

University of Groningen

Why growth rate differences persist

Rensman, M.

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version

Publisher's PDF, also known as Version of record

Publication date:

2006

[Link to publication in University of Groningen/UMCG research database](#)

Citation for published version (APA):

Rensman, M. (2006). *Why growth rate differences persist: International technology diffusion in the long run*. [Thesis fully internal (DIV), University of Groningen]. s.n.

Copyright

Other than for strictly personal use, it is not permitted to download or to forward/distribute the text or part of it without the consent of the author(s) and/or copyright holder(s), unless the work is under an open content license (like Creative Commons).

The publication may also be distributed here under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license. More information can be found on the University of Groningen website: <https://www.rug.nl/library/open-access/self-archiving-pure/taverne-amendment>.

Take-down policy

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Downloaded from the University of Groningen/UMCG research database (Pure): <http://www.rug.nl/research/portal>. For technical reasons the number of authors shown on this cover page is limited to 10 maximum.

Chapter 1

Introduction

1.1 Growth differences and international technology diffusion

To increase welfare in the long run, countries need to increase their productivity. There is ample evidence that growth rates of productivity differ across countries, even in the long run. The age-long international diffusion of technology apparently did not reduce these growth rate differences. In theory, new technologies adopted from a country with high productivity may increase the productivity of countries which lag behind. Indeed neoclassical theory assumes that the larger a country's productivity backlog is, the faster it should grow, leading to so-called β -convergence (Barro and Sala-i-Martin, 1995). If the latter countries catch up on the leader, growth rate differences should disappear in the long run. In reality, however, this has not happened. Hence questions arise about the role of technology diffusion in the convergence process. The current thesis explores the mechanism and impact of international technology diffusion on growth rate differences in historical perspective.

Table 1.1 shows the persistence of growth rate differences across countries. Some countries have more or less fully converged, while other countries follow diverging growth paths. Moreover, the convergence experiences have changed over time. After a period of falling behind the high productivity level of the United States during the interwar period, Western European countries caught up with the United States after the Second World War. The average productivity level for twelve European countries increased from 44% of the American level in 1950 to 83% in

1998. But there is no full catch up. Moreover, even within this group of European countries, growth rate differences are observed. In the period 1950-1973, German productivity increased with an annual growth rate of 5.9%, while British productivity increased at a lower rate of 3.1%. Between 1973 and 1998, the growth rate was lowest in the Netherlands with 1.8%, and the highest in France with 2.5%. Sometimes productivity leadership even changes (the so-called phenomenon of ‘leapfrogging’). For instance, in the late nineteenth century, the then world’s productivity leader the United Kingdom was surpassed by the United States. The British level declined from 113% of the American level in 1870 to 84% in 1913.

Table 1.1: Gross domestic product per hour worked (levels and growth rates), 1870-1998

| | 1870 | 1913 | 1950 | 1973 | 1990 | 1998 |
|---|-----------|---------|---------|---------|---------|---------|
| <i>1990 international dollar per hour</i> | | | | | | |
| United States | 2.3 | 5.1 | 12.7 | 23.7 | 30.1 | 34.6 |
| <i>US = 100</i> | | | | | | |
| France | 61 | 56 | 46 | 76 | 98 | 98 |
| Germany | 69 | 59 | 32 | 62 | 73 | 77 |
| Netherlands | 108 | 80 | 53 | 82 | 100 | 89 |
| United Kingdom | 113 | 84 | 63 | 67 | 71 | 79 |
| 12 West Europe | 71 | 61 | 44 | 68 | 80 | 83 |
| | 1870-1913 | 1913-50 | 1950-73 | 1973-98 | 1973-90 | 1990-98 |
| <i>Annual average compound growth rates</i> | | | | | | |
| United States | 1.9 | 2.5 | 2.8 | 1.5 | 1.4 | 1.7 |
| France | 1.7 | 1.9 | 5.0 | 2.5 | 2.9 | 1.7 |
| Germany | 1.6 | 0.8 | 5.9 | 2.4 | 2.4 | 2.4 |
| Netherlands | 1.2 | 1.3 | 4.8 | 1.8 | 2.6 | 0.2 |
| United Kingdom | 1.2 | 1.7 | 3.1 | 2.2 | 1.7 | 3.2 |
| 12 West Europe | 1.6 | 1.6 | 4.8 | 2.3 | 2.4 | 2.2 |

Source: Maddison (2001), Table E-7 and E-8. The 12 Western European countries are Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Sweden, Switzerland, and the UK. The productivity level of these 12 countries is a weighted average (Maddison, 2001, p.177).

