated goods, thus decreasing the number of children they have. Thus, consumerism progresses as a result of the agglomeration of manufacturing firms and with the decrease in transportation costs. Consumerism progresses in the region where the agglomeration of firms occurs because consumers can access many manufactured goods that do not include transportation costs. On the other hand, interregional transportation costs tend to be relatively lower in developed countries because of transport infrastructures such as highways, railroads, and airports, as well as innovative transportation technology. [6] Such a decrease in transportation costs lowers fertility rates. Thus, our model shows that the recent decrease in fertility rates has progressed with the decrease in transportation costs. The agglomeration of manufacturing firms and decreasing transportation costs are features of the modern world. Our study shows that these two features are the basis for interregional fertility variation and the time-series decrease in fertility rates through consumerism.

Theoretically, this study presents a tractable interregional trade model that follows the work of Helpman and Krugman (1985). Helpman and Krugman (1985) present Dixit–Stiglitz (1977)-type monopolistic competition models. Here, the interregional trade of differentiated goods incurs transportation costs, and differentiated goods are produced by monopolistically competitive firms whose production functions are under increasing returns to scale. They show that manufacturing firms agglomerate in large regions, which is induced by decrease in transportation costs. Krugman (1980) and Fujita, Krugman, and Venables (1999) also showed that decrease in transportation costs induce the agglomeration of manufacturing firms.

However, these studies do not consider endogenous fertility rates, so the model proposed here extend their model by constructing an interregional trade model with endogenous fertility. Our model also suggests that manufacturing firms agglomerate in the large region, thus lowering fertility rates in this region. Therefore, our model presents a possible mechanism that explains the

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the decline in the price of food goods.

[6] Glaeser and Koohlhase (2003) show that, during the 20th century, transportation costs of manufactured goods in the US decreased by over 90%.

interregional fertility variations. Few studies have investigated interregional fertility variations, but one exception is the study of Sato (2007), who also examines regional variations in fertility rates. Sato (2007) constructs a model in which urbanization induces an agglomeration economy and congestion diseconomies, and fertility rates decrease with urbanization. The agglomeration economy raises parents' incomes, which increases fertility rates owing to the income effect. However, it also reduces fertility rates owing to the substitution effect. In addition, congestion diseconomies decrease parents' incomes, which further reduces fertility rates. Sato (2007) shows that the sum of the substitution effect and congestion diseconomies overcomes the income effect of an agglomeration economy, and urbanization lowers fertility rates. However, in Sato (2007), agglomeration of firms are not considered. As we observe in Figure 2 and 4, the region with high population density attracts many firms. We construct a model with totally different framework from Sato, and in our model, the agglomeration of manufacturing firms emerges endogenously, and presents a possible explanation for the relationship among population density, fertility rates, agglomeration of firms. Since there are few studies that have analyzed the mechanism behind the interregional variations in fertility, our study presents consumerism as one possible reason for the interregional fertility variations.[7]

Many studies have presented models with endogenous fertility rates to explain the mechanism behind the recent decrease in fertility rates. For example, Becker, Murphy, and Tamura (1990) present a model in which fertility is closely related to the accumulation of human capital. In their model, parents obtain utility, not only from their consumption, but also from the quantity and quality of their children. Parents allocate a fixed amount of time to working, parenting, and educating their children. Hence, there is a quantity/quality trade-off for parents based on their optimum number of children and their qualities. Studies such as Galor (2005), Galor and Weil (2000), Kalemli-Ozcan, Ryder, and Weil (2000), and Kalemli-Ozcan (2002, 2003) and Tamura (2002, 2006), all follow Becker, Murphy, and Tamura (1990) by constructing models with a quantity/quality trade-off. All these models suggest an explanation for differences in fertility across regions and over time, based on differences in returns to human capital. The difference of returns to human capital is the important basis to explain the mechanism behind the fertility movements. The current paper offers a new and straight forward story which explains the fertility movements–a theory which nicely complements ideas proposed in these studies. More specifically, we presents that agglomeration of firms, which is one of the important features in the modern economy, brings about the recent fertility movements.

The mechanism presented by Sato (2007) was similar to that of Sato and Yamamoto (2005), which also studied the fertility decrease that occurred with economic growth. Sato and Yamamoto (2005) showed that urbanization, which

[7] To present congestion economy in our model, we can assume that agents consume lands and should commute to get the nominal income. Under this assumpetion, we can derive the result that fertility rates in the larger region may be lower than the smaller region. This is because the mean commuting time in the larger region should be longer than the smaller region, which decreases the working time and lower the fertility rates in the larger region.

is induced by an agglomeration economy, progresses with economic growth. With urbanization, fertility rates decrease along with the process of economic growth. They then point out that urbanization of manufacturing firms. Our study points out that the decrease in transportation costs plays an important role in explaining the recent decrease in fertility rates. Maruyama and Yamamoto (2010) have a similar mechanism to our model. Their study shows that the increase in consumption variety that occurs during economic growth decreases fertility rates. However, they focus on the relationship between fertility rates and economic growth, not on the regional variation in fertility rates.

Our study proposes one other explanation for the mechanism behind the recent fertility decrease. Since the decrease in fertility rates and the decrease in transportation costs of international/interregional trade are two major features in the modern economy, our study shows that the decrease in fertility rates in developed countries is based around the decrease in transportation costs.

The remainder of this paper is organized as follows. Section 2 presents the model. In Section 3, we analyze the model and present the results. Section 4 extends our two-region model to a multi-region model. Here, we show that manufacturing firms agglomerate in larger regions, and that the fertility rates in these regions subsequently drop. Finally, Section 5 concludes the paper.

2 The model

There are two regions, 1 and 2. Variables that refer to region 1 have the subscript 1 and those that refer to region 2 have the subscript 2. Each region is endowed with a fixed amount of labor, L_1 and L_2, respectively, while region 1 is larger than region 2: $L_1 > L_2$. [8] We assume that agents in both regions obtain utility from their consumption of homogeneous agricultural goods and differentiated manufactured goods, as well as from the number of children they have. Labor can be used to produce agricultural goods and differentiated manufactured goods, and/or to rear children. While labor can be mobile between sectors within the same region, it cannot be mobile between different regions.

