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The Expansion of the Commercial Sector and the Child Quantity-Quality Transition in a Malthusian World

Ken Tabata

School of Economics, Kwansei Gakuin University

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SCHOOL OF ECONOMICS

KWANSEI GAKUIN UNIVERSITY

1-155 Uegahara Ichiban-cho

Nishinomiya 662-8501, Japan

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Abstract

This paper constructs a simple Malthusian model to explain per capita income differences in the Malthusian era by focusing on regional variations in the expansion of the commercial sector. This paper shows that a larger productivity improvement in the skilled intensive commercial sector relative to the improvement in the unskilled intensive agricultural sector causes a higher per capita income in the Malthusian steady-state equilibrium by enhancing the child quantity-quality transition. From the late Middle Ages, Northwestern Europe (Britain and the Netherlands) was characterized by dramatic growth of both the commercial sector and urbanization, high literacy rates, and a low-pressure demographic regime, and thus, these regions developed very differently from the rest of Europe. Our results are somewhat consistent with the relevant experiences of Northwestern Europe in the preindustrial era.

JEL classification numbers: J10, N10, O11, O33

Keywords: Commercial Sector, Sectoral Productivity Improvement, Child Quantity-Quality Transition, Malthusian Era

*School of Economics, Kwansei Gakuin University; E-mail address: tabataken@kwansei.ac.jp

1 Introduction

In the Malthusian era, which includes much of human history, the positive relationship between population growth and per capita income led to stagnant living standards. Higher per capita income causes more births, fewer deaths and a larger population. However, because of diminishing returns to labor in production, a higher population gradually offsets any improvement in the income level, which forces it back to the original level of stagnant living standards. The entire world economy had been under this Malthusian regime until the beginning of the nineteenth century, when Western Europe escaped from the Malthusian Epoch and transitioned to the Post-Malthusian regime (Galor, 2005; Clark, 2007; Galor, 2011).

However, recent historical studies show that Malthusian equilibrium does not imply that per capita income must necessarily be at minimum subsistence levels. For example, according to Allen et al. (2011), even in the mid seventeenth century (a time when England's population was constant) the wage of unskilled laborers in England was well above the biological minimum food equivalent of about 1500 cal a day. One implication of this fact is that living standards across regions were not necessarily homogenous even in the Malthusian era. In particular, a number of recent studies have pointed to the emergence of Northwestern Europe (England and the Netherlands) as a high wage/per capita income economy during the early modern period, which is between the sixteenth and eighteenth centuries; indeed, there was dramatic growth of commercialization and urbanization as this region displaced the Iberian powers in long-distance trade to Asia and the New World (van Zanden, 1999; Allen, 2001; Broadberry and Gupta, 2006). At the same time, compared with the rest of Europe, Northwestern Europe generated an economy with a higher level of literacy, higher skill formation and a lower-pressure demographic regime (Wrigley et al., 1997; De Moor and van Zanden, 2010; Allen, 2011). Therefore, several historians and economists argue that this little divergence within Europe leads to the great divergence between Europe and Asia in the early 19th century (Broadberry and Gupta, 2006, 2007, Voigtländer and Voth, 2006).

Inspired by these historical findings, in this paper, we construct a simple Malthusian model in accordance with Ashraf and Galor (2011) to identify the necessary factors to explain regional per capita income differences in the preindustrial era. This paper extends the one-sector Malthusian model of Ashraf and Galor (2011) by introducing two production sectors: the skilled intensive commercial sector and the unskilled intensive agricultural sector. In addition, we explicitly consider parental trade-offs between the number and quality of children. We argue that the larger productivity improvement in the skilled intensive commercial sector relative to the improvement in the unskilled intensive agricultural sector increases the demand for skilled labor with basic literacy, numeracy and knowledge of market transactions, enhances the child quantity-quality transition, and induces the emergence of an economy that is characterized by high per capita income, a high literacy rate and a low-pressure demographic regime. The regional variations in the expansion of the commercial sector help to explain regional per capita income differences in the Malthusian World. Although we develop a simple, tractable model to capture the general features of a Malthusian equilibrium, our model may help to explain historically observed facts of Northwestern Europe in the preindustrial era.

The paper proceeds as follows: section 2 contains a literature review, section 3 presents the basic setup of our Malthusian model, and section 4 analyses the dynamic properties of the model and examines both the short-run and the long-run effects of sectoral differences in productivity improvement. Then, section 5 provides a historical narrative in which increasing demand for skilled labor due to growing commercialization induced the child quantity-quality transition, which led to the emergence of Northwestern Europe as the leading economy; it was characterized by high per capita income, a high literacy rate and a low-pressure demographic regime. Section 6 concludes.

2 Related Literature

As suggested by Sharp et al. (2011) and others, the determinants of per capita income in a Malthusian equilibrium are captured by the simple diagrammatic representation of Figure 1. Changes in the per capita income y_t have a double effect on population growth. Indeed, lower per capita income leads to later marriage and fewer births (i.e., preventive checks), which explains the upward-sloping birth schedule b_t in Figure 1. However, lower per capita income also leads to poor nutrition and a higher death rate (i.e., positive checks), which explains the downward-sloping death schedule d_t in Figure 1. The intersection of the birth and death schedules E_0 determines the equilibrium per capita income y_0^*, which is defined as the level of per capita income at which the population level remains constant over time. [1] Hence, the factors that potentially affect the position of the birth and/or death schedules can explain regional per capita income differences in the Malthusian era, which is evident from Figure1.

In this paper, we focus on the factors that affect the position of the birth schedules and argue that a larger productivity improvement in the skilled intensive commercial sector relative to the improvement

[1] When $y_t > y_0^*$, the birth rate momentarily exceeds the death rate, and thus, the population starts to increase; furthermore, with diminishing returns to labor in production, this pattern gradually decreases the level of per capita income. Similarly, when $y_t < y_0^*$, the death rate exceeds the birth rate, the population begins to shrink, and the level of per capita income gradually rises.

in the unskilled intensive agricultural sector induces downward shifts of the birth schedule by enhancing the child quantity-quality transition, which leads to the higher equilibrium per capita income that is depicted in Figure 1. Furthermore, we show that a proportional productivity improvement in both the commercial sector and the agricultural sector has no effect on the birth and death schedules, and thus, this improvement has no effect on the equilibrium per capita income.

This paper shares many research interests with recent literature that attempts to predict the determinants of per capita income in a Malthusian equilibrium (e.g., Voigtländer and Voth, 2009, 2010a, 2010b, Ashraf and Galor, 2011, Sharp et al., 2011, and Vollrath, 2011). In particular, Voigtländer and Voth (2010b), Sharp et al. (2011) and Vollrath (2011) are closely related to our research because they also focus on the factors that affect the position of the birth schedule in the preindustrial era. Voigtländer and Voth (2010b) argue that the positive shock to incomes after the Black Death increased the demand for pastoral products (e.g., meat, cheese and wool) in Europe, which led to the shift of agricultural production from crops to livestock. This positive demand shock for pastoral products expanded the employment opportunities of unmarried woman as servants, increased their opportunity costs of childrearing, laid the foundations for the European Marriage Pattern that was characterized by a high average age of marriage and a high female celibacy rate, and induced the downward shift of the birth schedule in Europe. Furthermore, Sharp et al. (2011) and Vollrath (2011) argue that a shift in the price of foods, and therefore, of children relative to the price of other goods plays a critical role in determining the position of the birth schedule. Sharp et al. (2011) state that higher industrial productivity increased the relative price of food, increased the costs of raising children, and induced a downward shift of the birth schedule. Instead, Vollrath (2011) states that the lower labor intensity of wheat production in Europe relative to rice production in Asia decreased the share of labor in agriculture, increased the relative price of food, increased the costs of raising children, and induced the downward shift of the birth schedule in Europe. As depicted in Figure 1, these downward shifts of the birth schedule in Europe led to a higher per capita income in Europe relative to the corresponding income in Asia in the preindustrial era.

In contrast, Clark (2007) and Voigtländer and Voth (2010a) focus on the factors that affect the position of the death schedule in the preindustrial era. For example, Voigtländer and Voth (2010a) argue that European wars and the sharp rise in European urbanization enhanced the spread of infectious diseases, raised European mortality, and induced the upward shift of the death schedule in Europe. Hence, as inferred from Figure 1, this upward shift in the European death schedule led to the higher per capita income in Europe relative to the corresponding income in Asia in the preindustrial era.

These existing Malthusian models show several very convincing factors that explain regional per capita income differences in the preindustrial era. However, none of these studies have examined how the expansion of the commercial sector and the corresponding child quality-quantity transition affect per capita income in the Malthusian equilibrium. Therefore, this paper offers a complementary approach to understanding per capita income variations across the Malthusian World.

Moreover, this paper is also closely related to Galor and Mountford (2006, 2008). Galor and Mountford (2006, 2008) argue that the expansion of international trade in the second phase of the industrial revolution enhanced the specialization of industrial economies in the production of industrial, skilled intensive goods. The associated rise in the demand for skilled labor has induced a gradual investment in the quality of the population, which has expedited a demographic transition, stimulated technological progress and further enhanced the comparative advantage of these industrial economies in the production of skilled intensive goods. In contrast, in non-industrial economies, international trade has generated an incentive to specialize in the production of unskilled intensive, non-industrial goods. The absence of a significant demand for human capital has provided limited incentives to invest in the quality of the population and the gains from trade have been utilized primarily to further increase the size of the population rather than increase the income of the existing population. Therefore, the historical patterns of international trade have reinforced the initial patterns of comparative advantage and generated a great divergence in income per capita across countries in the nineteenth and twentieth centuries.

