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Publication date:
2014

Document Version
Early version, also known as pre-print

Citation for published version (APA):

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Economic Growth and Migration∗

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The literature on growth theory lacks a precise sense of why there are interactions and dependencies between countries. Correspondingly, the spatial econometrics literature on growth empirics accounts for endogenous cross-country interactions, but lacks crucial insights from economic theory as to how such linkages should be precisely modeled. We address this weakness, by proposing a new economic model as a combination of an endogenous Romer-style growth model and a New Economic Geography model. The model admits two distinct sources of interactions between countries: mobility of high skilled workers and inter-country trade. Both of these sources develop from the New Economic Geography models, while the engine of the growth process is adapted from the endogenous growth literature. Motivated by higher wages, highly skilled workers migrate to the richer country, and there they work in the R&D sector. This in turn contributes towards economic growth in the richer country, and leads to divergence between the two countries. Trade in the manufactured good reduces the difference between the two countries but does not negate divergence. In its focus on both migration of highly skilled labour and its conclusion of divergence, the model captures the phenomenon of the Great Divergence in the 19th century. It is also consistent with evidence of club convergence in the 20th century. The implications of the model are verified by simulation.

Keywords: Economic growth; New Economic Geography; Cross-country interactions; Convergence; Migration; Trade.


∗Acknowledgement: We are grateful to many colleagues who have commented on this work, most notably Parantap Basu, Michael Ben-Gad, Atanas Christev, Leandro M. Magnusson, Stephen Millard, Charles Nolan, Robert Tamura and especially Mark Schaffer. The paper was presented at the Annual Conference 2014 of the Money, Macro and Finance Research Group. We thank to the participants at the conference for their valuable comments and suggestions. The usual disclaimer applies.

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1 Introduction

Corrado and Fingleton (2012) argue that the frequent criticism of the current growth empirics literature in spatial econometrics, that it lacks a link to economic theory, is misplaced. Specifically, in this literature spatial externalities arise from technological interdependence among countries, where knowledge accumulated in one country depends on knowledge accumulated in other countries. However, the specific patterns of spatial interactions and dependencies in empirical growth specifications are not theoretically founded: they are assumed to depend on geographic distances or trade. This is because a theory of why interactions between two countries matter for economic growth is largely missing.

This paper aims to close this gap by combining a Romer (1990) style endogenous growth model and a New Economic Geography model in the style of Krugman (1991). The interaction between countries is modeled in two ways. The first is the migration of high skilled workers and the second connection is trade of a manufactured good. The engine of growth draws upon the endogenous growth model and therefore the model predicts divergence. Both the migration largely of high-skilled workers and the prediction of divergence is in line with the Great Divergence in the 19th century. Equally, the model can relate to club divergence in current times.

Our two country model is based on three sectors in each country. The first, the R&D sector, uses high skilled workers and the existing stock of designs to produce new designs. Designs can be seen as patents or ideas to found new firms in the second sector, the manufacturing sector. Before these firms can start production, they need to buy exactly one design from the R&D sector. Low skilled labour and a fraction of high skilled workers is employed to produce a firm-specific differentiated manufactured good. The final sector, a traditional sector, uses solely unskilled labour to produce a homogeneous traditional good. This traditional good sector can be interpreted as a food producing agricultural sector.

The engine of growth is the R&D sector which accumulates designs. Designs are converted into new output enhancing firms. Therefore the number of designs represents the number of firms operating in the manufacturing sector. Different to Romer (1990), is the growth engine in this model is the varieties of goods produced by the manufacturing sector rather than the variety of intermediate goods (for example, machinery) which are transformed into one final homogeneous good. In line with the Romer model, a higher permanent growth rate can only be achieved by an increase in high skilled workers employed in the R&D sector. One country offers higher wages in the R&D sector, and this provides the incentive for high skilled workers to migrate.

Low skilled workers are immobile between countries but mobile between the two sectors, manufacturing and traditional. Some high skilled workers migrate to the higher wage offering country and contribute to the R&D sector there, allowing that country to grow faster. Corner solutions as well as interior solutions are possible. If the wage differential is very small, only a fraction of high skilled workers migrate. With an increase in the difference between wages, the interior solution moves towards the corner solution, in which all high skilled workers migrate at once.

In a sharp distinction from the literature, our model has two channels for interaction between countries: high skilled worker mobility and trade. Similar
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to the Romer (1990) model, our model predicts unbounded growth, an outcome which has important implications. The country which receives high skilled workers experiences unbounded growth, while in the case without trade the other country becomes stagnant, implying divergence. The divergence is moderated by trade. Simulations reveal that convergence in growth levels is possible, but there always remains a difference in income levels. Therefore the model explains the great divergence during the 19th century which was arguably driven by migration of high skilled workers. The model is also consistent with economic developments in the 20th century. At a broad level, it explains convergence clubs, even if the convergence or catch-up processes between countries within each club is not explicitly considered.

The difference in technological development between the beginning and the end of the 19th century is very vast. In the 19th century the “West” (Western Europe, US, Canada, Australia and New Zealand) started growing rapidly and left large parts of the world behind. Maddison (2007, p. 70-71) shows that the “West” experienced a growth rate of 1.07% between 1820 and 1870 and a rate of 1.56% between 1870 and 1913. GDP per capita increased from $1,202 to $3,988 between 1820 and 1913. The rest of the world remained nearly stagnant with growth rates of 0.1% and 0.86% between 1820 and 1870 and 1870 and 1913, respectively. Over the century (93 years) GDP per capita increased only from $667 to $1,526. Especially in these historical periods with little possibilities to distribute written knowledge, the only way to diffuse knowledge was movement of human capital, and hence high skilled migration was important. During the 19th century the first migration wave started. By the middle of the century, approximately 300,000 migrants dared to undertake the journey from Europe to the United States each year. The numbers rose until the end of the century to more than 500,000, and further to more than a million by the beginning of the 20th century (Williamson, 2006). Even within Europe there were large migration flows. About half of the Italian emigrants stayed in Europe, especially France and Germany, while 9 percent of the population in large British cities were Irish-born (Williamson, 2006).

The remainder of this paper is structured as follows. We review the literature in section 2, followed by the discussion of the model (section 3). Section 4 reports on a simulation of the model and finally section 5 concludes.

2 Literature

The literature on theories of economic growth and empirical studies of cross-country and regional growth are both vast and very diverse (Temple, 1999, 2003; Islam, 2003). While it is beyond the scope of the current paper to review this vast literature, we discuss selected contributions to the literature both as motivation for, and aid towards, developing our model in section 3.