The utility function of the agent in region i ($i = 1, 2$) is given by

$$U_i = A_i + \frac{1}{\mu}\left[C_i^{\alpha} m_i^{1-\alpha}\right]^{\mu}, \tag{1}$$

where

$$C_i = \left[\int_0^{n_i} x_i^i(j)^{\rho} dj + \int_0^{n_{i'}} x_i^{i'}(j')^{\rho} dj'\right]^{\frac{1}{\rho}}, \; 0 < \rho < 1, \; \rho > \alpha\mu, \; i, i' \in \{1, 2\}, \; i \neq i'. \tag{2}$$

Here, A_i represents the consumption of agricultural goods in region i, C_i is the composite of consumption of manufactured goods in region i, m_i is the number

[8] In our model, there is no interregional migration. As discussed in the introduction, fertility rates are lower in more densely populated regions, irrespective of whether there is migration between areas. Since our focus is to examine the mechanism behind this trend, for the sake of analytical simplicity, we assume no interregional migration.

of children in region i, and μ is a positive parameter. In addition, $x_k^l(j)$ denotes the consumption of manufactured goods of variety j in region k, which were produced in region Then, l. n_i is the number of varieties produced by a firm in region i. Here, $\frac{1}{1-\rho}$ represents the elasticity of substitution among differentiated goods. We assume $\rho > \alpha\mu$ to ensure the concavity of preferences over $x_k^l(j)$.

The manufactured goods in our model include goods produced in the service sector. In developed countries, there has been a large rise in the share of GDP from services. In general, goods produced in the service sector are thought of as "non-tradable," some types of goods, such as restaurants or entertainment, become "tradable." For example, franchise fast food restaurants such as McDonald's are practically identical, whether one visits one in Tokyo or Fukushima. Similarly, franchise restaurants such as TGI Fridays, Applebees, Ruby Tuesday, and so on, are likely identical across regions. In addition, "entertainment" has become more "tradable." In local US newspapers, radio stations, television stations, movie theaters, grocery stores, hair-cutting establishments, retail stores in malls, gas stations, and so on, are now all parts of national chains. Thus, the "programming" in these services has become more "tradable." Our differentiated goods aggregate many of these services.[9]

Following Becker (1965) and others, we assume that if parents have a child, they use time to rear the child. Their budget constraint thus becomes

$$w_i(1-\gamma m_i^\phi) = A_i + \int_0^{n_i} p_i^i(j)x_i(j)dj + \int_0^{n_{i'}} p_i^{i'}(j')x_i^{i'}(j')dj', \tag{3}$$

where $p_k^l(j)$ denotes the price of manufactured goods of variety j in region k, which are produced in region l, and w_i denotes the wage rate in region i. In addition, γm_i^ϕ is the cost of rearing children. We assume that the per capita cost of rearing children decreases with the number of children, and that $\mu(1-\alpha) < \phi < \frac{\mu(1-\alpha)}{1-\alpha\mu}$. The condition $\phi < \frac{\mu(1-\alpha)}{1-\alpha\mu}$ ensures that children are substitutional to differentiated goods, and the condition $\phi > \mu(1-\alpha)$ ensures the second-order condition of the consumer problem. We take homogeneous agricultural goods as the numeraire.

Then, we can obtain the following demand functions:

$$m_i = \left(\frac{w_i\gamma\phi}{1-\alpha}\right)^{\frac{1-\alpha\mu}{B}} \alpha^{-\frac{\alpha\mu}{B}} P_i^{\frac{\alpha\mu}{B}}, \tag{4}$$

$$P_i = \left(\int_0^{n_1+n_2} p_i(j)^{\frac{\rho}{\rho-1}} dj\right)^{\frac{\rho-1}{\rho}}, \tag{5}$$

$$x_i^l(j) = \left(\frac{w_i\gamma\phi}{1-\alpha}\right)^{\frac{\mu(1-\alpha)}{B}} \alpha^{\frac{\mu(1-\alpha)-\phi}{B}} p_i^l(j)^{\frac{1}{\rho-1}} P_i^{\frac{X}{B(1-\rho)}}, \tag{6}$$

where P_i is the "price index" in region i, while $B = \mu(1-\alpha) - \phi(1-\alpha\mu) > 0$ and $X = \rho\mu(1-\alpha) - \phi(\rho-\alpha\mu) > 0$ because $\mu(1-\alpha) < \phi < \frac{\mu(1-\alpha)}{1-\alpha\mu}$.

[9] An anonymous referee pointed out that many service goods can be involved in our differentiated goods.

Next, we describe the production structure of the agricultural sector. The agricultural goods market is perfectly competitive. We assume that, in both regions, one unit of agricultural goods is produced with one unit of labor, and that the interregional trade of homogeneous goods incurs no transportation costs. Therefore, the equilibrium wages in the two regions are both one: $w_1 = w_2 = 1$.

In the manufacturing sector, firms operate under Dixit–Stiglitz (1977)-type monopolistic competition. Each manufacturing firm produces differentiated goods, and each variety is produced by one firm. To start production activities, a firm in region j is required to pay a fixed input requirement that comprises f units of labor. Moreover, a firm uses one unit of labor in its region as the marginal input to produce one unit of manufactured goods. Potential firms can freely enter production activities, as long as the pure profits are positive and they can choose to locate in a region where profits are higher. Under this production structure, each manufacturing firm sets the following constant markup (mill) price:

$$p_1^1 = p_2^2 = \frac{1}{\rho}. \tag{7}$$

The interregional trade of manufactured goods incurs "iceberg"-type transportation costs. If a firm in one region sends one unit of its good to the other region, it must dispatch T units of the good. Hence, $T-1 > 0$ represents transportation costs. Thus, the price of imported manufactured goods in region i becomes $Tp_i^{i'}$ and $i \neq i'$. The price index in region i can therefore be written as

$$P_i = \frac{1}{\rho} \cdot (n_i + n_{i'}\tau)^{\frac{\rho-1}{\rho}}\ ,\ i, i' \in \{1, 2\}\ ,\ i \neq i', \tag{8}$$

where $\tau \equiv T^{\frac{\rho}{\rho-1}}$ and τ represent the freeness of trade. Then, $\tau = 0$ describes the case of an autarky, whereas $\tau = 1$ implies free trade. From (6) and (7), the profits of the firms in regions 1 and 2 can be expressed as follows:

$$\pi_i = (1-\rho)\rho^{\frac{\rho}{1-\rho}} \alpha^{\frac{\mu(1-\alpha)-\phi}{B}} (\frac{\gamma\phi}{1-\alpha})^{\frac{\mu(1-\alpha)}{B}} \left[L_i P_i^{\frac{X}{B(1-\rho)}} + \tau L_{i'} P_{i'}^{\frac{X}{B(1-\rho)}} \right] - f,\ i, i' \in \{1, 2\}\, . \tag{9}$$