Our paper's stress on the interactions between commercial development and the demographic transition is in accordance with the convincing arguments of Galor and Mountford (2006, 2008). However, differently from Galor and Mountford (2006, 2008), this paper employs a simple Malthusian model in accordance with Ashraf and Galor (2011), and we focus our analysis on the Malthusian equilibrium in the preindustrial era. In this sense, this paper complements Galor and Mountford (2006, 2008) by explicitly considering the effect of interactions between the commercial sector's development and the demographic transition on per capita income in the Malthusian World. [2]

[2]Furthermore, a link between commercialization and economic growth is stressed by Acemoglu et al. (2005) and Broadberry et al. (2012). Acemoglu et al. (2005) focus on the impact of Atlantic trade on institutions: growing trade strengthens the position of merchants in Northwestern Europe and enables them to impose effective constraints on the government's executive power; hence, growing trade contributes to the development of less extractive institutions. In addition, Broadberry et al. (2012) focus on the role of commercialization in raising wages as impersonal labor market transactions replace personalized customary relations. In the presence of an aggregate capital externality, the resulting shift in relative factor prices leads to higher capital intensity in the production technology, which results in a faster rate of technological progress.

3 The model

Consider an overlapping-generations economy in which economic activity extends over infinite discrete time. In every period t, a single homogenous good is produced by two sectors: the unskilled-labor-intensive agricultural sector and the skilled-labor-intensive commercial sector.

3.1 Production in the Agricultural and Commercial Sectors

In this paper, the agricultural sector is denoted by A, the commercial sector is denoted by C, the output produced in the agricultural sector in period t is denoted by $Y_{A,t}$, and the output produced in the commercial sector in period t is denoted by $Y_{C,t}$. The sectoral production technology is constant returns to scale using sector-specific fixed factors of production (e.g., the land and natural environments) and labor. Following Cervellati and Sunde (2005), for the sake of simplicity we restrict our attention to the extreme case in which every sector uses only one type of labor; that is, whereas the agricultural sector only employs unskilled labor, the commercial sector only employs skilled labor.

Then, the aggregate output in period t, or Y_t, is given by

$$
\begin{aligned}
Y_t &= Y_{A,t} + Y_{C,t}, \\
&= \Omega_A Z_A^{1-\beta} L_{u,t}^{\beta} + \Omega_C Z_C^{1-\beta} L_{s,t}^{\beta}, \\
&= \Omega_A L_{u,t}^{\beta} + \Omega_C L_{s,t}^{\beta},
\end{aligned} \tag{1}
$$

where $\beta \in (0,1)$.[3] Ω_i and Z_i denote the total factor productivity and sector-specific fixed factors of production in sector $i \in \{A, C\}$, and furthermore, $L_{u,t}$ and $L_{s,t}$ denote the aggregate levels of unskilled and skilled labor that are supplied in period t. Sector-specific fixed factors of production in the agricultural sector, which are denoted Z_A, include such factors as rural arable land and pasture, whereas sector-specific fixed factors of production in the commercial sector, which are denoted Z_C, include urban commercial land and fuel from woodland. To avoid unnecessary complication, we assume that both Z_A and Z_C are normalized to unity (i.e., we assume that $Z_i = 1$ for all $i \in \{A, C\}$). In the preindustrial economy, as stressed by Wringley (1900), the land was almost the exclusive source not only of food but also of the great bulk of the raw material and energy used in the non-agricultural sector. Nearly all of the motive power that drove production was conditioned by the universal dependence on organic sources, i.e., human and animal muscle supplemented by wind and water, where heat was provided by burning wood or charcoal (i.e., an organic economy). As Wrigley (1900) argues, "An organic economy, however

[3] Different productivity parameters β^A and β^C in the two sectors would not alter our qualitative results, but this extension would make it impossible to obtain a closed-form analytical solution.

advanced, was subject to negative feedback in the sense that the very process of growth set in train changes that made further growth additionally difficult because of the operations of declining marginal returns in production from the land." In this paper, to capture the essence of the organic economy in a simple way, we consider the situation where diminishing returns to labor in production prevail not only in the agricultural sector but also in the commercial sector due to sector-specific fixed factors.

Only workers with basic literacy, numeracy and knowledge of market transactions can work as skilled workers in the commercial sector. One of the distinctive features of the commercial sector is its dependency on the anonymous market or reliance on anonymous, impersonal relations rather than personalized customary relations. As formulated by Kumar and Matsusaka (2009), in general there are two forms of human/social capital that can be used to enforce contracts: local capital and market capital. Local capital takes the form of kinship, networks, patron-client relations, and in-depth knowledge about trading partners, which encompasses a variety of arrangements that are often labeled social capital. In contrast, market capital takes the form of knowledge about how to use third-party enforcement institutions such as courts, auditors, standardized accounting procedures, credit ratings, and commercial law. In this paper, we assume that basic literacy and numeracy are prerequisite for acquiring market capital and working in the commercial sector. Although this specification is clearly restrictive, it greatly eases the following analysis and captures one of the significant elements of the commercial sector.

Let $w_{s,t}$ denote the wage of skilled workers in the commercial sector, and let $w_{u,t}$ denote the wage of unskilled workers in the agricultural sector. Assuming perfectly competitive labor markets, profit maximization in the final good sector is consistent with the following conditions in the labor market:

$$w_{s,t} = \beta\Omega_C(L_{s,t})^{\beta-1}, \tag{2}$$

$$w_{u,t} = \beta\Omega_A(L_{u,t})^{\beta-1}. \tag{3}$$

Furthermore, the sum of the profits of each sector (the sum of the return on each sector's fixed specific factors) is given by

$$\pi_t = (1-\beta)\Omega_A L_{u,t}^{\beta} + (1-\beta)\Omega_C L_{s,t}^{\beta}. \tag{4}$$

Because this paper does not address landholding inequality issues, for simplicity we assume that all adult individuals hold equal amounts of each sector's specific fixed factors and share equally the sum of the profits of each sector.[4] Later, we explain this point briefly.

[4]This assumption does not alter our qualitative results.

3.2 Sector-biased productivity improvements

This paper addresses how sectoral differences in productivity improvement affect equilibrium outcomes. To examine this issue systematically, following Galor and Mountford (2008) and Weisdorf (2006) we assume that each sector's level of productivity, which is denoted Ω_i for $i \in \{A, C\}$, is affected by the overall level of technology Ω. However, the degree to which each sector's level of productivity Ω_i is affected by the overall level of technology Ω is not necessary the same. More specifically, we suppose that

$$\Omega_i = \theta_i \Omega^{\alpha_i}, \quad \alpha_i \in (0,1),\ \theta_i > 0,\ i \in \{A, C\} \tag{5}$$

where α_i expresses the degree to which each sector's level of productivity Ω_i is affected by the overall level of technology Ω. Under the specification in (5), the relation $\frac{\Omega_C}{\Omega_A} = \frac{\theta_C}{\theta_A}\Omega^{(\alpha_C - \alpha_A)}$ holds. Therefore, if $\alpha_C > \alpha_A$, the per-unit increase in the overall level of technology Ω leads to a larger productivity improvement in the commercial sector relative to the improvement in the agricultural sector. Similarly, if $\alpha_C < \alpha_A$, the per-unit increase in the overall level of technology Ω leads to a smaller productivity improvement in the commercial sector relative to the improvement in the agricultural sector. Moreover, if $\alpha_C = \alpha_A$, then the per-unit increase in the overall level of technology Ω leads to proportionate productivity improvements in both the commercial sector and the agricultural sector. In this sense, when $\alpha_C > \alpha_A$, the higher overall level of technology Ω generates commercial-sector-biased productivity improvement; when $\alpha_C < \alpha_A$, Ω generates agricultural-sector-biased productivity improvement; lastly, when $\alpha_C = \alpha_A$, Ω generates sector-neutral productivity improvement. In the following analysis, we rigorously examine the effect of the overall level of technology Ω on the equilibrium outcomes in each of the following cases: $\alpha_C > \alpha_A$, $\alpha_C < \alpha_A$ and $\alpha_C = \alpha_A$.

3.3 Households

The economy is populated by overlapping generations of individuals who live for two periods, childhood and adulthood. Children receive education, and adults can either be skilled or unskilled; their skill level depends on their education during their childhood. In the first period of life (childhood), people are supported and educated by their parents. Skilled offspring require larger investments from their parents to acquire basic literacy, numeracy and market capital. In the second period of life, adults are endowed with one unit of time of either skilled labor, which we denote s, or unskilled labor, which we denote u. Furthermore, adults inherit equal amounts of each sector-specific factor from their parents. In addition, adults inelastically supply their labor and receive wages as well as a rate of return from equally shared sector-specific factors, and furthermore, they decide on their consumption and the number and education of their children. In each period t, there is a continuum of adults of each type: $N_{u,t}$ is a measure of unskilled adults and $N_{s,t}$ is a measure of skilled adults. The total adult population N_t satisfies $N_t = N_{u,t} + N_{s,t}$.

As in Galor and Mountford (2006, 2008), individuals' preferences are defined over consumption and both the number and the potential wage income of their offspring. The preferences of a type i, $i = u, s$, of generation t (i.e., an individual who is born in period t-1) are represented by the utility function

$$U_{i,t} = (1-\gamma) ln c_{i,t} + \gamma ln[w_{u,t+1}(n^u_{i,t+1})^\sigma + w_{s,t+1}(n^s_{i,t+1})^\sigma], \quad \sigma \in (0,1), \tag{6}$$

where $c_{i,t}$ is consumption during adulthood, $n^u_{i,t+1}$ is the number of offspring who are trained to be unskilled workers, $n^s_{i,t+1}$ is the number of offspring who are trained to be skilled workers, and $w_{u,t+1}$ and $w_{s,t+1}$ are the wages paid to unskilled and skilled offspring in period $t+1$, respectively. We assume that whereas skilled adults can perform both skilled work and unskilled work, unskilled adults can only do unskilled work. Under this assumption, the skilled wage in the commercial sector cannot fall below the unskilled wage in the agricultural sector (i.e., $w_{s,t} \geq w_{u,t}$).