As a reaction to this, it has been argued that convergence and catching up are conditional on country-specific factors. Neoclassical growth theory therefore usually assumes *conditional* β -convergence. This means that countries do not end up at the same steady state productivity level as they differ in underlying parameters in the accumulation equation. Productivity leaders may be assumed to work at the technology frontier, while followers often exploit technologies which are less productive. According to the economic-historian Gerschenkron (1962) this ‘backwardness’ provides a potential to catch up with the leader by absorbing the leader’s superior technology. But an important source of differences in this light, which has often been ignored in growth theory, is the capability of a country to absorb technology from the productivity leader.

With persistent productivity growth differences, the question arises how technology diffusion interacts with economy, institutions and absorption capabilities, and how this affects the productivity of followers. The growth literature of the past two decades has provided several additional insights in the role of international technology diffusion. However, it still lacks a coherent view on how technology diffusion affects growth and productivity, and it is still in need of a stronger empirical foundation. Moreover, the various strands of the growth literature do not systematically use each others’ insights yet.

For example, modern endogenous growth theory assigns a key role to technological progress to explain long run productivity growth (Aghion and Howitt, 2005). It stresses the role of research and development (R&D), which generates new innovations and knowledge spillovers. Recent endogenous growth models with international knowledge spillovers suppose that R&D has two faces: it generates innovations, but also absorptive capacity (Cohen and Levinthal, 1989; Howitt, 2000; Griffith et al., 2004). Hence not only the technology leader, but also the follower country itself has to conduct R&D in order to be able to absorb technology from the leader. More fundamental sources of growth such as institutions, like the property rights system, financial institutions, and the organisation of education and research (North, 1990) play an implicit role in these models.

The economic-historical literature shows that absorption of foreign technology is not costless, inevitable or automatic. The literature more explicitly describes the importance of institutions (Crafts, 2003a). Furthermore, economic-historical studies show that technology catching up is not synonymous to productivity catching up. First, the productiv-

ity level of a follower might not only be determined by the speed of international technology diffusion but also by technological incongruencies leading to different technology systems (Broadberry, 1994a). A technology system is characterized by country-specific factor proportions and market conditions. Technological incongruencies are forced by these local circumstances. Second, foreign technology might not become well-embedded in the production structure due to a lack of social capability. Social capability relates to a country's innovation system, which influences its ability to innovate and absorb technology from elsewhere (Abramovitz, 1991). Social capability is determined by a variety of factors, such as culture and institutions.

Notwithstanding these insights from the recent literature, the empirical evidence on how technology diffusion is related to productivity differences between countries is still weak and mixed. Growth regressions based on endogenous growth models do not always provide robust results due to a variety of estimation problems (Durlauf et al., 2005), though many attempts are made (Keller, 2004). While the specific details on institutions from economic-historical studies might enrich the endogenous growth theory (Abramovitz, 1991; Mokyr, 2005), such details are often too loosely formulated or too case-specific to derive statistically robust causal relationships between international technology diffusion and economic growth. Finally, the debate about the actual basic historical time series of productivity and its determinants is ongoing (Ward and Devereux, 2003; Broadberry, 2003b).

The current thesis aims to contribute to the literature by bringing together the complementary insights from the theoretical and empirical literature on growth and technology diffusion in historical and international comparative perspective. I develop a conceptual framework to analyse technology diffusion in a long term perspective. I discuss new long run time series data on productivity and capital covering one and a half century of growth in the United States and the United Kingdom, and relate this to economic-historical evidence on technology systems and innovation systems in the two countries. I also conduct econometric tests of endogenous growth models with international technology diffusion at the macro-economic and industry level focusing on the post-World War II period. In these models, R&D plays a crucial role in the absorption of foreign leader technology.

This new empirical evidence appears to be largely in line with the recent literature on growth and technology. The contribution of this the-

sis is that I put the research results in a long run perspective. A second contribution is the joint use of economic-historical literature, growth accounting and formal endogenous growth theory. This clarifies how international technology diffusion influences catching up and convergence in the long run.

1.2 Aim and outline

The current thesis aims to examine several claims made in the theoretical and empirical literature on international technology diffusion and its effect on long run growth differences. The central question is:

How and to what extent does international technology diffusion affect labour productivity growth differences between countries in the long run?