3 Equilibrium

In this section, we study the equilibrium of the manufacturing firms in both regions. That is,

$$\pi_1 = \pi_2. \tag{10}$$

From (9) and (10), the relative price level is given by

$$\frac{P_1}{P_2} = (\frac{L_2}{L_1})^{\frac{B(1-\rho)}{X}}. \tag{11}$$

In this model, because region 1 is larger than region 2, the price level in region 1 is lower than in region 2. From (4) and (11), we can thus obtain the relative fertility rates as follows:

$$\frac{m_1}{m_2} = (\frac{L_2}{L_1})^{\frac{\alpha\mu(1-\rho)}{X}} = l^{\frac{-\alpha\mu(1-\rho)}{X}}. \tag{12}$$

From $L_1 > L_2$, the fertility rates in region 1 are lower than those in region 2. To summarize the results of (11) and (12), we obtain the following proposition.

Proposition 1 *The larger region has a lower price level and lower fertility rates.*

We can explain this proposition intuitively. In the larger region, demand is higher, and thus manufacturing firms agglomerate there. Thus, the price level in region 1 is lower than that in region 2 and the larger regions consume more manufactured goods. In this model, because manufactured goods and bearing children are substitutes, parents that live in larger regions bear fewer children.

By substituting (11) into (8), the relationship between n_1 and n_2 is given by

$$n_1 = \frac{l^{\frac{\rho B}{X}} - \tau}{1 - \tau l^{\frac{\rho B}{X}}} n_2, \tag{13}$$

where l denotes the relative population size; that is, $l \equiv L_1/L_2 > 1$. From (13), there are more firms in region 1 than in region 2. [10] Then, firms agglomerate in the larger region. Eq. (13) shows that, when $n_1 > 0$ and $n_2 > 0$, $\tau < l^{\frac{-\rho B}{X}} \equiv \bar{\tau}$. When $\tau > \bar{\tau}$, all manufacturing firms locate in region 1. From (13) and the free-entry condition of $\pi_1 = 0$, the number of manufacturing firms located in region 2 is given by [11]

$$n_2 = \frac{1 - \tau l^{\frac{\rho B}{X}}}{1 - \tau} (1 + \tau)^{\frac{-\alpha\mu\phi(1-\rho)}{X}} \Psi^{-\frac{\rho B}{X}}, \tag{14}$$

where

$$\Psi = f(1-\rho)^{-1} \rho^{\frac{\alpha\mu\phi}{B}} \alpha^{\frac{\phi-\mu(1-\alpha)}{B}} (\frac{\gamma\phi}{1-\alpha})^{\frac{-\mu(1-\alpha)}{B}} L_2^{-1}. \tag{15}$$

Then, by differentiating (14) and (13) with respect to τ, we can obtain the following equations:

$$\frac{\partial n_2}{\partial \tau} = -n_2 \left[\frac{l^{\frac{\rho B}{X}} - 1}{(1-\tau)(1 - \tau l^{\frac{\rho B}{X}})} + \frac{\alpha\mu\phi(1-\rho)}{(1+\tau)X} \right] \Psi^{-\frac{\rho B}{X}} < 0, \tag{16}$$

[10] By subtracting the denominator of (13) from the numerator of (13), we can show $\frac{n_1}{n_2} > 1$.

$$l^{\frac{\rho B}{X}} - \tau - 1 + \tau l^{\frac{\rho B}{X}} = (1+\tau)(l^{\frac{\rho B}{X}} - 1) > 0,$$

because $l > 1$.

[11] See Appendix for proof.

$$\frac{\partial n_1}{\partial \tau} = \frac{n_2}{(1-\tau^2)(1-\tau l^{\frac{\rho B}{X}})X} F(\tau), \tag{17}$$

where

$$F(\tau) = (1+\tau)(l^{\frac{\rho B}{X}} - 1)X - \alpha\mu\phi(1-\tau)(1-\rho)(l^{\frac{\rho B}{X}} - \tau). \tag{18}$$

Thus, we can obtain the following proposition (see Appendix for proof).

Proposition 2 *Suppose $\tau < \bar{\tau}$ is satisfied.*

1) When $l > (\frac{X}{X-\alpha\mu\phi(1-\rho)})^{\frac{X}{\rho B}}$, a decrease in transportation costs increases the number of manufacturing firms located in region 1. When $1 < l < (\frac{X}{X-\alpha\mu\phi(1-\rho)})^{\frac{X}{\rho B}}$ holds, a decrease in transportation costs decreases the number of manufacturing firms located in region 1 for $0 < \tau < \tau^*$, where $F(\tau^*) = 0$, increases the number of manufacturing firms in region 1 for $\tau^* < \tau < \bar{\tau}$.

2) A decrease in transportation costs decreases the number of manufacturing firms in region 2.

3) A decrease in transportation costs decreases the total number of manufacturing firms.