Individuals inherit equal amounts of each sector-specific factor from their parents, inelastically supply their labor, and generate an income $I_{i,t}$,

$$I_{i,t} = w_{i,t} + \frac{\pi_t}{N_t}, \quad i = u, s. \tag{7}$$

This income is composed of wage income $w_{i,t}$ and income from equally shared sector-specific factor holdings $\frac{\pi_t}{N_t}$. We denote the cost required to bring up a skilled offspring as $\frac{1}{\tau^s}$ and the cost required to bring up an unskilled offspring as $\frac{1}{\tau^u}$, where $0 < \tau^s < \tau^u$. Thus, the budget constraint of a type i of generation t, $i = u, s$, is

$$c_{i,t} + \frac{1}{\tau^u} n^u_{i,t+1} + \frac{1}{\tau^s} n^s_{i,t+1} = I_{i,t}, \quad i = u, s. \tag{8}$$

Given that $\tau^s < \tau^u$, skilled offspring are more expensive than unskilled offspring because parents have to send children to school or hire tutors to learn basic reading, writing, arithmetic skills, accounting, law, and other skills that comprise market capital. It is natural to assume that market capital is more expensive to acquire than local capital, which unskilled workers more intensively acquire. Whereas investment in market capital typically requires formal schooling with both a direct cost (tuition, books, etc.) and an indirect cost (because children are unable to work), local capital can be accumulated passively during time spent at home, possibly in household production.[5]

[5]For example, Kumar and Matsusaka (2009) state that local capital can be created through marriage alliances (for

Type i individuals of generation t choose c_{it}, $n^u_{i,t+1}$ and $n^s_{i,t+1}$ to maximize (6) subject to (7) and (8). An alternative way of formulating this problem is to imagine type i individuals as choosing a total education cost $E_{i,t}$ that they spend on raising offspring, that is, $E_{i,t} \equiv \frac{1}{\tau^u} n^u_{i,t+1} + \frac{1}{\tau^s} n^s_{i,t+1}$ and the fraction $f_{i,t+1}$ of this cost is what they spend on skilled offspring. Then, the number of offspring is given by $n^s_{i,t+1} = \tau^s f_{i,t+1} E_{i,t}$ and $n^u_{i,t+1} = \tau^u f_{i,t+1} E_{i,t}$. In this equivalent formulation, type i individuals of generation t choose E_{it} and $f_{i,t+1} \in [0,1]$ to maximize

$$U_{i,t} = (1-\gamma) ln(I_{i,t} - E_{i,t}) + \gamma ln[w_{u,t+1}(\tau^u)^\sigma (1-f_{i,t+1})^\sigma + w_{s,t+1}(\tau^s)^\sigma f^\sigma_{i,t+1}] + \gamma\sigma ln E_{i,t}, \quad i = u, s. \quad (9)$$

Then, the optimal consumption $c_{i,t}$, the expenditure for children $E_{i,t}$, the expenditure share for skilled offspring $f_{i,t+1}$, the number of skilled offspring $n^s_{i,t+1}$, the number of unskilled offspring $n^u_{i,t+1}$ and the total number of offspring per household $n_{i,t+1}$, are as follows:

$$c_{i,t} = \frac{1-\gamma}{1-\gamma+\gamma\sigma} I_{i,t}, \quad i = u, s, \quad (10)$$

$$E_{i,t} = \frac{\gamma\sigma}{1-\gamma+\gamma\sigma} I_{i,t}, \quad i = u, s, \quad (11)$$

$$f_{i,t+1} = f_{t+1} = \frac{\omega_{t+1}^{\frac{1}{1-\sigma}} (\frac{\tau^s}{\tau^u})^{\frac{\sigma}{1-\sigma}}}{1 + \omega_{t+1}^{\frac{1}{1-\sigma}} (\frac{\tau^s}{\tau^u})^{\frac{\sigma}{1-\sigma}}} \equiv f(\omega_{t+1}), \quad i = u, s, \quad (12)$$

$$n^u_{i,t+1} = \tau^u (1-f_{t+1}) E_{i,t}, \quad i = u, s, \quad (13)$$

$$n^s_{i,t+1} = \tau^s f_{t+1} E_{i,t}, \quad i = u, s, \quad (14)$$

$$n_{i,t+1} = n^u_{i,t+1} + n^s_{i,t+1} = [\tau^u (1-f_{t+1}) + \tau^s f_{t+1}] E_{i,t}, \quad i = u, s, \quad (15)$$

where $\omega_{t+1} \equiv \frac{w_{s,t+1}}{w_{u,t+1}}$. Here, ω_{t+1} denotes the skilled premium in period $t+1$ or wage differentials between the commercial sector and the agricultural sector in period $t+1$. From (12), the expenditure share for skilled offspring becomes constant across different skill-type parents because it only depends on market variables such as τ^s, τ^u and ω_{t+1}. In addition, the skill premium in period $t+1$, which we denote ω_{t+1}, positively affects the expenditure share for skilled offspring in period t, or f_{t+1}. To stress this fact, we describe f_{t+1} as $f(\omega_{t+1})$, which satisfies the following properties: $\frac{\partial f_t}{\partial \omega_{t+1}} = \frac{f_{t+1}(1-f_{t+1})}{(1-\sigma)\omega_{t+1}} > 0$, $\lim_{\omega_{t+1} \to 1} f(\omega_{t+1}) = \frac{(\frac{\tau^s}{\tau^u})^{\frac{\sigma}{1-\sigma}}}{1+(\frac{\tau^s}{\tau^u})^{\frac{\sigma}{1-\sigma}}} \equiv \underline{f}$ and $\lim_{\omega_{t+1} \to \infty} f(\omega_{t+1}) = \infty$. Thus, from equations (13) to (15) and because $\tau^s < \tau^u$, the higher skill premium in period $t+1$, which we denote ω_{t+1}, ceteris paribus leads to a higher share of skilled offspring and a lower total number of children per household $n_{i,t+1}$. Therefore, the higher expected skill premium in period $t+1$ or the wage differentials between the commercial sector

example, in parts of rural India it was a longstanding custom for a man to marry his niece) and giving gifts (which anthropological studies indicate is an important expenditure in many local economies).

and the rural agricultural sector in period $t+1$ (or ω_{t+1}) leads to a child quantity-quality transition in period t.

Moreover, because $w_{s,t} \geq w_{u,t}$, from (11) and (15) we can see that the relation $n_{s,t+1} \geq n_{u,t+1}$ holds due to $I_{s,t} \geq I_{u,t}$. This result indicates that skilled parents have larger numbers of (surviving) offspring than unskilled parents. This theoretical result is consistent with Clark's (2007) finding in preindustrial England that the rich (high status and high-income occupations) had more surviving children than the poor (low status and low-income occupations). Allen (2008) also points out that reproductive success among the rich can be observed not only in England, but also in countries such as South Germany, Austria, France, Sweden, Switzerland, and China.

As in Foreman-Peck (2011), we can interpret the above household decision problem as the joint fertility and marriage decision problem of unmarried couples. In the absence of effective contraception and given a strong stigmatization of premarital sex, delayed marriage was one of the effective ways for couples to reduce childbearing in preindustrial periods (see De Moor and van Zanden, 2009).

3.4 Population structure

The total number of adults in period $t+1$, which we denote N_{t+1}, must be equal to the total number of offspring at the end of period t: $N_{t+1} = \sum_{i=u,s} n_{i,t+1} N_{i,t}$. Using equations (2) to (4), (7), (11) and (15), this law of motion of population can be rewritten as follows:

$$\begin{aligned} N_{t+1} &= \sum_{i=u,s} n_{i,t+1} N_{i,t}, \\ &= [\tau^u(1-f_{t+1}) + \tau^s f_{t+1}] \sum_{i=u,s} E_{i,t} N_{i,t}, \\ &= \frac{\gamma\sigma}{1-\gamma+\gamma\sigma} [\tau^u(1-f_{t+1}) + \tau^s f_{t+1}] Y_t. \end{aligned} \tag{16}$$

Analogously, we can express the number of unskilled adults in period $t+1$ ($N_{u,t+1}$) and the number of skilled adults in period $t+1$ ($N_{s,t+1}$) as follows.

$$N_{u,t+1} = \frac{\gamma\sigma}{1-\gamma+\gamma\sigma} \tau^u (1-f_{t+1}) Y_t, \tag{17}$$

$$N_{s,t+1} = \frac{\gamma\sigma}{1-\gamma+\gamma\sigma} \tau^s f_{t+1} Y_t. \tag{18}$$

3.5 The equilibrium skill premium

In the following analysis, to avoid unnecessary lexicographic explanations, we focus our analysis on the case where the equilibrium wage of skilled workers in the commercial sector is strictly higher than the equilibrium wage of unskilled workers in the agricultural sector (i.e., the case in which $w_{s,t} > w_{u,t}$), and all skilled adults can work as skilled workers in the commercial sector. Therefore, in equilibrium the following labor-market-clearing conditions hold:

$$L_{u,t} = N_{u,t}, \tag{19}$$

$$L_{s,t} = N_{s,t}. \tag{20}$$

As we will briefly discuss, the above equilibrium conditions hold when the productivity of the urban commercial sector Ω_C (or the cost of raising skilled offspring $\frac{1}{\tau^s}$) is sufficiently high to satisfy the following inequality:

$$\Omega_C > (\frac{\tau^s}{\tau^u})^{\frac{1-\beta}{1-\sigma}}\Omega_A \Leftrightarrow \theta_C > (\frac{\tau^s}{\tau^u})^{\frac{1-\beta}{1-\sigma}}\Omega^{-(\alpha_C-\alpha_A)}\theta_A. \tag{21}$$

The second inequality in (21) can be verified by substituting (5) into the first inequality in (21). We assume that above parameters' conditions hold in the following analysis.