1 Jewkes et al. (1961) provides a comprehensive overview of important inventions in the 19th century, such as the high pressure steam engine and combustion engine, innovations in the textile industry, telegraph and telephone, electric lamps, rubber and steel.


3 High skilled workers were not necessarily well educated. In the context of the 19th century, skill can be seen more as an ability to perform sophisticated jobs and to create ideas.
2.1 Growth Theory and Empirics

In discussing the determinants of long run growth, the literature has placed main emphasis on the factors of production and their exogenous accumulation (Solow, 1956; Mankiw et al., 1992; Islam, 1995). Together, the endogenous accumulation of factors of production has also been explored (Romer, 1990; Grossman and Helpman, 1994). Another question which was raised within this framework was: why is productivity so different across countries? Hall and Jones (1999) relate total factor productivity to social infrastructure, a description of institutions and government policies; see also Hall and Jones (1999, p. 84). Better social infrastructure improves capital accumulation, educational attainment and productivity and therefore boosts output per capita. Hall and Jones (1999) construct an index of social infrastructure and use as instruments the distance from the equator, the predicted trade share of an economy and the fraction of population with a Western European language as first language. Their finding is that the differences in the social infrastructure, especially with the distance from the equator as the favoured instrument, account for a large proportion of the differences in income across countries. Acemoglu et al. (2001) use a different measure of institutions, protection against expropriation, and instrument this with settler mortality. Their estimation leads to large effects of institutions on income per capita. In either case, an instrumental variable approach is necessary because there is potential for reverse causality in the relationship between institutions and economic growth; see Glaeser et al. (2004) and Acemoglu et al. (2005, 2012) and Albouy (2012) for further discussion. Better institutions may foster investments into human and physical capital what improves growth in income. On the other hand, higher human capital and income growth potentially aid the development of institutions.

The nature of institutions is closely related to geography. This justifies the approach in Acemoglu et al. (2001) of using a geography related instrument to account for the endogeneity of institutions. Spolaore and Wacziarg (2013) argue that the main channels of the geography effect are either directly on the factors of production or indirectly through history. Direct effects include climate and temperature (Sachs, 2001), while examples for the indirect effects are diseases (Acemoglu and Johnson, 2007), genetic distance (Spolaore and Wacziarg, 2009), and/or ancestral origin of the current population of a country (Putterman and Weil, 2010).

Also, trade is loosely connected to geography. Its impact on growth is undoubtedly, as shown in Frankel and Romer (1999) and in more recent work by Wacziarg and Welch (2007). Basu and Bhattachary (2012) relate trade to investments in human capital. They find that countries with a well educated population are more open to trade and experience higher growth rates.

Finally, in the context of this paper, there is another important question related to geography. Countries potentially interact with their neighbours, so the location of a country is crucial. As an example, for Mexico it is not only important to be located in North America with its distinct geographical factors, but being a neighbour to the US is essential as well. This issue has been addressed in the spatial econometrics literature by assuming that neighbouring countries have greater knowledge spillovers; see, for example, Fingleton and López-Bazo (2006) and Ertur and Kochi (2007). We turn to this literature next.

*English, French, German, Portuguese or Spanish; see Hall and Jones (1999, p. 100).
2.2 Growth Empirics and Spatial Econometrics

Within a growth model, channels for the effect of space on growth are mobility of the factors of production or technology. Koch (2008) takes space explicitly into account within a growth empirical setting, emphasizing in particular the importance of interdependence of the total factor productivity across countries. In his estimation of a spatial error model, factor productivity as captured by the error term not only depends on the country itself but on other countries’ productivity as well. The paper finds that if spatial effects are ignored, traditional results are biased. Similarly, Ertur and Koch (2007, 2011) show that spatial dependencies in TFP matters for a multi-country Schumpeterian growth as well as a Solow Growth model. Both models were augmented with technological interdependencies between countries.

Lesage and Fischer (2008) estimate a growth equation with a spatial Durbin model on data for 255 regions in 25 EU countries. Their findings are that characteristics of neighbouring regions, how the region is connected to its neighbours and the strength of this connection are more important than direct effects of the region itself. Fingleton and López-Bazo (2006) stress the importance of technological diffusion and pecuniary externalities for the long run growth of regions. In a recent paper, Ho et al. (2013) estimate a spatial lag model using a spatial weight matrix based on trade data. They find positive spillover effects of growth between countries, when such spillover is measured by bilateral trade. This relationship drives the rate of convergence to a higher level than in traditional models.

In summary, all papers in this literature have the common conclusion, that ignoring spatial effects such as endogenous spatial lags leads to biased and inconsistent estimates of empirical growth models. Therefore, the traditional results obtained in the literature so far are not valid and cannot as such be used to refute or accept any specific theory of growth. Additionally, spatial dependencies are included in the models. Spillovers are assumed to exist, but a theoretical justification as to why they should depend on geographic distance or trade is absent. Specifically, there is no clear sense from this literature as to why spillovers should be related to geographic distances, or indeed to other potential channels of cross-country linkage such as labour mobility (migration) or trade. This is the domain of the current paper.

2.3 New Economic Geography

New Economic Geography (NEG) models, initiated by Krugman (1991), provide a natural way to integrate space into theories of economic growth. The two-region two-sector model, standard in this literature, explains the concentration of skill intensive manufacturing firms in a region with respect to the consumption maximization behaviour of mobile, highly skilled workers. While the NEG models provide useful explanation for agglomeration, they do not have an explicit source or engine of growth, and are therefore not adequate for modelling the growth process in itself.

An extension of the NEG models are New Economic Geography and Growth (NEGG) models, such as Baldwin and Forslid (2000), Baldwin and Martin (2004) and Cerina and Pigliaru (2007). A capital accumulating sector is added to the economy and works as the engine of growth. However, from a growth
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theory perspective there are some drawbacks. First, the concept of capital is not clearly defined in the NEGG models. Baldwin and Martin (2004) describe immobile capital as human capital while mobile capital would be physical capital or patents. From a growth theory perspective, this ambiguity is problematic because there is considerable distinction between physical and human capital which is crucial for interpretation and policy.

Second, there is in these models no distinction between highly skilled workers and low skilled workers. This rules out the role of migration of high-skilled workers as a driver of cross-country interactions. Finally, the effect of geographical agglomeration on income growth lies at the core of these models, while economic growth is only a by-product of agglomeration. We will address these issues in developing our growth model in the section 3.

2.4 Migration

Migration and its impact on the host country as well as on the country of origin are widely discussed topics in economics, mainly in labour and development economics. By contrast with the existing literature, our work here focuses on the connection between high skilled migration and economic growth.