The first item of Proposition 2 shows the relationship between transportation costs and the number of firms in region 1. The second item of Proposition 2 investigates how a decrease in transportation costs affects the number of firms in region 2. The third item of Proposition 2 represents the effect of a decrease in transportation costs on the total number firms. There are two effects of a decrease in transportation costs on the number of firms in both regions: the *location shift effect* and the *competition effect*. Since the market size of region 1 is larger than that of region 2, some manufacturing firms shift their production plants from the smaller to the larger region to decrease transportation costs. Therefore, the number of firms in region 1 increases and the number of firms in region 2 decreases when transportation costs decrease. This is the *location shift effect*. On the other hand, when transportation costs decrease, the competition between local and foreign firms intensifies. Then, the manufactured goods market in both regions becomes competitive and profits decrease. This effect decreases the number of firms in both regions. This is the *competition effect*. When the amount of labor in region 1 is sufficiently large, region 1 attracts more manufacturing firms and the *location shift effect* becomes large compared to the *competition effect*. In this case, a decrease in transportation costs increases the number of firms in region 1. When the difference between the amount of labor in regions 1 and 2 is not that great, the *location shift effect* on the number of firms in region 1 becomes small, and the *location shift effect* becomes smaller than the *competition effect*. In this case, a decrease in transportation costs decreases the number of firms in region 1. In region 2, both the *location shift effect and the competition effect* reduce the number of manufacturing firms. The *location shift effect* only influences the relative number of firms, but has no effect on the total number of firms. Therefore, a decrease in transportation costs decreases the total number of firms.

We also investigate how this decrease in transportation costs affects the price indices and fertility rates in both regions. Thus, we can obtain the following proposition (see Appendix for proof).

Proposition 3 *Suppose $\tau < \bar{\tau}$ is satisfied. A decrease in transportation costs decreases the price indices and the fertility rates in both regions.*

Furthermore, such a decrease in the interregional transportation costs of manufactured goods lowers the price levels in both regions. Since manufactured goods and bearing children are substitutes, a decrease in the price of manufactured goods reduces the number of children.

In the next step, we examine the case in which $\tau > \bar{\tau}$. When $\tau > \bar{\tau}$, all manufacturing firms agglomerate in region 1 and $n_2 = 0$. Eqs. (4) and (8) show that, in this case

$$\frac{m_1}{m_2} = \tau^{\frac{\alpha\mu(1-\rho)}{\rho X}}. \tag{19}$$

When $\tau > \bar{\tau}$, $\tau^{\frac{\alpha\mu(1-\rho)}{\rho X}} > (\frac{L_2}{L_1})^{\frac{\alpha\mu(1-\rho)}{X}} = l^{\frac{-\alpha\mu(1-\rho)}{X}}$. Thus, the full agglomeration of manufacturing firms (i.e., when all manufacturing firms agglomerate in the large region) reduces the difference in the fertility rates of the two regions.

Proposition 4 *When $\tau > \bar{\tau}$, the full agglomeration of manufacturing firms occurs, reducing the difference in fertility rates between the two regions as transportation costs decrease.*

This proposition states that, when transportation costs are low, full agglomeration is observed. If full agglomeration occurs, the difference in the fertility rates between the large and small regions begins to decrease. Moreover, another decrease in transportation costs further reduces the difference between these fertility rates, since $\partial\tau^{\frac{\alpha\mu(1-\rho)}{\rho X}}/\tau > 0$.

4 Multi-region case

In this section, we extend the presented model by assuming that there are $N > 2$ regions. Region i hosts an exogenously given mass of L_i consumers, and $L_1 > L_2 > ... > L_N$ holds. In addition, the preferences of each region are identical and the utility function is given by (1). Then, although demand for manufactured goods and for bearing children is the same as that detailed in the previous section, the price index in region i is given by

$$P_i = \left[\sum_{k=1}^{N} \int_0^{n_k} p_i^k(j)^{\frac{\rho}{\rho-1}} dj\right]^{\frac{\rho-1}{\rho}}. \tag{20}$$

The production structures of the agricultural goods and manufactured goods sectors remain the same as before. Thus, the wage rate in each region becomes unity, because the interregional trade of agricultural goods incurs no costs, and one unit of agricultural goods is produced with one unit of labor in each region. For analytical simplicity, the interregional transportation costs in the manufactured goods sector remain the same . Therefore, the price of manufactured goods becomes $p_i^i = 1/\rho$ and $p_k^i = T/\rho$, while $i \neq k$. Hence, the profits of the manufacturing firms located in region i are given by

$$\pi_i = (1-\rho)\rho^{\frac{\rho}{1-\rho}}\alpha^{\frac{\mu(1-\alpha)-\phi}{B}}(\frac{\gamma\phi}{1-\alpha})^{\frac{\mu(1-\alpha)}{B}}\left[(1-\tau)L_iP_i^{\frac{X}{B(1-\rho)}}+\tau\sum_{k=1}^{N}L_kP_k^{\frac{X}{B(1-\rho)}}\right]-f. \tag{21}$$

The price index in region i becomes

$$P_i = \frac{1}{\rho}\left[(1-\tau)n_i+\tau\sum_{k=1}^{N}n_k\right]^{\frac{\rho-1}{\rho}}. \tag{22}$$

Now, we examine the equilibria of the manufacturing firms located in each region. Thus, $\pi_1 = \pi_2 = ... = \pi_N$ holds. From (21) and (22), the relative price index between region i and region k is given by

$$\frac{P_i}{P_k} = (\frac{L_k}{L_i})^{\frac{B(1-\rho)}{X}}. \tag{23}$$

Thus, a larger region has a lower price index, and from $L_1 > L_2 > ... > L_N$, $P_1 < P_2 < ... < P_N$ holds. Because the larger region attracts more manufacturing firms, the price level in that region is lower. From the above equation, we can obtain the relative fertility rates of regions i and k, as follows:

$$\frac{m_i}{m_k} = (\frac{L_k}{L_i})^{\frac{\alpha\mu(1-\rho)}{X}}. \tag{24}$$

This equation shows that a larger region has a lower fertility rate, and from $L_1 > L_2 > ... > L_N$, $m_1 < m_2 < ... < m_N$ holds. Since the price level in the larger region is lower, the ratio of the consumption of manufactured goods to bearing children is greater. Hence, summarizing the results of the multi-region case, we obtain the following proposition:

Proposition 5 *In the multi-region case, both the price level and fertility rates in the larger regions are lower than in the smaller regions.*

This proposition states that fertility rates in large regions are lower than those in small regions, which is consistent with the findings of previous studies. Manufacturing firms agglomerate in large regions, which lowers their price indices. Consequently, the relative price of working time, which provides agents with their nominal income, to bearing children is higher in large regions than it is small regions. Therefore, agents in large regions have fewer children than those in small regions. Hence, the number of firms in region i can be described as[12]