Under the assumptions in (21), by substituting equations (5) and (17) to (20) into (2) and (3) and rearranging the result, we can express the equilibrium skill premium in period t or the wage differentials between the commercial sector and the agricultural sector in period t, which we denote by ω_t, as a function of Ω. That is, $\omega_t = \omega(\Omega)$, which is implicitly defined by the following equation:

$$\Lambda(\omega_t;\Omega) \equiv \omega_t - \frac{\theta_C}{\theta_A}\Omega^{(\alpha_C-\alpha_A)}(\frac{\tau^u}{\tau^s})^{1-\beta}[\frac{1-f(\omega_t)}{f(\omega_t)}]^{1-\beta} = 0. \tag{22}$$

This paper addresses how sectoral differences in productivity improvement affect equilibrium outcomes. To investigate this issue, the parameter Ω is highlighted explicitly. As depicted in Figure 2, under the assumptions in (21), ω_t is determined uniquely in the region where the relations $\omega_t > 1$ and $w_{s,t} > w_{u,t}$ hold. Furthermore, from (12) and (22) we can confirm that $\omega(\Omega)$ satisfies the following properties:

$$\frac{\partial\omega(\Omega)}{\partial\Omega} = \frac{\omega_t}{\Omega}\frac{(1-\sigma)(\alpha_C-\alpha_A)}{1-\sigma+1-\beta}\begin{cases} >0, & \text{if } \alpha_C > \alpha_A, \\ =0, & \text{if } \alpha_C = \alpha_A, \\ <0, & \text{if } \alpha_C < \alpha_A. \end{cases}$$

As depicted in Figure 2 (i.e., $\Omega' > \Omega$), when $\alpha_C > \alpha_A$, the higher overall level of technology Ω generates commercial-sector-biased productivity improvement, which leads to a higher skill premium. Similarly, when $\alpha_C < \alpha_A$, the higher overall level of technology Ω generates agricultural-sector-biased productivity improvement, which leads to a lower skill premium. However, when $\alpha_C = \alpha_A$, the higher overall level of technology Ω generates sector-neutral productivity improvement, which has no effect on the skill premium.

Furthermore, by substituting $\omega(\Omega)$ into (12), we can express the expenditure share for skilled offspring f_t as a function of Ω.

$$f_t = \frac{[\omega(\Omega)]^{\frac{1}{1-\sigma}}(\frac{\tau^s}{\tau^u})^{\frac{\sigma}{1-\sigma}}}{1+[\omega(\Omega)]^{\frac{1}{1-\sigma}}(\frac{\tau^s}{\tau^u})^{\frac{\sigma}{1-\sigma}}} \equiv f(\Omega). \tag{23}$$

From (23), we can confirm that $f(\Omega)$ satisfies the following properties:

$$\frac{\partial f(\Omega)}{\partial \Omega} = \frac{f_t(1-f_t)}{\Omega}\frac{\alpha_C - \alpha_A}{1-\sigma+1-\beta}\begin{cases} > 0, & \text{if} \quad \alpha_C > \alpha_A, \\ = 0, & \text{if} \quad \alpha_C = \alpha_A, \\ < 0, & \text{if} \quad \alpha_C < \alpha_A. \end{cases}$$

When $\alpha_C > \alpha_A$, the higher overall level of technology Ω generates commercial-sector-biased productivity improvement, which leads to a higher expenditure share for skilled offspring. Similarly, when $\alpha_C < \alpha_A$, the higher overall level of technology Ω generates agricultural-sector-biased productivity improvement, which leads to a lower expenditure share for skilled offspring. However, when $\alpha_C = \alpha_A$, the higher overall level of technology Ω generates sector-neutral productivity improvement, which has no effect on the expenditure share of skilled offspring.

In summation, these results indicate that a larger productivity improvement in the commercial sector relative to the improvement in the agricultural sector leads to higher skill premiums, a higher share of skilled offspring, and lower total numbers of children per household. However, the proportional productivity improvement in both the commercial sector and the agricultural sector has no direct effect on skill premiums, the share of skilled offspring, and the total numbers of children per household.

4 The evolution of the economy

4.1 Population dynamics

By substituting equations (5), (17) to (20) and (23) into (16), we obtain that the time path of the adult population is governed by the following first-order difference equation:

$$\begin{aligned} N_{t+1} &= \Upsilon(\Omega) y_t N_t, \\ &= \Upsilon(\Omega)\Gamma(\Omega) N_t^{\beta} \equiv \Phi(N_t; \Omega), \end{aligned} \tag{24}$$

where

$$y_t \equiv \frac{Y_t}{N_t} = \Gamma(\Omega) N_t^{\beta-1},$$

$$\Upsilon(\Omega) \equiv \frac{\gamma\sigma}{1-\gamma+\gamma\sigma}[\tau^u(1-f(\Omega)) + \tau^s f(\Omega)],$$

$$\Gamma(\Omega) \equiv \theta_C \Omega^{\alpha_C} f(\Omega)^{\beta} + \theta_A \Omega^{\alpha_A}(1-f(\Omega))^{\beta}.$$

Here, y_t denotes the average per capita income in period t, which positively affects the population growth rate. The term $\Upsilon(\Omega)$ captures how fertility decisions of generation t change in response to changes in Ω in period $t+1$, and $\Gamma(\Omega)$ captures how the average per capita income in period t, which we denote y_t, changes in response to a change in Ω in period t with fully taking into accounts of the effect of Ω on the labor allocations in period t.

Then, $\Upsilon(\Omega)$ satisfies the following properties:

$$\frac{\partial \Upsilon(\Omega)}{\partial \Omega} = \underbrace{\frac{\gamma\sigma}{1-\gamma+\gamma\sigma}(\tau^s - \tau^u)}_{(-)} \frac{\partial f(\Omega)}{\partial \Omega} \begin{cases} < 0, & \text{if} \quad \alpha_C > \alpha_A, \\ = 0, & \text{if} \quad \alpha_C = \alpha_A, \\ > 0, & \text{if} \quad \alpha_C < \alpha_A. \end{cases}$$

When $\alpha_C > \alpha_A$, the sign of $\frac{\partial \Upsilon(\Omega)}{\partial \Omega}$ becomes negative because the inequality $\frac{\partial f(\Omega)}{\partial \Omega} > 0$ holds. The higher overall level of technology Ω generates commercial-sector-biased productivity improvement, which provides negative impacts on the population growth rate by inducing the child quantity-quality transition. Similarly, when $\alpha_C < \alpha_A$, the sign of $\frac{\partial \Upsilon(\Omega)}{\partial \Omega}$ becomes positive because the inequality $\frac{\partial f(\Omega)}{\partial \Omega} < 0$ holds. The higher overall level of technology Ω generates agricultural-sector-biased productivity improvement, which provides positive impacts on the population growth rate by retarding the child quantity-quality transition.

However, when $\alpha_C = \alpha_A$, the relation $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} = 0$ holds because the equation $\frac{\partial f(\Omega)}{\partial \Omega} = 0$ holds. The higher overall level of technology Ω generates sector-neutral productivity improvement, which has no impact on the population growth rate due to its neutral effects on the child quantity-quality transition.

Furthermore, $\Gamma(\Omega)$ satisfies the following properties:

$$\frac{\partial \Gamma(\Omega)}{\partial \Omega} = \underbrace{\frac{\Gamma(\Omega)}{\Omega}}_{(+)} \{ \underbrace{\alpha_C \phi_{C,t} + \alpha_A \phi_{A,t}}_{(+)} + \frac{\beta(\alpha_C - \alpha_A)(\phi_{C,t} - f_t)}{1-\sigma+1-\beta} \} \begin{cases} > 0, & \text{if} \quad \alpha_C > \alpha_A \quad \& \quad \phi_C(\Omega) \geq f(\Omega), \\ > 0, & \text{if} \quad \alpha_C = \alpha_A, \\ > 0, & \text{if} \quad \alpha_C < \alpha_A \quad \& \quad \phi_C(\Omega) \leq f(\Omega), \end{cases}$$

where

$$\phi_{C,t} = \phi_C(\Omega) \equiv \frac{\theta_C \Omega^{\alpha_C} f(\Omega)^\beta}{\theta_C \Omega^{\alpha_C} f(\Omega)^\beta + \theta_A \Omega^{\alpha_A}(1-f(\Omega))^\beta},$$

$$\phi_{A,t} = \phi_A(\Omega) \equiv \frac{\theta_A \Omega^{\alpha_A}(1-f(\Omega))^\beta}{\theta_C \Omega^{\alpha_C} f(\Omega)^\beta + \theta_A \Omega^{\alpha_A}(1-f(\Omega))^\beta}.$$

Here, $\phi_C(\Omega)$ and $\phi_A(\Omega)$ capture the production shares of the commercial sector and the agricultural sector, respectively, and satisfy $\sum \phi_{i,t} = 1$ for $i = \{A, C\}$.