It is relatively obvious why high skilled migrants should have an effect on the income of the host country. Prominent anecdotal evidences are plenty. Consider, for example, Alexander Graham Bell who was born in Edinburgh (Scotland, U.K.) and migrated to the United States, where he founded the Bell Telephone Company. Marie Curie immigrated in 1891 from Poland to France, where she conducted her research on radioactivity. Further notable examples are Albert Einstein, Ludwig von Mises and Oskar Morgenstern, who all left their country of birth and developed their ideas to the benefit of their adopted countries. Likewise, many German rocket engineers migrated, partly forced, after the 2nd World War to the US and the USSR, where they played a key role in the construction of the first space rockets.

The above anecdotal evidence is supported by empirical work. Hornung (2014) analyzes the effect of well educated 18th century Huguenot immigrants into Prussia on productivity 100 years later and finds a positive long run effect. After the collapse of the Soviet Union, over 1,000 Soviet mathematicians migrated to other countries, with a large fraction settling in the United States. Borjas and Doran (2012) find that international differences in productivity can be explained by these migration flows. Likewise, Moser et al. (2014) study Jewish migration into US after the takeover of the NSDAP (Nationalsozialistische Deutsche Arbeiterpartei - National Socialist German Workers’ Party) in Germany. Their baseline estimates indicate that the arrival of German Jewish immigrants led to a 31 percent increase in innovation in the research fields of these emigres. Wadhwani et al. (2007) estimate that the contribution of non-US citizens to international patents increased from 7.3% in 1998 to 24.2% in 2006.
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According to Kerr (2013), immigrants represent 16% of the US workforce with a bachelors degree and they accounted for a majority of the increase in the Science, Technology, Engineering, and Mathematics workforce in the US since 1995. Thus, OECD (2011, p. 52) states: “In absolute numbers, highly skilled foreign-born individuals contribute heavily to the human capital endowments of regions in the United States, Canada and Australia.”

The above-mentioned examples underline the importance of highly skilled migrants to their host countries. Mobility of high skilled workers as a channel for interactions between countries is neglected in theoretical models of economic growth. At the same time the growth empirics literature assumes spillovers, mainly diffusion of knowledge, without providing adequate theory for how and why knowledge spreads. Interactions between countries are modeled in the New Economic Geography literature. However, these models either lack an engine of growth or are limited by a lack of richness in modelling physical and human capital.

3 A Growth Model with Mobile Labour

In this section, we develop our model of economic growth, as a combination of the endogenous growth model by Romer (1990) and models from the New Economic Geography literature, especially Krugman (1991), Baldwin and Martin (2004) and Forslid and Ottaviano (2003).

This is a two-country model. The economy in an index country $i$ consists of three sectors: a R&D, a manufacturing and a traditional goods sector. The R&D sector produces designs which are used by the manufacturing sector to found firms. Each firm in the manufacturing sector produces a unique heterogeneous good. Both the manufacturing sector and the traditional goods sector use unskilled labour, which is immobile, while the R&D sector employs highly skilled mobile labour.

Besides relying on the work of Romer (1990), the model lends emphasis to the importance of human capital for economic growth, a point stressed by Lucas (2009a,b). Our point of difference with the latter work is that this model does not include any diffusion of knowledge. Instead of diffusion, the spread of knowledge in this model is through migration, and thus by movements of highly skilled persons. The paper can be understood as emphasizing the importance of labour movements in the Lucas fashion and switching off diffusion of knowledge. Extensions to include knowledge diffusion lies in the domain to future work.

3.1 R&D Sector

The R&D sector in each country $i$ is oriented on Romer (1990), and produces designs under perfect competition. Input factors are the existing stock of designs $A_i$ and the number of highly skilled workers $H^R_i$. $\dot{A}_i$ is the number of new designs in country $i$ and produced according to

$$\dot{A}_i = \delta H^R_i A_i.$$  \hspace{1cm} (1)

The production function has two implications. First, a higher number of employees in the R&D sector implies a higher output of designs. Secondly, the designs
are accumulated and increase the productivity in future periods. Therefore there are two effects of an exogenous increase in the number of highly skilled workers, a growth effect and a level effect.

The firms in the R&D sector sell the designs at a price $p^A_i$ in a perfectly competitive market to the manufacturing firms. R&D firms pay the highly skilled workers their marginal product, $w^R_i = \delta A_i p^A_i$. Thus the profit equation of a R&D firm is:

$$\pi^A_i = p^A_i \hat{A}_i - w^R_i H^R_i.$$  

It is assumed that designs produced in one country remain within this country. This implies that there is no technology or knowledge diffusion. However, in the open economy case, the other country benefits from the availability of a higher variety of manufactured goods.

### 3.2 Manufacturing Sector

A firm in the manufacturing sector produces variety $s$ with a constant marginal product of unskilled labour. Before a firm can start producing, it has to buy exactly one design from the R&D sector at price $p^A_i$. This implies that in country $i$, there are exactly $A_i$ firms. Moreover each manufacturing firm requires a share $H^s_i = H_i \frac{\alpha_i}{\nu_i}$ of high skilled workers. These employees can be interpreted as administrative staff or managers required to run a firm. Each firm produces one unique intermediate good $x_i(s)$ with the following production function:

$$x_i(s) = \phi A_i L^s_i.$$  

$x_i(s)$ is decomposed into two parts. One part is sold in country $i$ and the rest exported to country $j$ with iceberg costs $\tau$. Thus the total amount of the manufactured good produced in country $i$ is $x_{ii}(s) + \tau x_{ij}(s)$. $\tau$ measures the number of units of the manufactured good that have to be produced in order to satisfy the foreign demand of one unit, implying $\tau \geq 1$. In the case of zero transportation costs $\tau$ equals 1. As trade costs increase to infinity, trade becomes so expensive such that any trade between the countries is precluded.

Denoting the wage for unskilled labour as $w^s_i$, the profit equation for a firm in country $i$ is:

$$\pi^s_i = p^s_{ii}(x_i(s)) + p^s_{ij}(x_{ij}(s)) - w^s_i L^s_i - w^H_i H^s_i - p^A_i.$$  

The cost function has two parts: variable costs of unskilled labour, $w^s_i L^s_i$, and fixed costs – the price of the design, $p^A_i$, and labour costs for the high skilled

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7 For simplicity, the marginal product of labour is assumed to be constant. The main advantage of this simplifying assumption is that the price does not depend on the quantity of $x_i$ and the level of technology. Therefore, computation of the price index $P_i$ becomes more straightforward. The assumption is in line with Forslid and Ottaviano (2003).