[12] We show the process with which we derive Eq. (25) in the Appendix.

$$n_i = \frac{1}{1-\tau}\left(\frac{1-\tau+\tau N}{\eta}\right)^{\frac{B\rho}{X}}\left(\rho L_i^{\frac{B\rho}{X}} - \frac{\rho\tau}{1-\tau+\tau N}\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}\right). \tag{25}$$

where $\eta \equiv f(1-\rho)^{-1}\rho^{\frac{\rho}{1-\rho}}\alpha^{\frac{\phi-\mu(1-\alpha)}{B}}(\frac{\gamma\phi}{1-\alpha})^{\frac{-\mu(1-\alpha)}{B}}$. The term $\frac{\rho\tau}{1-\tau+\tau N}$ is the increasing function of τ and becomes zero when $\tau = 0$. When $\tau = 1$, $\frac{\rho\tau}{1-\tau+\tau N} = \frac{\rho}{N}$. Then, in the regions where

$$L_i^{\frac{B\rho}{X}} - \frac{1}{N}\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}} < 0$$

is satisfied, the transportation cost level, τ_i^*, satisfies $L_i^{\frac{B\rho}{X}} - \frac{\tau_i^*}{1-\tau_i^*+\tau_i^* N}\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}} = 0$. Therefore, $n_i = 0$when $\tau \geq \tau_i^*$. In addition, we observe that $\tau_1^* < \tau_2^*$ when $L_1 < L_2$.. Thus, manufacturing firms disappear from smaller regions when transportation costs fall.

Proposition 6 *1) In those regions in which $L_i^{\frac{B\rho}{X}} - \frac{1}{N}\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}} < 0$ is satisfied, $n_i = 0$ when $\tau \geq \tau_i^*$.*
2) $\tau_i^* < \tau_k^*$ when $L_i < L_k$..

When region i has no firms, the fertility rates in that region relative to those of region k, which has manufacturing firms, is[13]

$$\frac{m_i}{m_k} = \left(\frac{1-\tau+\tau N}{\tau}\frac{L_i^{\frac{B\rho}{X}}}{\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}}\right)^{\frac{(1-\rho)\alpha\mu}{\rho B}}. \tag{26}$$

Therefore, $m_i/m_k > 1$ and $\partial(m_i/m_k)/\partial\tau < 0$, since $\rho L_i^{\frac{B\rho}{X}} - \frac{\rho\tau}{1-\tau+\tau N}\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}$.

Proposition 7 *The fertility rates of (smaller) regions that have no manufacturing firms are larger than those of (larger) regions that have manufacturing firms. Moreover, the difference in the fertility rates of these two regions decreases with a decrease in transportation costs.*

In summary, by using the multi-region case, we showed that (i) the number of manufacturing firms is larger in large regions than it is in small regions; (ii) fertility rates in small regions are higher than those in large regions; (iii) when transportation costs become low, small regions lose manufacturing firms; and (iv) fertility rates in small regions are higher than they are in regions that have manufacturing firms.

[13] We show the process with which we derive Eq. (26) in the Appendix.

5 Conclusion

In this paper, we prsented an interregional trade model with endogenous fertility rates, following the work of Krugman (1980), Helpman and Krugman (1985), and Fujita, Krugman, and Venables (1999). By using the model presented here, we showed that manufacturing firms agglomerate in a large region, which lowers fertility rates in that large region in comparison to a small region. In addition, we found that a decrease in transportation costs results in the agglomeration of manufacturing firms, which also lowers the fertility rates in both large and small regions. Moreover, by extending our two-region model to a multi-region model, we showed that the number of manufacturing firms in larger regions is always greater than in smaller regions, which means that fertility rates in the larger region are always lower than in the smaller region.

Our initial model was a relatively simple model that focused on the effect of consumerism. By extending the model, we were able to investigate the difference in fertility rates between regions and the decrease in the fertility rates more closely. First, in our model, consumerism is an important determinant of fertility rates. However, many other candidates may influence fertility rates as well. In this regard, future research should aim to construct an interregional trade model with a quality/quantity trade-off in line with the study of Becker, Murphy, and Tamura (199). Second, in our simple model, we assume there is no interregional migration. From this assumption, our model concluded that both the amount of labor in the two regions and fertility rates are different. Third, it will be intresting to construct a dynamic version of our framework. It wil be a natural extension to construct a dynamic model with endogenous fertility rates.

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A The derivation of (14)

Here, we show the derivation of (14). From the free-entry condition, we can obtain the following equation:

$$(1-\rho)\rho^{\frac{\rho}{1-\rho}}\alpha^{\frac{\mu(1-\alpha)-\phi}{B}}\left(\frac{\gamma\phi}{1-\alpha}\right)^{\frac{\mu(1-\alpha)}{B}}\left[L_1P_1^{\frac{X}{B(1-\rho)}}+\tau L_2P_2^{\frac{X}{B(1-\rho)}}\right]=f. \tag{27}$$

By using (8) and (13), we can rewrite the square brackets of (27) as follows:

$$\begin{aligned}\left[L_1P_1^{\frac{X}{B(1-\rho)}}+\tau L_2P_2^{\frac{X}{B(1-\rho)}}\right] &= L_2\rho^{\frac{-X}{B(1-\rho)}}\left[l(n_1+\tau n_2)^{\frac{-X}{\rho B}}+\tau(\tau n_1+n_2)^{\frac{-X}{\rho B}}\right] \\ &= L_2\left(\frac{(1-\tau^2)\rho n_2}{1-\tau l^{\frac{\rho B}{X}}}\right)^{-\frac{X}{\rho B}}(1+\tau).\end{aligned} \tag{28}$$

Then, by substituting (28) into (27), we can obtain the number of manufacturing firms located region 2.