When $\alpha_C = \alpha_A$, the sign of $\frac{\partial \Gamma(\Omega)}{\partial \Omega}$ becomes positive because the term $\frac{\beta(\alpha_C - \alpha_A)(\phi_{C,t} - f_t)}{1-\sigma+1-\beta}$ turns out to be zero. It indicates that the higher overall level of technology Ω and the corresponding sector-neutral productivity improvement positively affect the population growth rate by temporarily increasing the average per capita income y_t.

However, when $\alpha_C > \alpha_A$ or $\alpha_C < \alpha_A$, the sign of $\frac{\partial \Gamma(\Omega)}{\partial \Omega}$ is not determined because the sign of $\frac{\beta(\alpha_C - \alpha_A)(\phi_{C,t} - f_t)}{1-\sigma+1-\beta}$ is generally ambiguous. This ambiguity indicates that the effects of both the commercial and the agricultural sectors' biased productivity improvement on the population growth rate through changes in average per capita income y_t is generally ambiguous. However, when the inequality $\phi_C(\Omega) \geq f(\Omega)$ holds, we can confirm that the higher overall level of technology Ω and the corresponding commercial-sector-biased productivity improvement positively affects the population growth rate by temporarily increasing the average per capita income y_t. Similarly, when $\phi_C(\Omega) \leq f(\Omega)$, the higher overall level of technology Ω and the corresponding agricultural-sector-biased productivity improvement positively affects the population growth rate by temporarily increasing the average per capita income y_t.

From (24) (as depicted in Figure 3), because $\frac{\partial \Phi(N_t;\Omega)}{\partial N_t} > 0$ and $\frac{\partial^2 \Phi(N_t;\Omega)}{\partial N_t^2} < 0$, $\Phi(N_t;\Omega)$ is strictly concave in N_t and satisfies $\lim_{N_t \to 0} \Phi(N_t;\Omega) = 0$ and $\lim_{N_t \to \infty} \Phi(N_t;\Omega) = \infty$. Hence, for a given level of the technology parameter Ω, because $N_0 > 0$, there exists a unique, stable steady-state level of the adult population $\bar{N}$:

$$\bar{N} = [\Upsilon(\Omega)\Gamma(\Omega)]^{\frac{1}{1-\beta}} \equiv \bar{N}(\Omega). \tag{25}$$

Therefore, from (25) with respect to the effect of Ω on the steady-state adult population $\bar{N}$, we obtain the following comparative statics results.

$$\frac{\partial \bar{N}(\Omega)}{\partial \Omega} = \underbrace{\frac{\bar{N}}{(1-\beta)\Omega}}_{(+)}\left[\frac{\Omega_C}{\Upsilon}\frac{\partial \Upsilon(\Omega)}{\partial \Omega} + \frac{\Omega}{\Gamma}\frac{\partial \Gamma(\Omega)}{\partial \Omega}\right], \begin{cases} > 0, & \text{if } \ \alpha_C = \alpha_A, \\ > 0, & \text{if } \ \alpha_C < \alpha_A \ \ \& \ \ \phi_C(\Omega) \leq f(\Omega). \end{cases}$$

When $\alpha_C = \alpha_A$, the sign of $\frac{\partial \bar{N}(\Omega)}{\partial \Omega}$ becomes positive because the following relations hold: $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} = 0$ and $\frac{\partial \Gamma(\Omega)}{\partial \Omega} > 0$. As depicted in Figure 3 (i.e., $\Omega' > \Omega$), this positive sign indicates that the higher overall level of technology Ω and the corresponding sector-neutral productivity improvement leads to a higher steady-state adult population size $\bar{N}$ by temporarily increasing the average per capita income y_t.

However, when $\alpha_C > \alpha_A$, the sign of $\frac{\partial \bar{N}(\Omega)}{\partial \Omega}$ is not determined because the sign of $\frac{\partial \Gamma(\Omega)}{\partial \Omega}$ is generally ambiguous, while the inequality $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} < 0$ holds. This undetermined sign indicates that the effect of the commercial-sector-biased productivity improvement on the steady-state adult population size $\bar{N}$ is generally ambiguous. The intuition behind this result is as follows: whereas the commercial-sector-biased productivity improvement due to the rise in Ω negatively affects the population growth rate by enhancing the child quantity-quality transition (i.e., $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} < 0$), it may positively affect the population growth rate by raising the average per capita income y_t temporarily, in particular, when $\phi_C(\Omega) \geq f(\Omega)$ (i.e.$\frac{\partial \Gamma(\Omega)}{\partial \Omega} > 0$). Therefore, the overall effects of the commercial-sector-biased productivity improvement on the steady-state adult population size $\bar{N}$ are generally ambiguous and depend on the parameter values.

Moreover, when $\alpha_C < \alpha_A$, the sign of $\frac{\partial \bar{N}(\Omega)}{\partial \Omega}$ is not determined because the sign of $\frac{\partial \Gamma(\Omega)}{\partial \Omega}$ is generally ambiguous, while the inequality $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} > 0$ holds. This undetermined sign indicates that the effect of the agricultural-sector-biased productivity improvement on the steady-state adult population size $\bar{N}$ is generally ambiguous. The intuition behind this result is that whereas the agricultural-sector-biased productivity improvement due to the rise in Ω positively affects the population growth rate by retarding the child quantity-quality transition (i.e., $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} > 0$), it may possibly negatively affect the population growth rate by decreasing the average per capita income y_t temporarily (i.e., $\frac{\partial \Gamma(\Omega)}{\partial \Omega} < 0$). The range of parameter values that satisfy $\frac{\partial \Gamma(\Omega)}{\partial \Omega} < 0$ is quite small because the negative values of $\frac{\beta(\alpha_C - \alpha_A)(\phi_{C,t} - f_t)}{1-\sigma+1-\beta}$ must dominate the positive value of $\alpha_C \phi_{C,t} + \alpha_A \phi_{A,t}$. Nevertheless, we cannot rule out this possibility in the parameter regions where the relation $\phi_C(\Omega) > f(\Omega)$ holds. Therefore, the overall effects of the agricultural-sector-biased productivity improvement on the steady-state adult population size $\bar{N}$ are generally ambiguous and depend on the parameter values. However, when the inequality $\phi_C(\Omega) \leq f(\Omega)$ holds, we can confirm that the sign of $\frac{\partial \bar{N}(\Omega)}{\partial \Omega}$ is positive because the sign of $\frac{\partial \Gamma(\Omega)}{\partial \Omega}$ is also positive. Therefore, when the inequality $\phi_C(\Omega) \leq f(\Omega)$ holds, the higher overall level of technology Ω and the corresponding agricultural-sector-biased productivity improvement leads to a higher steady-state adult population size $\bar{N}$.

In summation, these results indicate that the proportional productivity improvement in both the commercial sector and the agricultural sector produces an average per capita income increase in the short run, and this increase generates a gradual increase in the population and leads to a larger steady-state population size. In contrast, the short-run effect of both the commercial and the agricultural sectors' biased productivity improvement on the average per capita income y_t is generally ambiguous. However, the properties of $\Gamma(\Omega)$ suggest that both commercial-sector-biased and agricultural-sector-biased productivity improvements produce an average per capita income increase in the short run under a wide range of plausible parameter values, and this increase positively affects the steady-state population size. However, the commercial-sector-biased productivity improvement induces the child quantity-quality transition, which negatively affects the population growth rate over time and relieves the demographic pressure of the economy. In contrast, agricultural-sector-biased productivity improvement retards the child quantity-quality transition, which positively affects the population growth rate over time and deteriorates the demographic pressure of the economy. Therefore, in the long run and ceteris paribus, commercial-sector-biased productivity improvement is more likely to generate a moderate increase or even a decline in the steady-state population size, whereas agricultural-sector-biased productivity improvement is more likely to generate a large increase in the steady-state population size.

4.2 The time path for the average per capita income

The evolution of the average per capita income y_t is determined by the initial level of average per capita income and the number of (surviving) children per adult. Specifically, due to equations (1), (5), (17) to (20), (23) and (24), the average per capita income in period $t+1$, or y_{t+1}, satisfies

$$\begin{aligned} y_{t+1} &= \Gamma(\Omega) N_{t+1}^{\beta-1}, \\ &= \Gamma(\Omega)(\Upsilon(\Omega) y_t N_t)^{\beta-1}, \\ &= \frac{{y_t}^{\beta}}{[\Upsilon(\Omega)]^{1-\beta}} \equiv \Psi(y_t; \Omega), \end{aligned} \tag{26}$$

which is depicted in Figure 4, as $\frac{\partial \Psi(y_t;\Omega)}{\partial y_t} > 0$ and $\frac{\partial^2 \Psi(y_t;\Omega)}{\partial y_t^2} < 0$, $\Psi(y_t;\Omega)$ is strictly concave and satisfies $\lim_{y_t \to 0} \Psi(y_t;\Omega) = 0$ and $\lim_{y_t \to \infty} \Psi(y_t;\Omega) = \infty$. Hence, for a given level of the technology parameter Ω, because $y_0 > 0$, there exists a unique, stable steady-state level of average per capita income $\bar{y}$:

$$\bar{y} = \frac{1}{\Upsilon(\Omega)} \equiv \bar{y}(\Omega). \tag{27}$$

Therefore, from (27), with respect to the effect of Ω on the steady-state average per capita income $\bar{y}$, we obtain the following comparative statics results.

$$\frac{\partial \bar{y}(\Omega)}{\partial \Omega} = -\frac{\bar{y}}{\Upsilon} \frac{\partial \Upsilon(\Omega)}{\partial \Omega} \begin{cases} > 0, & \text{if} \quad \alpha_C > \alpha_A, \\ = 0, & \text{if} \quad \alpha_C = \alpha_A, \\ < 0, & \text{if} \quad \alpha_C < \alpha_A. \end{cases}$$

When $\alpha_C = \alpha_A$, the relation $\frac{\partial \bar{y}(\Omega)}{\partial \Omega} = 0$ holds because the equation $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} = 0$ holds. This equation indicates that a higher overall level of technology Ω and a corresponding sector-neutral productivity improvement has no effect on the steady-state average per capita income $\bar{y}$. A sector-neutral productivity improvement produces an average per capita income increase in the short run. However, due to (24), this increase in average per capita income generates a gradual increase in the population. Therefore, in the long run, the average per capita income gradually declines due to diminishing returns from labor and reverts back to the original steady-state value.