8 This assumption comes from the Romer model. In the NEG models, a fixed input requirement is included but this is not seen as a requirement for firm entry. Buying a second design would not improve the output of a firm. Therefore the manufacturing sector has increasing returns to scale.

9 The first subscript refers to the country of consumption, the second to the country where the product is produced. Thus $x_{ij}$ is produced in country $i$ and exported to or consumed in country $j$. Note that, by assumption the prices of $x_{ii}$ and $x_{jj}$ are the same in both countries, otherwise it would be possible that highly skilled migrants migrate due to a higher real income that is only due to lower prices. Such migration motives may not be very realistic.
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Since each firm produces a differentiated good, the market is characterized by monopolistic competition. Unskilled workers are paid the marginal product of labour in the traditional sector; \( w^T_i = \phi A_i \). Finally, to ensure that high skilled workers have no incentive to move from one sector to another, wages in the manufacturing and the R&D sector have to be equal, \( w^H_i = w^R_i = \delta A_i p^A_i \).

### 3.3 Traditional Goods Sector

The Traditional Goods sector uses unskilled labour \( L^T_i \) as an input and produces a homogeneous traditional good. For simplicity it is assumed that one input produces exactly one unit of output. Firms in the sector produce the good under perfect competition according to the following production function:

\[
T_i = L^T_i.
\]

The firms sell their product at a price \( p^T_i \) and pay wages \( w^T_i \). This forms the following profit equation:

\[
\pi^T_i = p^T_i T_i - w^T_i L^T_i. \tag{4}
\]

Since the competitive firms make no profits, the paid wage equals the price for the traditional good, \( w^T_i = p^T_i \). In equilibrium, unskilled labour is paid the same wage in both sectors to prevent workers moving from the traditional to the manufacturing sector or vice versa. This assumption quantifies the wage in the manufacturing sector to be: \( w^H_i = w^T_i = p^T_i \). Following standard NEG models the traditional good can be traded at no cost.

### 3.4 Consumers

The representative consumer in country \( i \) maximizes a Cobb-Douglas utility function with both goods:

\[
U_i = X^\mu_i T^\gamma_i \tag{5}
\]

with the composite \( X_i \)

\[
X_i = \left[ \int_0^{A_i} x_i(s)^{\frac{1}{\gamma}} ds + \int_0^{A_j} x_{ij}(s)^{\frac{1}{\gamma}} ds \right]^{\frac{1}{1-\gamma}}
\]

\[
= \left[ \int_0^{A_i+A_j} x_i^C(s)^{\frac{1}{\gamma}} ds \right]^{\frac{1}{1-\gamma}}
\]

\( \sigma > 1. \)

The choice of the varieties depends on a CES function, with \( \sigma \) denoting the elasticity of substitution between the different varieties. Each consumer faces the

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9

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10The wages of the high skilled workers is fixed in the R&D sector, and manufacturing firms take this as given.

11This assumption is also made in [Krugman (1991)] and [Forslid and Ottaviano (2003)].
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following budget constraint, which can be expressed by two different equations:

\[ Y_i = w^T_i L^T_i + w^x_i L^x_i + w^R_i H^R_i + w^H_i H^H_i \]  \hspace{1cm} (6)

\[ = p^T_i T_i + \int_{0}^{A_i} p_i(s) x_i(s) ds + \int_{0}^{A_j} p_j(s) x_j(s) ds \]  \hspace{1cm} (7)

\[ = p^T_i + P_i X_i. \]  \hspace{1cm} (8)

Eq. (6) is the income of the households from working and has to equal the spending of the household (Eq. (7) and (8)). Wages in the R&D sector are denoted by a superscript \( R \), while wages in the two other sectors are denoted by \( x \) for the manufacturing and \( T \) for the traditional goods sector. \( H_i \) is the supply of high skilled workers, including both domestic and migrant foreign workers. \( L_i = A_i L^x_i + L^T_i \) is the total supply of unskilled labour which is the sum of the two remaining sectors.

Further, households consume a subsistence level of the traditional good, \( T_i \geq T_i^{min} \), which can be interpreted as the necessary consumption of food. As mentioned before, high skilled workers are mobile; they can move from country \( j \) to country \( i \). They migrate if their income in the country of destination is higher compared to their home country. There is no motive for migration if the income in both countries is equal. Hence the total amount of high skilled workers in country \( i \) is:

\[ H_i = m_i(w_i^H, w_j^H) = (1 - m_{ij})L^H_i + m_{ij}L^H_j \]

\[ m_{ij} = \begin{cases} 
0, & \text{if } w_i^H \geq w_j^H \\
(0, 1], & \text{if } w_i^H < w_j^H 
\end{cases} \]

\[ m_{ji} = \begin{cases} 
0, & \text{if } w_j^H \geq w_i^H \\
(0, 1], & \text{if } w_j^H < w_i^H 
\end{cases} . \]

where \( m_{ij} \) is the fraction of high skilled workers (in country \( i \)) who migrate from country \( i \) to country \( j \). The same holds for country \( j \).

\[ H_j = m_j(w_i^H, w_j^H) = (1 - m_{ji})L^H_j + m_{ji}L^H_i . \]

There are two potential equilibrium outcomes. In the corner solution, all high skilled workers migrate to the country with higher wages, while in the interior solution only a fraction of the high skilled workers migrate. The interior solution implies that the wage differential between the two countries is relatively small. Migration will occur until either wages are equalized or all high skilled workers have migrated, which is again the corner solution. In the interior solution, the distribution of high skilled workers is more balanced and both countries grow.

3.5 The Growth Engine

In our model, the sole engine of growth is the R&D sector producing new designs. If a new design is invented (or produced), a new firm in the manufacturing sector can be founded. The importance of the designs to the manufacturing firms is similar to Romer (1990). In the context here, designs can be seen as patents or technologies which are used to produce a good. A firm buys the patent and has the right to produce and sell the product based exclusively on the patent, acting as a monopolist in the specific differentiated good. The number of designs
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increases the number of firms, making the R&D sector crucial for the growth process of an economy.

The growth of designs $\hat{A}_i$ depends on the number of highly skilled workers and the existing inventions. A higher number of highly skilled workers increases the number of new designs. Also, a large stock of designs increases the number of new designs. The first implication is that countries which are on the technology frontier have a higher production of new designs. Second, even though the firm in the R&D sector sells the design exclusively to one firm in the manufacturing sector, the research firm is allowed using it for the production of further designs.