B Proof of Proposition 2

B.1 Proof of (1) and (2) of Proposition 2

By differentiating (14) with respect to τ, we can obtain the following equation:

$$\Psi^{\frac{\rho B}{X}}\frac{\partial n_2}{\partial \tau} = n_2\left[-\frac{l^{\frac{\rho B}{X}}}{1-\tau l^{\frac{\rho B}{X}}} + \frac{1}{1-\tau} - \frac{\alpha\mu\phi(1-\rho)}{(1+\tau)X}\right]$$
$$= -n_2\left[\frac{l^{\frac{\rho B}{X}}-1}{(1-\tau)(1-\tau l^{\frac{\rho B}{X}})} + \frac{\alpha\mu\phi(1-\rho)}{(1+\tau)X}\right] < 0, \tag{29}$$

because $\tau < \bar{\tau}$. Then, we can differentiate (13) with respect to τ as follows:

$$\frac{\partial n_1}{\partial \tau} = \frac{l^{\frac{2\rho B}{X}}-1}{(1-\tau l^{\frac{\rho B}{X}})^2}n_2 + \frac{l^{\frac{\rho B}{X}}-\tau}{1-\tau l^{\frac{\rho B}{X}}}\frac{\partial n_2}{\partial \tau}. \tag{30}$$

By substituting (29) into the above equation, we obtain

$$\frac{\partial n_1}{\partial \tau} = n_2\left[\frac{(1-\tau)(l^{\frac{2\rho B}{X}}-1)-(l^{\frac{\rho B}{X}}-\tau)(l^{\frac{\rho B}{X}}-1)}{(1-\tau)(1-\tau l^{\frac{\rho B}{X}})^2} - \frac{\alpha\mu\phi(1-\rho)}{(1+\tau)X}\frac{l^{\frac{\rho B}{X}}-\tau}{1-\tau l^{\frac{\rho B}{X}}}\right]$$
$$= \frac{n_2}{1-\tau l^{\frac{\rho B}{X}}}\left[\frac{l^{\frac{\rho B}{X}}-1}{1-\tau} - \frac{\alpha\mu\phi(1-\rho)(l^{\frac{\rho B}{X}}-\tau)}{(1+\tau)X}\right]$$
$$= \frac{n_2}{(1-\tau^2)(1-\tau l^{\frac{\rho B}{X}})X}F(\tau), \tag{31}$$

where

$$F(\tau) = (1+\tau)(l^{\frac{\rho B}{X}}-1)X - \alpha\mu\phi(1-\tau)(1-\rho)(l^{\frac{\rho B}{X}}-\tau). \tag{32}$$

From (31), the sign of $\partial n_1/\partial\tau$ depends on the sign of $F(\tau)$. The first and second derivatives of $F(\tau)$ are given by

$$F'(\tau) = (l^{\frac{\rho B}{X}}-1)X + \alpha\mu\phi(1-\rho)(l^{\frac{\rho B}{X}}+1-2\tau) > 0, \tag{33}$$
$$F''(\tau) = -2\alpha\mu\phi(1-\rho) < 0. \tag{34}$$

Thus, $F(\tau)$ is a monotonically increasing function in $0 < \tau < \bar{\tau}$. The value of $F(\bar{\tau})$ is given by

$$F(\bar{\tau}) = (l^{\frac{\rho B}{X}} - l^{-\frac{\rho B}{X}})Q + \alpha\mu\phi(1-\rho)(1-l^{-\frac{2\rho B}{X}}) > 0. \tag{35}$$

Therefore, because $F(\tau)$ is a monotonically increasing function and $F(\bar{\tau})$ is positive, when $F(0)$ is positive, $F(\tau) > 0$ holds for $0 < \tau < \bar{\tau}$. The value of $F(0)$ is given by

$$F(0) = (X - \alpha\mu\phi(1-\rho))l^{\frac{\rho B}{X}} - X. \tag{36}$$

When $l > (\frac{X}{X-\alpha\mu\phi(1-\rho)})^{\frac{X}{\rho B}}$ holds, $F(0)$ is positive, and thus $\partial n_1/\partial\tau$ is also positive. When $l < (\frac{X}{X-\alpha\mu\phi(1-\rho)})^{\frac{X}{\rho B}}$ holds, $F(0)$ is negative. In this case, there exists τ^* that satisfies $F(\tau^*) = 0$. Therefore, when $0 < \tau < \tau^*$, $F(\tau)$ is negative and $\partial n_1/\partial\tau$ is also negative. When $\tau^* < \tau < \bar{\tau}$, both $F(\tau)$ and $\partial n_1/\partial\tau$ are positive.

B.2 Proof of (3) of Proposition 2

The total number of manufacturing firms is given by

$$n_1 + n_2 = (1+\tau)^{-\frac{\alpha\mu\phi(1-\rho)}{X}} (l^{\frac{\rho B}{X}}) \Psi^{-\frac{\rho B}{X}}. \tag{37}$$

Then, by differentiating the above equation with respect to τ, we can obtain

$$\frac{\partial(n_1+n_2)}{\partial\tau} = -\frac{\alpha\mu\phi(1-\rho)}{X}(l^{\frac{\rho B}{X}} - 1)(1+\tau)^{-\frac{\alpha\mu\phi(1-\rho)+X}{X}} \Psi^{-\frac{\rho B}{X}} < 0. \tag{38}$$

Thus, a decline in transportation costs decreases the total number of manufacturing firms.

C Proof of Proposition 3

Neither (11) nor (12) depends on τ. Therefore, $\frac{\partial P_1}{\partial\tau} = \frac{\partial P_2}{\partial\tau}$ and $\frac{\partial m_1}{\partial\tau} = \frac{\partial m_2}{\partial\tau}$ hold. By substituting (13) into (8), the price index in region 1 is represented by

$$P_1 = \frac{l^{\frac{(\rho-1)B}{X}}}{\rho} \left[\frac{(1-\tau^2)n_2}{1-\tau l^{\frac{\rho B}{X}}}\right]^{\frac{\rho-1}{\rho}}. \tag{39}$$

Since $\rho < 1$, the sign of $\partial P_1/\partial\tau$ is not the same as the sign of the first derivative in the square brackets of (39). Then, to investigate the sign of $\partial P_1/\partial\tau$, we obtain the following equation by differentiating the term in the square brackets of (39) with respect to τ, as follows:

$$\frac{\partial}{\partial\tau}\left(\frac{(1-\tau^2)n_2}{1-\tau l^{\frac{\rho B}{X}}}\right) = \frac{l^{\frac{\rho B}{X}}(1+\tau^2) - 2\tau}{(1-\tau l^{\frac{\rho B}{X}})^2} n_2 + \frac{1-\tau^2}{1-\tau l^{\frac{\rho B}{X}}}\frac{\partial n_2}{\partial\tau}. \tag{40}$$