However, when $\alpha_C > \alpha_A$, the sign of $\frac{\partial \bar{y}(\Omega)}{\partial \Omega}$ becomes positive because the inequality $\frac{\partial \Upsilon(\Omega)}{\partial \Omega} < 0$ holds. As Figure 4 (i.e., $\Omega' > \Omega$) demonstrates, this positive sign indicates that the higher overall level of technology Ω and the corresponding commercial-sector-biased productivity improvement leads to a higher steady-state average per capita income $\bar{y}$. This commercial-sector-biased productivity improvement enhances the child quantity-quality transition, which negatively affects the population growth over time; thus, this improvement relieves the demographic pressure of the economy. Therefore, in the long run the average per capita income becomes higher than the original steady-state value.

Moreover, when $\alpha_C < \alpha_A$, the sign of $\frac{\partial \bar{y}(\Omega)}{\partial \Omega}$ becomes negative because the inequality $\frac{\partial \bar{y}(\Omega)}{\partial \Omega} > 0$ holds. This negative sign indicates that the higher overall level of technology Ω and the corresponding agricultural-sector-biased productivity improvement leads to a lower steady-state average per capita income $\bar{y}$. Because the agricultural-sector-biased productivity improvement retards the child quantity-quality transition, which positively affects the population growth over time; thus, this improvement deteriorates the demographic pressure of the economy. Therefore, in the long run the average per capita income becomes lower than the original steady-state value.

By summarizing these results, we obtain the following proposition.

Proposition 1. *In the steady-state equilibrium, the following statements hold.*

1. *A proportional productivity improvement in both the commercial sector and the agricultural sector leads to a larger steady-state population size but has no effect on the steady-state average per capita income.*

2. *A larger productivity improvement in the commercial sector relative to the improvement in the agricultural sector has an ambiguous effect on the steady-state population size but has a positive effect on the steady-state average per capita income.*

3. *A larger productivity improvement in the agricultural sector relative to the improvement in the commercial sector has an ambiguous effect on the steady-state population size but has a negative effect on the steady-state average per capita income.*

Proposition 1 indicates that a larger productivity improvement in the skilled intensive commercial sector relative to the improvement in the unskilled intensive agricultural sector increases the demand for skilled labor with basic literacy, numeracy and knowledge of market transactions, enhances the child quantity-quality transition, and induces the emergence of an economy characterized by a high per capita income, a high literacy rate and a low-pressure demographic regime.[6] Hence, regional variations in the expansion of the commercial sector help explain regional per capita income differences in the Malthusian World.

5 Historical evidence: the emergence of Northwestern Europe as a leading economy in the early modern period

In this section, we combine several historical evidences with our theoretical results, which were presented in the previous section. Although we develop a simple and tractable model to capture the general features of a Malthusian equilibrium, our model may help to explain the historically observed facts of Northwestern Europe in the preindustrial era. From the late Middle Ages, Northwestern Europe (Britain and the Netherlands) was characterized by dramatic growth of the commercial sector, urbanization, high literacy rates, and a low-pressure demographic regime, and thus, this region developed very differently from the rest of Europe. Our theoretical results could partly explain the relevant experiences of Northwestern Europe in the preindustrial era. However, although we stress the importance of the interactions between the commercial sector's development and the regional demographic transition as a factor to explain the emergence of Northwestern Europe, it would be foolish to argue that it is the only factor. Our approach should be seen as complementary to the other factors that have already been proposed in the existing literature.

5.1 Growing commercialization and the rising demand for literacy

The regional variations in the expansion of the commercial sector within Europe can be most easily captured quantitatively by the share of the population that lives in urban areas, as towns were the centers of commerce. Table 1 provides data on the share of the population that lived in towns with at least 10,000 inhabitants. In Europe as a whole, the trend is upwards from 1400. However, the regional trends of urbanization show a pattern of divergence within Europe. In the late medieval period, north Italy and the Low Countries were two main urban centers of commerce. During the sixteenth century, due to the opening of new trade routes to Asia and the New World, there was a brief surge in Portugal and Spain, whereas urbanization stagnated in north Italy after 1500.[7] However, the most dramatic

[6]Our theoretical results do not contradict Ashraf and Galor's (2011) empirical findings that technological superiority and higher land productivity had significant positive effects on population density but insignificant effects on the standard of living during the time period 1-1500 CE. In our model, this prediction holds when both the commercial sector and the agricultural sector expand proportionally.

[7]Note that the opening of new trade routes to Asia and the New World undermined Venice's key role at the Mediterranean end of the Silk Road.

growth of urbanization in the early modern period occurred in the Netherlands during the sixteenth and seventeenth centuries and in England during the seventeenth and eighteenth centuries. Those countries displaced Portugal and Spain in long-distance trade and commercialized their domestic economies to an unprecedented extent.

The extent of commercialization and the expansion of the non-agricultural sector that accompanied it are also captured in Table 2 by the declining share of the labor force that was engaged in agriculture. The link between commercialization and the share of the labor force in agriculture has been advocated in the historical literature on proto-industrialization following the work of Mendels (1972), who perceived that commercialization led to the development of industry in the countryside before the industrial revolution. In 1500, the release of labor from agriculture had proceeded further in the Netherlands than in the rest of Europe. The Dutch economy relied increasingly on imports of basic agricultural products and paid for them with exports of higher value-added products (de Vries and van der Woude, 1997). After 1500, England was the most transformed country. By 1800, the fraction of the population in agriculture had dropped to 36 % and England was the most urbanized country in Europe. By the eve of the industrial revolution, agriculture's share of the labor force in England and the Netherlands was substantially lower than in the rest of Europe.

The expansion of the commercial sector increased the demand for labor with basic reading, writing, and arithmetic skills. For several European countries, it is possible to track developments in literacy as measured by the proportion of the population who could sign their names. Table 3 shows estimates of literacy in 1500 and in 1800. Although literacy rose everywhere in Europe, the growth was the greatest in Northwestern Europe. Allen (2011, p. 26) argues, "[T]he Reformation does not explain the rise, as is often assumed, for literacy was as high in northeastern France, Belgium, and the Rhine Valley–all Catholic areas–as in the Netherlands and England. The rise in literacy was due to the high wage, commercial economy." Therefore, Allen (2011, p. 26) concludes, "[T]he expansion of commerce and manufacturing increased the demand for education by making it economically valuable; at the same time, the high wage economy provided parents with the money to pay for schooling their children." The theoretical model presented in the previous section basically follows Allen's (2011) arguments.

5.2 Real consumption wages and per capita income

Table 4 sets out the pattern of the real consumption wages of European unskilled building laborers for the period 1300-1850, and London in the period 1500-49 is used as the numeraire. The silver wage is the silver content of the money wage in the local currency. The real consumption wage is obtained by dividing the silver wage by the silver price of basic consumption goods.

The real consumption wages rose substantially across the whole continent of Europe following the Black Death, which struck in the middle of the fourteenth century and wiped out between a third and a half of the population (Herlihy, 1997). Thus, this episode of European economic history is broadly consistent with the Malthusian model, and it shows a strong negative relationship between real wages and the population. In the first half of the fifteenth century, the real consumption wage was similar across Europe at approximately twice its pre-Black Death level. However, from the second half of the fifteenth century, Britain and the Netherlands followed a very different path from the rest of Europe; these two countries maintained their real consumption wages at the post-Black Death level, whereas the rest of the continent faced the collapse of real wages as population growth resumed.

Table 5 presents the results of the latest research on the reconstruction of national income during the late medieval and early modern periods in a number of countries; the results are summarized by Broadberry et al. (2012). The per capita GDP data show that Northwestern Europe began pulling ahead of the rest of Europe in the late sixteenth century. Thus, the national income data reinforce the conclusion that Britain and the Netherlands followed a different path from the rest of Europe. Considering that in the same period Britain and the Netherlands witnessed an increase in the level of urbanization, as noted above, we can argue that increasing demand for skilled labor and corresponding demographic changes may have contributed to the emergence of high per capita income in Northwestern Europe.