Then, the growth rate of designs is:

$$\frac{\dot{A}_i}{A_i} = \delta H^R_i.$$  \hspace{1cm} (9)

Equation (9) implies that a permanent increase in the growth rate of designs is possible only with an increase in the number of highly skilled workers. Therefore the differentiation between the growth and the level effect is important. If the number of highly skilled workers increases from period $t - 1$ to $t$, the growth effect will be the increase in the growth rate of the designs at the end of period $t$, while the level effect will set in from period $t + 1$ in the form of a higher stock of designs $A_i$. The implication is that, two countries with the same number of persons employed in the R&D sector may have the same growth rate but may be at different number of designs (or technology) and thus income. This implies that the initial income level is determined by the initial level of technology. A country’s growth rate depends solely on the number of high skilled workers but not on the technology level.

Additionally the model implies that there is no catch up effect. Even though the country left behind will benefit from trade, immobility of ideas means that a technological catch up (or designs catch up) is ruled out. Finally, as in Romer (1990), our model predicts unbounded growth.

3.6 Closing the model

After the three sectors, the behaviour of the consumers and highly skilled workers are explained, the model is closed. It is assumed that the size of the skilled and unskilled labour force ($L^H_i$ and $L_i$) are predetermined and fixed. Within each period, the number of firms ($A_i$) is exogenous as well.

First, we derive the price index and quantities demanded by consumers. A two stage optimization of (5) with respect to (8), based on Dixit and Stiglitz (1977), leads to the following values for $x_{ii}(s), x_{jj}(s), x_{ij}(s)$ and $x_{ji}(s)$:

$$x_{ii}(s) = \frac{\sigma - 1}{\sigma} \left( \frac{Y_i}{R_i} - \frac{p_i^T T_i}{R_i} \right)$$  \hspace{1cm} (10)

$$x_{jj}(s) = \frac{\sigma - 1}{\sigma} \left( \frac{Y_j}{R_j} - \frac{p_j^T T_j}{R_j} \right)$$  \hspace{1cm} (11)

$$x_{ij}(s) = \tau^{-\sigma} \frac{\sigma - 1}{\sigma} \left( \frac{Y_i}{R_i} - \frac{p_i^T T_i}{R_i} \right)$$  \hspace{1cm} (12)

$$x_{ji}(s) = \tau^{-\sigma} \frac{\sigma - 1}{\sigma} \left( \frac{Y_j}{R_j} - \frac{p_j^T T_j}{R_j} \right)$$  \hspace{1cm} (13)
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with

\[ R_i = A_i + \tau^{1-\sigma} A_j \]

Demand for the good produced by the traditional goods sector equals:

\[ T_i = \max \left( \frac{\gamma Y_i}{\mu + \gamma p_i}, T_i^{\min} \right) \] (14)

Next, we derive prices. The manufacturing firms maximize their profits using the inverse demand functions for the manufactured goods. Thus, they set the following prices for each good:

\[ p_{ii}(s) = p_{ii} = \frac{\sigma}{\sigma - 1}, \quad p_{ji}(s) = p_{ji} = \frac{\sigma}{\sigma - 1} \tau = p_{ii} \tau \]

In either case, the second equality holds because of symmetry in the production functions of the two countries. The goods price is independent of the quantity of the manufactured good or the technological level \( A_i \), depending only the elasticity of substitution between the different varieties. Moreover the price for each variety is the same.

Then, the price index for country \( i \) is:

\[ P_i = \left[ \int_0^{A_i} p_{ii}(s)^{1-\sigma} ds + \int_0^{A_j} p_{ij}(s)^{1-\sigma} ds \right]^{\frac{1}{1-\sigma}} \]

\[ = \frac{\sigma}{\sigma - 1} R_i^{1-\sigma}. \]

The price index falls with an increase in the number of domestic and foreign firms. In terms of workers, a larger R&D sector with a large output implies a falling price index.

In the following it is assumed that only the subsistence level of the traditional good is consumed, as implied by \( \gamma = 0 \) and \( \mu = 1 \).

Similar to [Romer (1990)], manufacturing firms make no profits because they bid for the design produced by the R&D sector. Therefore the price for a design is:

\[ \pi_i^x = p_{ii} x_{ii} + p_{ji} x_{ji} - w^x_i L_i^x - w^H_i H_i^x - p_i^A = 0 \]

\[ \Rightarrow p_i^A = \frac{p_{ii} x_{ii} + p_{ji} x_{ji} - w^x_i L_i^x}{1 + \delta \alpha H_i} = \frac{x_i}{(\sigma - 1) (1 + \delta \alpha H_i)} \]

\[ w_i^H = p_i^A \dot{A}_i = \delta A_i \frac{x_i}{(\sigma - 1) (1 + \delta \alpha H_i)}. \]

As the price for each variety is the same, all firms in the manufacturing sector produce the same quantity of the firm specific variety, implying \( x_i(s) = x_i = x_{ii} + \tau x_{ji} \). Thus, the price for the designs depends negatively on the number of high skilled workers residing in country \( i \). In addition to the adverse dependence of high skilled workers, the wage for the same depends positively on the number of designs. This rules out the possibility that the ordering of wages for high skilled workers in the two countries reverses. In other words, if country \( i \) has a higher wage and receives more high skilled workers in \( t \), the wage will be higher for all following periods.
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Under the assumption that all labour markets clear:

\[ H_i = A_iH_i^x + H_i^R \]
\[ L_i = A_iL_i^x + L_i^T \]

income can be expressed as:

\[ Y_i = \frac{\sigma R_i}{\sigma - 1} L_i + \left( p_i^T - \frac{\sigma R_i}{\sigma - 1} \right) T_i + \tau^{1-\sigma} \frac{R_i}{R_j} p_j^T T_j - \tau^{1-\sigma} \frac{R_i}{R_j} Y_j \]

or as:

\[ Y_i = \frac{1}{1 + \tau^{2(1-\sigma)}} \left( z_i - \tau^{1-\sigma} z_j \right) \]

with

\[ z_i = \frac{\sigma R_i}{\sigma - 1} L_i + \left( p_i^T - \frac{\sigma R_i}{\sigma - 1} \right) T_i + \tau^{1-\sigma} \frac{R_i}{R_j} p_j^T T_j. \]

Since \( \sigma > 1 \), as transportation costs increase to infinity, that is \( \tau \to \infty \), there is literally no trade and \( \tau^{1-\sigma} \to 0 \). Then, the price level only depends on the number of domestic designs (\( R_i = A_i \)) and the growth rate can be expressed as:

\[ \dot{Y}_i = \delta A_i \left( \frac{\sigma}{\sigma - 1} L_i - \left( \sigma (1-\sigma) \right) \frac{1}{A_i} \right) \]
\[ = \delta A_i \left( 1 - \frac{\alpha}{A_i} \right) = \delta \left( (1 - m_{ji}) L_j^H + m_{ij} L_i^H \right) \left( 1 - \frac{\alpha}{A_i} \right) . \]

Under autarky, the result is the same as Romer (1990). A higher growth rate is only obtained if the number of workers employed in the R&D sector increases.