Then, by substituting (14) into the above equation, we can rewrite it as follows:

$$\begin{aligned}
\frac{\partial}{\partial\tau}\left(\frac{(1-\tau^2)n_2}{1-\tau l^{\frac{\rho B}{X}}}\right) &= n_2\left[\frac{l^{\frac{\rho B}{X}}(1+\tau^2) - 2\tau}{(1-\tau l^{\frac{\rho B}{X}})^2} - \frac{(1+\tau)(l^{\frac{\rho B}{X}}-1)}{(1-\tau l^{\frac{\rho B}{X}})^2} - \frac{\alpha\mu\phi(1-\rho)(1-\tau)}{(1-\tau l^{\frac{\rho B}{X}})X}\right] \\
&= n_2\left[\frac{-\tau(1-\tau)l^{\frac{\rho B}{X}} + 1 - \tau}{(1-\tau l^{\frac{\rho B}{X}})^2} - \frac{\alpha\mu\phi(1-\rho)(1-\tau)}{(1-\tau l^{\frac{\rho B}{X}})X}\right] \\
&= \frac{n_2}{X}\frac{1-\tau}{1-\tau l^{\frac{\rho B}{X}}}\left[X - \alpha\mu\phi(1-\rho)\right] && (41) \\
&= \frac{n_2}{X}\frac{1-\tau}{1-\tau l^{\frac{\rho B}{X}}} Q > 0. && (42)
\end{aligned}$$

Therefore, the sign of $\partial P_1/\partial\tau$ is negative and a decline in transportation costs decreases the price levels in both regions. Next, we investigate how trade liberalization affects fertility rates. By differentiating (4) with respect to τ, we obtain the following equation:

$$\frac{\partial m_1}{\partial\tau} = (\frac{\gamma\phi}{1-\alpha})^{\frac{1-\alpha\mu}{B}} \alpha^{-\frac{\alpha\mu}{B}} \frac{\alpha\mu}{B} P_1^{\frac{\alpha\mu - B}{B}} \frac{\partial P_1}{\partial\tau} < 0, \tag{43}$$

because $\partial P_1/\partial\tau < 0$. Therefore, a decline in transportation costs decreases fertility rates in both regions.

D The derivations of (25) and (26)

In the multi-region case,

$$\pi_i = (1-\rho)\rho^{\frac{\rho}{1-\rho}}\alpha^{\frac{\mu(1-\alpha)-\phi}{B}}(\frac{\gamma\phi}{1-\alpha})^{\frac{\mu(1-\alpha)}{B}}\left[(1-\tau)L_i P_i^{\frac{X}{B(1-\rho)}} + \tau\sum_{k=1}^{N} L_k P_k^{\frac{X}{B(1-\rho)}}\right] - f, \tag{44}$$

and

$$P_i = \frac{1}{\rho}\left[(1-\tau)n_i + \tau\sum_{k=1}^{N} n_k\right]^{\frac{\rho-1}{\rho}}. \tag{45}$$

The free-entry condition, $\pi_i = 0$, ensures that

$$(1-\tau+\tau N)L_i P_i^{\frac{x}{B(1-\rho)}} = \eta. \tag{46}$$

Eq. (46) can be translated to

$$P_i^{\frac{\rho}{\rho-1}} = \left(\frac{1-\tau+\tau N}{\eta}\right)^{\frac{B\rho}{X}} L_i^{\frac{B\rho}{X}}. \tag{47}$$

Therefore, we derive that

$$\sum_{k=1}^{N} P_k^{\frac{\rho}{\rho-1}} = \left(\frac{1-\tau+\tau N}{\eta}\right)^{\frac{B\rho}{X}} \sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}. \tag{48}$$

From (45) and (48),

$$\sum_{k=1}^{N} n_k = \frac{\rho}{1-\tau+\tau N}\left(\frac{1-\tau+\tau N}{\eta}\right)^{\frac{B\rho}{X}} \sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}. \tag{49}$$

We substitute (47) and (49) into (45), and obtain

$$n_i = \frac{1}{1-\tau}\left(\frac{1-\tau+\tau N}{\eta}\right)^{\frac{B\rho}{X}}\left(\rho L_i^{\frac{B\rho}{X}} - \frac{\rho\tau}{1-\tau+\tau N}\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}\right).$$

This is Eq. (25).

Next, the price index in region i, which has no manufacturing firms, is

$$P_i = \frac{1}{\rho}\left[\tau\sum_{k=1}^{N} n_k\right]^{\frac{\rho-1}{\rho}}. \tag{50}$$

We substitute (25) and (49) into (45) and (50), respectively. Then, we derive the price indices in region i relative to region k, which has manufacturing firms, as follows:

$$\frac{P_i}{P_k} = \left(\frac{1 - \tau + \tau N}{\tau} \frac{L_i^{\frac{B\rho}{X}}}{\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}} \right)^{\frac{(1-\rho)}{\rho}}.$$

Therefore,

$$\frac{m_i}{m_k} = \left(\frac{P_i}{P_k} \right)^{\frac{\alpha\mu}{B}} = \left(\frac{1 - \tau + \tau N}{\tau} \frac{L_i^{\frac{B\rho}{X}}}{\sum_{k=1}^{N} L_k^{\frac{B\rho}{X}}} \right)^{\frac{(1-\rho)\alpha\mu}{\rho B}}.$$

This is Eq. (26).