5.3 Low-pressure demographic regimes

Western European families practiced a unique and peculiar form of fertility limitation in the three or four centuries before the First World War (Hanjal, 1965, Foreman-Peck, 2011). Women did not marry when they became fertile, but at a markedly later age. Indeed, a woman's age upon her first marriage could be as high as 25 or 28. Additionally, a high percentage (up to 15 percent) never married (Voigtländer and Voth, 2009). Overall, the European marriage pattern (EMP) prevented between a quarter and half of all possible births (Clark, 2007). Fertility control in Northwestern Europe was particularly stringent. In Southern Europe, the EMP reduced fertility by less, and in Eastern Europe, the EMP did not exist. Table 6 shows the average female age of first marriage in several Western Europe countries during the seventeenth century; this age ranges from 24 to 27, and there are marked contrasts with Southern and

Eastern European countries with early marriage. Furthermore, Table 7 shows the relationship between the proportion of single women and the birth rate in 1900. A negative relationship between the proportion of single women and the birth rate still apparently holds despite alternative methods of fertility control. The great majority of women aged 20-24 were single in Northwestern Europe, whereas most were married in Southern and Eastern Europe. Wrigley et al. (1997) present a detailed quantitative picture of England during the seventeenth century and conclude that England was already controlling its fertility through late marriage; thus, England cannot be characterized as having been in a high-pressure Malthusian equilibrium (i.e., a low-pressure demographic regime) at that time.[8]

What caused Western Europeans to adopt this marriage pattern is still unclear and controversial (see Voigtländer and Voth, 2009, De Moor and van Zanden, 2010, Foreman-Peck 2011). In their recent survey, De Moor and van Zanden (2010) argue that the EMP was first centered in the Netherlands and England in the fifteenth century. At that time, Catholic ideology was emphasizing the importance of individual choice in marriage rather than arranged marriages. Individual searches for a partner required attaining at least the age of 18-20, whereas arranged marriages could be set up for younger persons. These ideas were given force through high wages and expanding employment opportunities in the post-Black Death period, especially in rapid commercializing Northwestern European regions, which allowed women to refuse marriage unless the terms were favorable. De Moor and van Zanden (2010) also note that growing commercialization motivated northern European parents to invest heavily in their children, who consequently achieved high literacy rates. This paper argues that a higher demand for skilled labor with basic literacy, numeracy and market capital due to growing commercialization leads to greater investment in children, later marriages, and a lower fertility rate, which supports the persistency of the EMP.

6 Concluding remarks

This paper constructed a simple Malthusian model to explain the per capita income differences in the Malthusian era by focusing on regional variations in the expansion of the commercial sector. In addition, this paper showed that a larger productivity improvement in the skilled intensive commercial sector relative to the improvement in the unskilled intensive agricultural sector leads to higher per capita income in the Malthusian steady-state equilibrium by enhancing the child quantity-quality transition.

[8] There is considerable uncertainty about the size of the pre-plague population in England. A slow recovery was not a universal feature of the Northwestern European experience, as the Netherlands experienced rapid population growth (Pamuk, 2007).

From the late Middle Ages, Northwestern Europe (Britain and the Netherlands) were characterized by widespread commercialization, rapid urbanization, high literacy rates, and low-pressure demographic regimes, and thus, they developed very differently from the rest of Europe. Our results are partly consistent with the experiences of Northwestern Europe in the preindustrial era.

Before concluding this paper, we mention several limitations of our research and briefly discuss directions for further research. First, we remark on the causes of commercial-sector expansions. In our theoretical model, the productivity level of each sector is exogenously given and the large productivity improvement in the commercial sector relative to the improvement in the agricultural sector leads to the expansion of the commercial sector. In the historical context, accurate estimates of sectoral differences in productivity rises are generally difficult. Moreover, the abstract definition of the commercial sector in our model makes accurate estimates of it problematic. Nevertheless, many historical evidences, narratives and arguments are at least consistent with the fact that Northwestern Europe experienced a large productivity rise in its commercial sector relative to the rise in its agricultural sector during preindustrial periods. However, the factors that generated this commercial sector's productivity rise are beyond the scope of this paper. Most historical arguments attribute the expansion of the commercial sector to the so-called first globalization. The newly invented full-rigged ships and the corresponding development of navigation techniques opened new trade routes, and as a result, Northwestern Europe displaced the Iberian powers in long-distance trade to Asia and the New World. Indeed, the English and Dutch trade with their colonies drove their economies forward, and hence, these countries' cities and export-oriented manufacturing grew, which led to the expansion of their commercial sectors. Therefore, following Galor and Mountford (2006, 2008), an explicit consideration of international trade factors is a promising direction for future research.

Second, we remark on the historical data on skill premiums. Table 8 shows the available skill premiums measured as the ratio of the daily wage of skilled craftsmen to the daily wage of unskilled construction workers, which are based on data collected by the International Scientific Committee on price history. From table 8, we cannot observe any secular trends or tendency that would indicate that skill premiums did rise monotonically in Northwestern Europe or that skill premiums in Northwestern Europe were higher than in the rest of Europe. This result is analogous to the criticism of Clark (2005) on unified growth theory that the skill premiums did not rise at the time of the industrial revolution, which Galor (2005) counters with the suggestion that although the demand for human capital was increasing, this demand was offset by an increase in the supply of human capital. In addition to Galor's (2005) suggestion, the measured wage premium of skilled craftsman in Table 8 may not accurately reflect the concept of our paper's skill premium because we defined skilled workers in a very abstract way (i.e., workers with basic literacy, numeracy and market capital). At a minimum, a much wider coverage of occupations with respect to wage data are necessary to estimate the skill premiums in a comparable way to our theoretical results. In this sense, the empirical plausibility of our theoretical results is still an open question, and additional empirical analysis is a promising direction for future research.

Third, this paper is restricted to a simple, analytical, solvable version of the Malthusian model and only focuses on the effect of sectoral differences in productivity improvement. This simplification enabled us to understand the general features of a Malthusian equilibrium. However, because our definition of the commercial sector is abstract and the availability of data is limited, it is difficult to calibrate and simulate our model with actual data in a convincing way. Therefore, constructing a more elaborate numerical version of our model that fully takes into account the interactions between commercial development and demographic change is a promising direction for future research.

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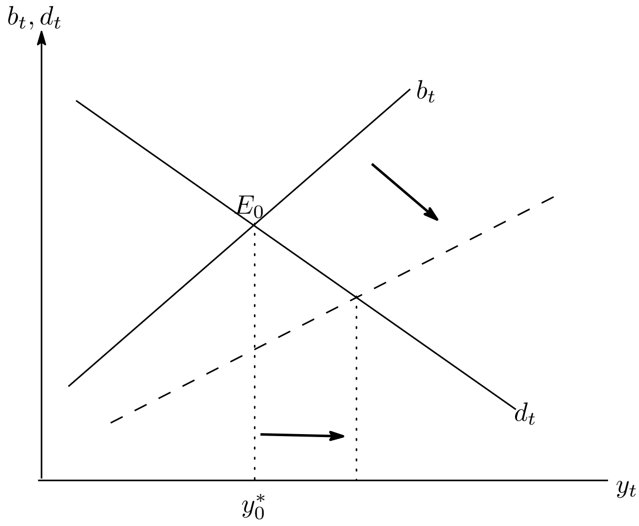

Figure 1: Determinants of per capita income and downward shifts of b_t

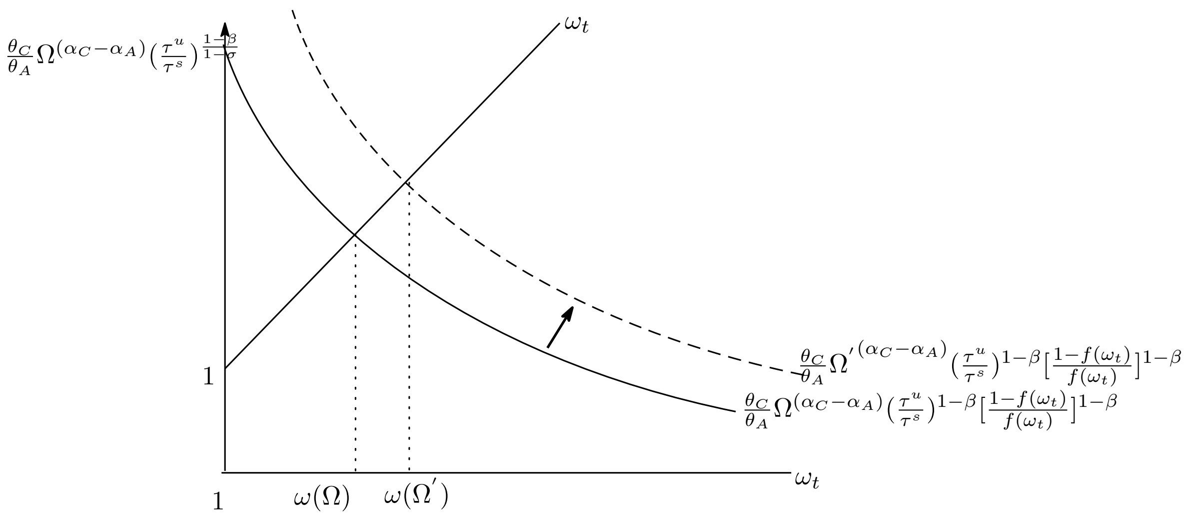

Figure 2: Equilibrium skill premium:$\Omega' > \Omega$ when $\alpha_C > \alpha_A$

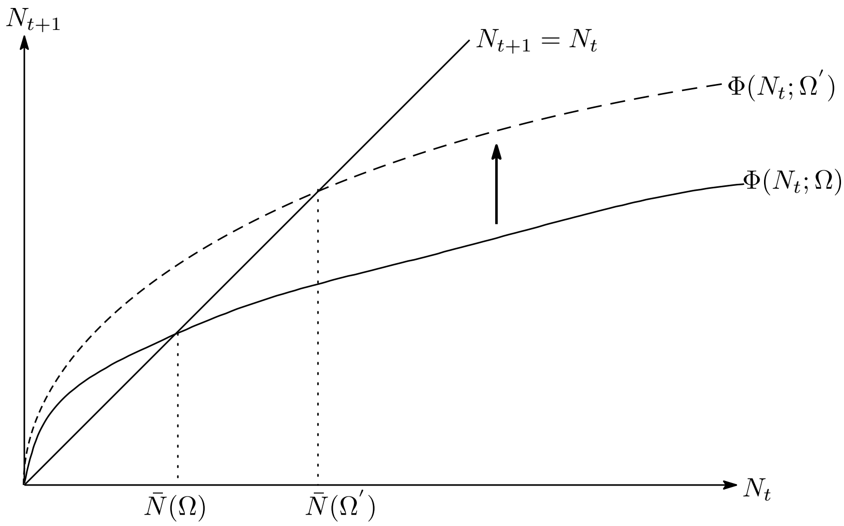

Figure 3: Evolution of population size:$\Omega^{'} > \Omega$ when $\alpha_C = \alpha_A$