3.7 High Skilled Worker Migration

High skilled workers migrate if the wage differential between the countries is positive.\(^{12}\) Since ordering of wages is preserved and high skilled workers are homogeneous, migration flows will be only in one direction. If migration is costless, migration will happen until wages are equalized:

\[ w_i^H = w_j^H \]
\[ \delta A_i \frac{x_i}{1 + \delta \alpha H_i} = \delta A_j \frac{x_j}{1 + \delta \alpha H_j}, \]
\[ \delta A_i \frac{x_i}{1 + \delta \alpha \left( [1 - m_{ij}] L_i^H + m_{ji} L_j^H \right)} = \delta A_j \frac{x_j}{1 + \delta \alpha \left( [1 - m_{ji}] L_j^H + m_{ij} L_i^H \right)}. \]

Since there are only labour movements from country \( j \) to \( i \) (implying \( m_{ji} > 0 \) and \( m_{ij} = 0 \)), labour movement becomes:

\[ m_{ji} = \frac{A_j^2 L_j^x \left( \frac{1}{\tau^{\alpha H}} + L_i^H \right) - A_i^2 L_i^x \left( \frac{1}{\tau^{\alpha H}} + L_j^H \right)}{L_j^H \left( \frac{1}{\tau^{\alpha H}} + A_j^2 L_j^x \right)}. \]  

\(^{12}\) Since the interior solution moves towards the corner solution if the wage differential is large, we discuss only the interior solution with a maximum of 1, which is the corner solution.
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There is no labour movement if the difference between the terms in the numerator equals zero. Assuming that the traditional sector requires a constant share of unskilled labour, the amount of unskilled labour in the manufacturing sectors, \( L_i^u \) and \( L_j^u \), remains constant. As the model does not include any population growth, the total number of high skilled workers across the two countries is constant as well. Therefore, labour mobility depends solely on the stock of varieties or the number of firms. Migration increases with an increase in the difference of the number of firms between the two countries. Thus, in terms of the model, the larger country attracts more high skilled workers. Migration flows are positive as \( A_i > A_j \) implies \( w_i^A > w_j^A \).

Migration can be then summarized as

\[
\begin{align*}
    m_{ji} &= \begin{cases} 
        \min \left( \frac{A_i^2 L_i^u \left( \frac{1}{w_i^L} + L_i^H \right) - A_j^2 L_j^u \left( \frac{1}{w_j^L} + L_j^H \right)}{L_i^H \left( A_i^2 L_i^u + A_j^2 L_j^u \right)}, 1 \right), & \text{if } w_i^H > w_j^H \\
        0, & \text{if } w_i^H \leq w_j^H 
    \end{cases} \\
    m_{ij} &= \begin{cases} 
        \min \left( \frac{A_j^2 L_j^u \left( \frac{1}{w_j^L} + L_j^H \right) - A_i^2 L_i^u \left( \frac{1}{w_i^L} + L_i^H \right)}{L_j^H \left( A_i^2 L_i^u + A_j^2 L_j^u \right)}, 1 \right), & \text{if } w_i^H > w_j^H \\
        0, & \text{if } w_i^H \leq w_j^H 
    \end{cases}
\]

3.8 Incorporating Migration Costs

The assumption of zero migration costs is unrealistic. Migrants incur costs to establish social networks, learn and work using a foreign language and culture, and so on. These costs can be summarized as utility costs. On the other hand, the act of migration itself bears costs. In the following main emphasis is put on the latter. Costs of moving from country \( j \) to country \( i \) are \( k \), with any further assumptions about the origin of the costs. \(^\text{13}\) There will be migration if the wage in the host country minus the costs is larger than in the domestic country:

\[ w_i^H - k > w_j^H \]

Assuming again that there is no migration from country \( i \) to \( j \), migration flows from \( j \) to \( i \) can be described as:

\[
    m_{ji} = \frac{1}{2 \left( k - \frac{w_j^H - w_i^H}{\sigma} \right)} \left\{ \frac{k \delta \alpha (\sigma - 1) (L_i^H - L_j^H) + \delta \phi \left( A_i^2 L_i^u + A_j^2 L_j^u \right)}{L_j^H \left( A_i^2 L_i^u + A_j^2 L_j^u \right)} \right. \\
    & \quad - \left[ k^2 (\sigma (\sigma - 2) + 1) (4 + \delta \alpha^2 (L_i^H + L_j^H)^2 + 4 \delta \alpha (L_i^H + L_j^H)) \right. \\
    & \quad + \delta^2 \phi^2 (A_i^2 L_i^u + A_j^2 L_j^u)^2 + (\sigma - 1) (A_i^2 L_i^u - A_j^2 L_j^u) \\
    & \quad \left. \left( 2 \sigma + \delta \alpha (L_i^H + L_j^H) \right) \right)^{\frac{1}{2}} \right\} 
\]

(16)

Compared to the case without migration costs, interpretation of equation \(^\text{16}\) is somewhat complicated. \(^\text{13}\) The main driver of migration is still the difference

\(^{13}\) Including migration costs in the consumer budget constraint does not lead to substantial changes in the demand functions for the two goods, so long as the costs are independent of \( x_i \) and \( T_i \). This condition holds if \( T_i = T_i^\text{min} \). If \( T_i > T_i^\text{min} \) then \( L_i^u \) and \( L_j^u \) depend on \( T_i \), which would then as well depend on \( x_i \).

\(^{14}\) Apart from equation \(^\text{16}\), there is another potential solution for \( m_{jii} \). In this solution, the term in squared brackets, that is \([\ldots]\), would have a positive sign in front of it. This solution is inadmissible as it would predict migration flows from country \( i \) to \( j \) even in the case of \( w_j^H > w_i^H \).
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in the stock of firms, since the other variables remain constant. Migration costs will have the effect of postponing migration until the wage differential is large enough to cover the costs. The influence of costs of migration is further discussed in the context of simulations in section 4.

This completes description of our proposed model. The model has the following key characteristics. First, a higher number of highly skilled workers leads to a higher number of designs which in turn enhances growth. In addition, the richer country receives more highly skilled workers and therefore the difference between the two countries increases. In the steady state, when a fraction or the entire stock of high skilled workers moves to one country, the model explains divergence.