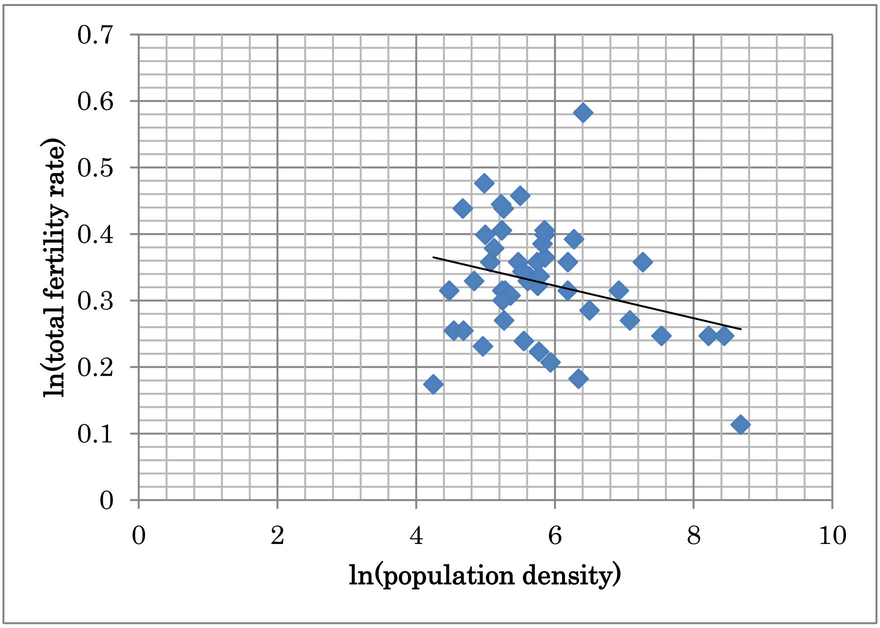

Figure 1: Population density and total fertility rate of Japanese prefectures for the year 2009

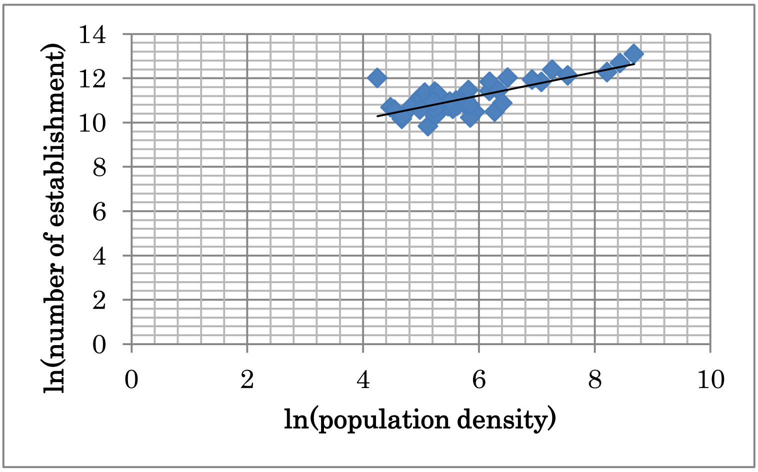

Figure 2: Population density and number of establishment of Japanese prefectures for the year 2009

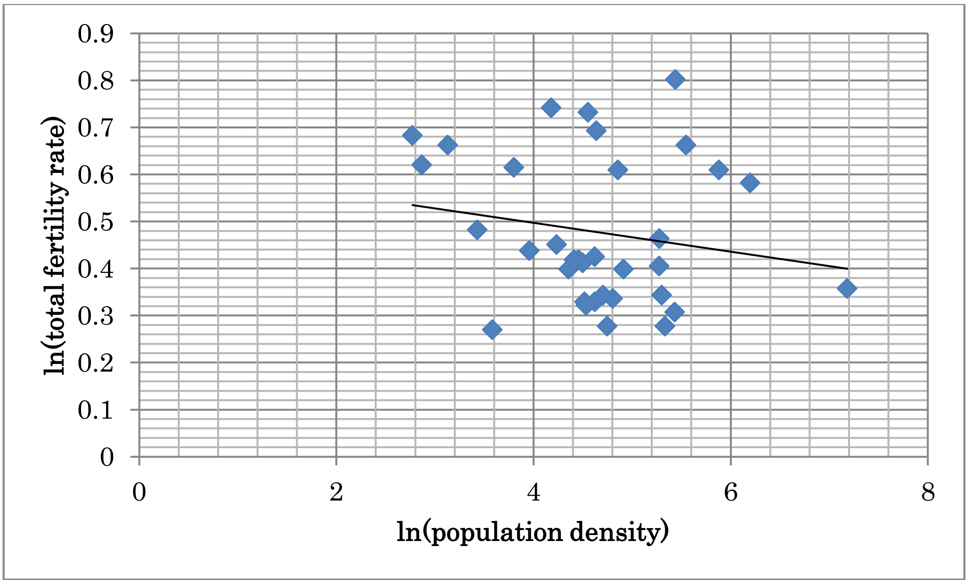

Figure 3: Population density and total fertility rate of EU countries for the year 2010.

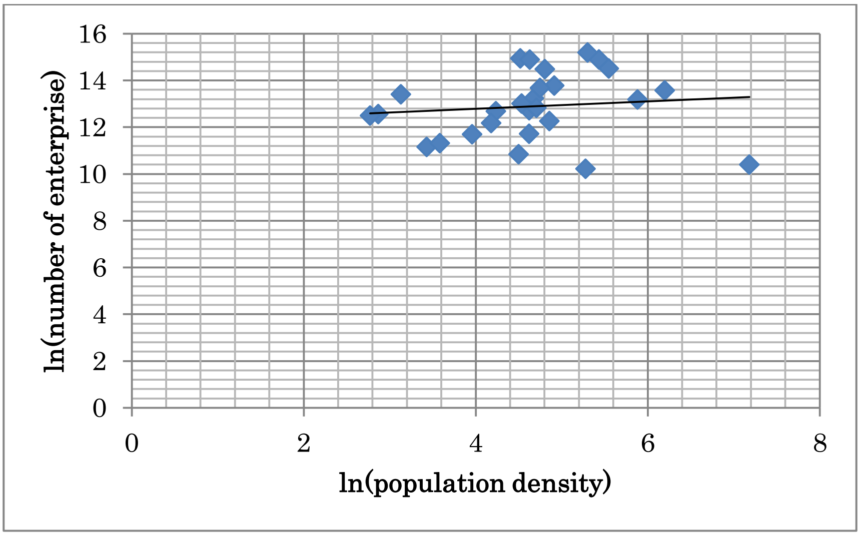

Figure 4: Population density and number of enterprise of EU countries for the year 2010