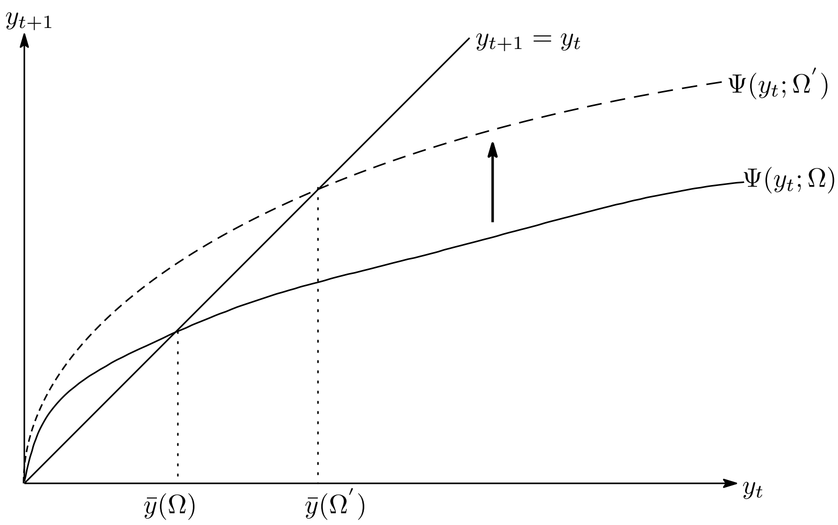

Figure 4: Evolution of income per capita:$\Omega^{'} > \Omega$ when $\alpha_C > \alpha_A$

Table 1: European urbanization rates (%)

	1300	1400	1500	1600	1700	1750	1800	1870
Northwestern Europe								
Scandinavia			0.7	2.1	4.3	4.6	4.6	5.5
England (Wales)	4.0	2.5	2.3	6.0	13.2	16.4	22.1	43.0
Scotland			2.3	1.5	5.3	11.5	23.9	36.3
Ireland	0.8	2.1		1.0	5.1	5.1	7.3	14.2
Netherlands			17.1	29.5	32.5	29.6	28.6	29.1
Belgium	18.2	21.9	17.6	15.1	20.2	16.5	16.6	25.0
France	5.2	4.7	5.0	6.3	8.7	8.7	8.9	18.1
Southern Europe								
Italy CN	18.0	12.4	16.4	14.4	13.0	13.6	14.2	13.4
Italy SI	9.4	3.3	12.7	18.6	16.1	19.4	21.0	26.4
Spain	12.1	10.2	11.4	14.5	9.6	9.1	14.7	16.4
Portugal	3.6	4.1	4.8	11.4	9.5	7.5	7.8	10.9
Central-Eastern Europe								
Switzerland	3.0	2.0	2.8	2.7	3.3	4.6	3.7	8.2
Austria (Czech, Hung)	0.6	0.5	0.8	1.6	1.7	2.6	3.1	7.7
Germany	3.4	3.9	5.0	4.4	5.4	5.7	6.1	17.0
Poland	1.0	1.3	5.4	6.6	3.8	3.4	4.1	7.8
Balkans	5.2	4.6	7.7	13.3	14.0	12.3	9.8	10.6
Russia (European)	2.1	2.3	2.0	2.2	2.1	2.5	3.6	6.7
EUROPE	5.4	4.3	5.6	7.3	8.2	8.0	8.8	15.0

Source: Malanima, P. (2009)

The urbanization rate is dened as the proportion of the population living in setlements of at least 10,000.

Table 2 Share of agriculture in the labour force (%)

	1300	1400	1500	1600	1700	1750	1800
England	76%	74%	73%	69%	55%	45%	36%
Netherlands			57%	49%	42%	42%	41%
Italy	63%	61%	62%	60%	59%	59%	58%
France		71%	73%	68%	63%	61%	59%
Ploland		76%	75%	67%	63%	59%	56%

Sorce: Allen, R.C. (2000)

Table3 Adult Literacy 1500, 1800 (%)

	1500	1800
Northwestern Europe		
England	6%	53%
Netherlands	10%	68%
Belgium	10%	49%
France	7%	37%
Southern Europe		
Italy	9%	22%
Spain	9%	20%
Central-Eastern Europe		
Germany	6%	35%
Austria/Hungary	6%	21%
Poland	6%	21%

Source: Allen, R. C., (2009)

Table 4: Daily real consumption wages of European unskilledbuilding labourers (London 1500-49 = 100)

	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800
Northwestern Europe											
London	57	75	107	113	100	85	80	96	110	99	98
Amsterdam					97	74	92	98	107	98	79
Antwerp			101	109	98	88	93	88	92	88	82
Paris					62	60	59	60	56	51	65
Southern Europe											
Valencia			108	103	79	63	62	53	51	41	
Madrid						56	51		58	42	
Florence/Milan	44	87	107	77	62	53	57	51	47	35	26
Naples					73	54	69		88	50	33
Central-Eastern Europe											
Gdansk					78	50	69	72	73	61	40
Warsaw						75	66	72	45	64	82
Krakow			92	73	67	74	65	67	58	63	40
Vienna			115	101	88	60	61	63	61	50	27
Leipzig						34	35	57	53	44	53
Augsburg					62	50	39	63	55	50	

Source: Broadberry, S.N. and B. Gupta, (2006),
derived from the database underlying Allen, R.C. (2001)

Table 5 GDP per capita levels (in 1990 international dollars)

	1250	1300	1350	1400	1450	1500	1550	1600	1650	1700	1750	1800	1850
Northwestern Europe													
England	737	730	767	1095	1172	1164	1138	1144	1215	1649	1688	2085	3006
Holland			876	1195	1373	1454	1432	2662	2691	2105	2355	2408	1886
Belgium						929	1089	1073	1203	1264	1357	1497	
France						727		841		986		1230	
Southern Europe													
Spain	1249	1249	1388	1145	1160	1160	1294	1219	1175	1145	1190	1249	1487
Italy		1482	1376	1601	1668	1403	1337	1244	1271	1350	1403	1244	1350
Central-Eastern Europe													
Germany						1332		894	1130	1068	1162	1140	1428
Poland						462		516		566		636	
Austria						707		837		993		1218	

Source: Netherlands: van Zanden and van Leeuwen (2011); France, Austria, Poland: Maddison (2003),
England: Broadberry et al. (2011).
Italy: Malanima (2011); Belgium: Buyst (2009), Blomme and van der Wee (1994); Germany: Pster (2009);
Spain: Álvarez-Nogal and Prados de la Escosura (2009)

Table 6: Age of marriage in seventeenth century Western Europe

	Average age of woman at First Marriage
England	25
France	24.6
Belgium	25
Germany	26.4
Scandinavia	26.7

Source: Flinn (1981).

Table 7 European fertility and proportion of woman single in 1900 (%)

	Birth rate	Percentage women aged 20–24 single	Percentage women aged 25–29 single
Northwestern Europe			
Great Britain	28.7	73	42
Netherlands	31.6	79	44
Belgium	28.9	71	41
France	21.3	58	30
Denmark	29.7	73	42
Finland	32.6	68	40
Sweden	27.0	80	52
Norway	29.7	77	48
Southern Europe			
Italy	33.0	60	30
Spain	33.9	55	26
Portugal	30.5	69	41
Central-Eastern Europe			
Switzerland	28.6	78	45
Austria	35.0	66	38
Hungary	39.4	36	15
Germany	35.6	71	34
Romania	38.8	20	8
Serbia	42.4	16	2
Russia	49.3	28	9
Bulgaria	42.3	24	3

Source: Foreman-Peck, J. (2011).

Table8 Skill premium (ratio of skilled wage to unskilled wage)

	1500-49	1550-99	1600-49	1650-99	1700-49	1750-99	1800-49
Northwestern Europe							
London	1.56	1.50	1.59	1.49	1.40	1.55	1.63
Southern England	1.68	1.50	1.49	1.50	1.49	1.52	1.51
Amsterdam	1.45	1.49	1.44	1.40	1.31	1.29	1.32
Antwerp	1.73	1.75	1.66	1.66	1.67	1.67	1.66
Paris	1.57	1.64	1.61	1.59	1.61	1.79	1.66
Southern Europe							
Valencia	1.55	1.29	1.19	1.49	1.51	1.49	
Madrid		1.98	2.51		2.27	2.02	2.06
Milan			1.78	1.95	1.91	1.86	2.00
Florence	1.83	1.97	2.26				
Naples	2.06	1.57	1.47		1.23	1.50	1.73
Central-Eastern Europe							
Gdansk	1.33	2.23	1.68	1.79	1.76	1.41	1.67
Warsaw		1.44	1.75	1.59	2.79	2.18	2.22
Krakow	2.00	1.79	1.24	1.41	1.50	1.31	2.17
Vienna	1.48	1.50	1.25	1.49	1.50	1.60	1.52
Leipzig		1.74	1.94	1.79	1.68	1.61	1.52
Augsburg	1.67	1.35	1.35	1.38	1.43	1.26	

Source Broadberry, S.N. and Gupta, B. (2006)