Countries are linked to each other by two factors: labour migration and trade. The country with more manufacturing firms attracts high skilled workers from the other country and benefits from a higher growth rate. The country with the smaller number of manufacturing firms remains stagnant at a lower level. The second linkage is trade. The country with a lower variety of manufactured goods benefits from the growth in the richer country by importing a higher number of varieties, while at the same time exporting a fixed quantity of its manufactured good.

Like any other theoretical growth model, the above model represents an abstraction of reality. To obtain realistic interpretations, it is useful to consider conceptual distinctions between cross-country or inter-region migration and growth dependences. World history offers a huge range of examples of labour movement between countries or regions. By varying the structural parameters, our model can be applicable to both the above cases.

Divergence emerges as an essential outcome of the model. As outlined in the Introduction (section 1), substantial divergence across countries was an essential feature of the 19th century. In the 20th century, there is evidence of club-convergence (Baumol 1986; Islam 2003), where groups of countries converge to a common equilibrium, but unconditional convergence across all countries is absent. Thus, the divergence outcome of our model is also consistent with contemporary evidence on ‘convergence clubs’. It may be noted, however, that our model has no mechanism for catch-up or convergence within each such club. Therefore this model should be seen more as an attempt to consider interactions between countries or regions within a growth model, rather than offering a full explanation for economic growth and convergence/ divergence across countries and regions.

Another potential critique is that the model focuses on wage differences rather than on utility as the motive for migration. However, as the Cobb-Douglas utility function is strictly increasing in both goods and both because both goods are normal goods, both motives are coincident. Finally, in our model the decision to migrate is purely economic. Political or geographical reasons such as conflict or natural disasters often motivate migration. In the context of our

---

15Empirical analysis in Baumol (1986) suggests convergence for 16 OECD countries, but not for a broader sample of countries. Islam (2003) writes: “[P]rodded by Romer, Baumol also considers the relationship in an extended sample of 72 countries. In this larger sample, however, he does not find evidence of convergence. ... The numerical results of this regression were not presented, but Baumol reported that it yielded ‘slightly positive slopes,’ indicating a process of rather divergence.”
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4 Simulation

In this section, we carry out a simulation to understand the impact of migration and trade on income, in the context of the economic model developed in section 3. For this purpose, we introduce dynamics in the accumulation of designs. The number of designs over subsequent periods evolves as:

\[ A_{i,t+1} = \dot{A}_{i,t} + A_{i,t} = A_{i,t}(\delta H_{i,t} + 1). \] (17)

For our simulations, the choice of the initial values and the parameters are of crucial importance. Assume that both countries have the same number of firms (or designs) and the same population size, but one country has a higher number (proportion) of high skilled workers. We consider the following initial values for the designs and stock of workers:

- \( A_i = 10 \)
- \( A_j = 10 \)
- \( L_i = 6 \)
- \( L_j = 8 \)
- \( L^H_i = 4 \)
- \( L^H_j = 2 \)

The above parameters imply that country \( i \) will have higher income due to a larger number of highly skilled workers. Therefore highly skilled workers will migrate from \( j \) to \( i \) whenever such migration is allowed.

In the following, we assume that the manufacturing and the traditional sector both require two units of unskilled labour for each unit produced. The demand for the traditional good is restricted to be 1 in both countries. We also assume the following parameters for the marginal rate of substitution between the manufactured goods and the traditional good:

- \( \delta = 0.5 \)
- \( \sigma = 8 \)
- \( \phi = 0.5 \)
- \( \alpha = 0.1 \)
- \( \mu = 1 \)
- \( \gamma = 0 \)
- \( T_i = T_{i,\text{min}} = 1 \)
- \( T_j = T_{j,\text{min}} = 1 \)

For trade, we consider two cases: (a) Very high transportation costs so that there is no trade, implies trade costs are set such that \( \tau^{1-\sigma} = 0 \); (b) otherwise, for each traded unit 1.5 units have to be produced \( (\tau = 1.5) \). When migration is allowed, it is introduced only from period 5 onwards. In addition there are no constraints for migration, implying that from one period to the next, a fraction of all highly skilled workers are allowed to move between countries.

First, the model is simulated without migration or trade. This case is used as a baseline and compared to simulations with migration and/ or trade.

4.1 Baseline (no migration, no trade)

Figure 1 shows simulation results of the baseline model without migration and trade \( (\tau \to \infty, \tau^{1-\sigma} = 0) \). Output 1a, the number of firms 1b, and the relative
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prices (14) and the wage in the manufacturing sector (11) are transformed in logarithms. The model behaves as expected from an endogenous Romer style model. Output increases with a constant rate, the number of firms and hence varieties increase with the same rate. The wages of high skilled workers increases at a constant rate as well. The increase is smaller than for the number of varieties as wage is scaled down by $\delta$ and the price of the varieties, which falls with an increase in $A_i$. Since there is no migration, the number of high skilled workers remains the same. The number of low skilled workers employed in a single firm in the manufacturing sector decreases over time as the number of firms increases. In the first period 0.7 unskilled workers are employed in each of the 10 firms of the manufacturing sector in country $j$. More workers are employed in each firm in country $j$ as less additional firms are founded than in $i$.

4.2 Migration, but no Trade

Figure 2 shows a simulation with and without migration but no trade. A solid line refers to the case with and a dashed line to the case without migration in all graphs.

As soon as migration is introduced in period 5 (indicated by a vertical dashed line), high skilled workers start moving to country $i$ as shown in Panel 2c. After two periods all high skilled workers employed in the R&D sector have moved to country $i$, leaving the R&D sector in country $j$ empty. This movements boosts the amount of produced designs in country $i$ while the amount of designs in country $j$ remains at the same level. The number of designs, and so the number of firms, do not change anymore and therefore demand remains the same. As before, the amount of unskilled labour allocated to the manufacturing sector in both countries decreases but stays constant for country $j$ after the introduction of migration. The wage for high skilled workers and the relative price in country $j$ do not change anymore, because the number of designs remains constant. The simulation clearly shows that the country which receives more high skilled worker benefits from migration by increasing the growth rate of designs and therefore experiencing a higher output growth rate. Thus, migration leads to divergence.

4.3 Trade, but no Migration

To find out how trade affects the model, Figure 3 shows simulation results with ($\tau = 1.5$) and without trade ($\tau^{1-\sigma} = 0$). High skilled workers are immobile and not allowed to move between countries. Therefore trade is the only interaction between countries. In the case without trade, the model is exactly as the baseline specification in Figure 1. Below we highlight differences to this baseline with the case with trade.

The number of varieties, or firms, is the same in both cases, since trade does not lead to any changes in the distribution of the high skilled workers. Therefore the number of low skilled workers employed in each firm as shown in Panel 3d does not change as well. The output increases because the demand for the manufactured goods increases due to the possibility of trade. Both countries benefit from trade, even though country $j$ benefits more, as Panel 3a shows.\textsuperscript{16}

\textsuperscript{16}The trade benefits for country $i$ are very small and almost impossible to distinguish from the graphs. Note that the graph plots logarithm of output.
Thus, trade introduces a degree of catch-up or convergence. Country \( j \) imports more goods as country \( i \) offers a higher variety of different goods. The changes in the relative prices are small. Again the change is larger for country \( j \) than for country \( i \). The reason is the number of foreign designs enters the price level only by a factor 0.06.\(^7\)

The simulation reveals that, in comparison with migration, the effect of trade is of a smaller magnitude. The country with the smaller manufacturing sector is the main beneficiary.

### 4.4 Both Migration and Trade

In Figure 4, we allow for both migration and trade from period 5 onwards. Costs of trade are set to \( \tau = 1.5 \), implying that for each unit of the manufactured good which is sold abroad, half a unit is lost in transportation. As in the case of migration only (see Figure 2), all high skilled workers migrate to country \( i \) within 2 periods. Therefore country \( i \) produces more designs, while the stock of designs remains constant in country \( j \). As the number of designs remains constant, no new firms can be founded and therefore country \( j \) is not able to export more of the manufactured good to country \( i \) (see Panel 4d). However the imports of the manufactured good into country \( j \) increases. Producing more designs leads to a higher growth rate of income in country \( i \), similar to the case with migration but no trade. Similarly to the case of trade only (see Figure 3) the growth rate of country \( j \) converges to the growth rate of country \( i \). Thus trade dampens the negative effect of migration.

Despite trade, the growth rate of the poorer country cannot overtake the growth rate of the richer country. A thought experiment can be used to illustrate this. If trade is possible without any costs, \( \tau = 1 \), then the demand for the domestic and imported manufactured good will be the same. Therefore the location of production does not make any difference to the availability of the manufactured good; both countries benefit from a higher number of firms in any country. To put it differently, trade costs of zero would “merge” the two countries and their growth rates would be the same. Further, convergence in growth rates does not imply convergence in income – the richer country remains at a higher income level.

The simulation shows that trade offsets the negative effects of migration for the country which loses high skilled workers. The richer country benefits more from the additional high skilled workers than from the opportunity of trade.

### 4.5 Migration Costs

Figure 5 shows simulation with costless migration and migrations costs of 200, which is in the order of the wage in the R&D sector in period 5. Panel 5c shows that migration is shifted by 1 period into the future. Moreover all highly skilled workers migrate immediately in the next period. This is because the difference in the number of the firms does not increase linearly over time. All high skilled workers moved to country \( i \) within 2 periods or 1 period, without and with costs respectively. The shift due to migration costs causes a delay until country \( i \)’s growth rate of output to reaches the same rate as in the case without costs.

\(^7\)The main driver for the price changes is \( R_i = A_i + \tau^{1-\sigma} A_j \), where \( \tau^{1-\sigma} = 0.0585 \).
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The simulations show that the country with the higher variety in the manufacturing sector attracts high skilled workers. The time it takes for all high skilled workers to migrate varies with the costs; with higher costs, it takes longer for the migration to complete. The host country experiences an economic boom, while the other country remains stagnant, implying divergence. A historical context would be the migration waves in the 19th century. As pointed out in the Introduction (Section 1), the 19th century in the western world, and especially the United States, was marked by huge economic development. At the same time the rest of the world experienced only minor growth. In our model the main driver for migration is the difference in wages, which was according to Hatton (2004) one of the main reasons for migration back in these historical times.

5 Conclusion

Satisfactory theoretically founded spatial interactions are absent in standard growth models in the literature. While some of the empirical spatial econometric growth literature emphasizes spatial dependence, this is typically modeled in terms of knowledge diffusion. However, theory provides no motivation as to why such diffusion exists, or even why geography should constitute the main driver for knowledge spillovers. This paper provides an economic model to address this gap in the literature. Migration and trade provide two alternative mechanisms for cross-country interactions in our model.

To model interactions between countries, the restriction of immobile high skilled labour is removed. Therefore a New Economic Geography model in the style of Krugman (1991) and an endogenous growth model in the style of Romer (1990) are combined to develop a new two-country economic model. The model retains the microfoundation, trade of a manufactured good and migration of labour from the New Economic Geography models. On the other hand, the engine of growth and the feature of unbounded growth, explaining in this context divergence between two countries, originate from the endogenous Romer-style growth model.

High skilled workers migrate to the higher wage offering country and contribute to the R&D sector, enhancing output growth. This leads to divergence. While benefits from trade negate part of this divergence, convergence or catch-up does not emerge as an outcome. Simulations confirm the predictions derived from theory. High skilled workers migrate from the country which offers a lower wage and, under autarky, this country stagnates. The country which attracts high skilled workers experiences a growth boom. When trade is allowed, both countries experience growth, but still there is some divergence. Further, simulations show that migration costs lead to delay in migration, but because of rising wage costs, this does not ultimately deter migration.

Based on migration of high skilled labour and the conclusion of divergence, the proposed model explains the great divergence of the 19th century. While there is no mechanism for catch-up or convergence within the model, it is also consistent with the club-convergence evidence in recent times.

The proposed model may be viewed as a first step towards introducing endogenous spatial interactions in appropriately theoretically founded spatial growth models. Therefore, it presents a rich agenda for future research. First,
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the model can be validated against cross-country economic data for the 19th and 20th centuries. Second, in line with the literature, the possibility of diffusion in knowledge and technology can be introduced. Third, a model for the labour market can be added and therefore effort in enhancement of skills can be introduced. Finally, potential migration of unskilled labour can also be allowed.
6 References


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Appendices

A  Graphs

Figure 1: Baseline Model (no migration, no trade)
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Figure 2: Migration, but no trade
Migration is allowed from period 5 onwards.
Figure 3: Trade, but no migration
Simulation without and with trade. Trade costs are set to $\tau = 1.5$. 
Figure 4: Migration and Trade
Migration and Trade are allowed from period 5 onwards. Trade costs are set to \( \tau = 1.5 \).
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Figure 5: Migration with and without costs
Migration is allowed from period 5 onwards, costs of migration are 50 and no trade.