The central question is subdivided into three subquestions in order to disentangle the various forces at work in the mechanism of international technology diffusion:

1. How do international differences in technology systems and innovation systems affect international technology diffusion and growth differences in the long run (Chapter 3)?
2. To what extent do countries differ in the absorption of foreign technology by means of own R&D, conditional on international differences in technology systems and innovation systems (Chapter 4)?
3. What is the importance of the diffusion of industry-specific technology and general purpose technology for the growth of industries, conditional on international differences in technology systems and innovation systems (Chapter 5)?

The thesis starts with a survey of the theoretical and empirical growth literature in order to extract insights on the relationship between technology diffusion and growth from different viewpoints (Chapter 2). Using these insights might help to add to the construction of theory and to gain empirical understanding. The survey is an extensive review of different studies on economic growth, innovation and technology diffusion. This review puts the issue of international technology diffusion

into perspective within the current growth literature. The research in the subsequent Chapters 3 to 5 mainly builds on the insights from the economic-historical approach of technology and economic growth, growth accounting methods and endogenous growth theory.

Long run changes in technology congruence and social capability Chapter 3 aims to answer the first subquestion. What are the required means and the capabilities for an economy for productive absorption of new technologies? The chapter builds a conceptual framework on the relationship between technology diffusion and long run growth differences. In this framework, technological incongruence and international differences in social capabilities are the key factors explaining different diffusion and absorption paths in the long run. Technological incongruence is described by differences in technology systems, which are characterized by factor proportions and market conditions. Differences in technology systems between a follower and a leader country complicates easy transfer of technology. Differences in social capabilities are described by differences in innovation systems. These differ in terms of institutions and organisations involved in innovation and absorption of foreign technology. Important institutions for absorption are institutions for human capital and research, and the intellectual property rights system. Technology systems and in particular innovation systems only change over a long period of time.

These issues are explored with comparative Anglo-American evidence from 1840 to 1990. The empirical analysis uses new quantitative evidence on comparative labour productivity, capital intensity and joint factor productivity. It is complemented by a systematic search of dispersed and often qualitative evidence from the economic-historical literature on international technology diffusion. The Anglo-American experience suggests that transfer of institutions for human capital and research might have been more important for long run comparative economic performance than technology transfer itself. It also suggests that these transfers related to the innovation systems take more time to diffuse.

International technology diffusion and R&D Given international differences in technology systems and innovation systems, to which extent do countries succeed to increase economic growth by means of R&D and technology catching up? Chapter 4 develops a formal macro-

economic growth model, in which R&D efforts of a follower country helps to reduce its technology gap with a leader country, until the follower achieves its equilibrium growth rate. As countries differ in technology systems and innovation systems, R&D efforts to absorb foreign technology is expected to have different growth effects across countries.

The model is estimated for the market sector as a whole and the manufacturing sector separately in France, Germany and the UK in the period 1956-1996, with the US as the presumed leader country. The results suggest that technology growth appears to account for a large part of productivity growth, and that its role differs across countries and sectors. Capital intensity growth has a complementary role in technology diffusion by supporting and embodying innovations. More importantly, the estimations reveal that given the technology gap in the previous year, R&D efforts increase the technology level of the three countries. Without R&D efforts, the distance of the countries to the technology frontier in the US will increase. Countries appear to differ in the need for R&D to exploit the catch up potential. Conditional on the international differences in technology systems and innovation systems, the long run distance to the technology frontier will continue to differ across follower countries, and technology growth differences with the US may persist.

Technology diffusion channels and industrial R&D The macro-economic growth model in Chapter 4 does not reveal the way by which leading edge foreign technology is absorbed by a follower country. Chapter 5 refines the macro-economic model by distinguishing two types of technology, which are absorbed by industries, namely industry purpose technology and general purpose technology. Industries may differ in the extent of absorption and impact of such different types of technologies. First, technology might only be relevant for a specific industry. This is labeled industry purpose technology. It is directly transferred from a similar leading foreign industry into the follower industry. The second type of technology has characteristics which makes it applicable to various sectors in the economy. This so-called general purpose technology (e.g. information and communication technology) also originates from the foreign leader country, but is not directly absorbed by the follower industry. Instead, it is assumed that this type of technology is absorbed at national level and adjusted to local circumstances. Then it is transferred from the domestic technology pool into the follower industry. This assumption captures the idea of the importance of a properly working

domestic innovation system for an industry.

The model is estimated with data for six manufacturing industries in France, Germany and the UK in the period 1973-1993. These industries range from high-tech to low-tech. The US is considered as a benchmark for the European economies. The relatively small sample increases estimation problems, but the model appears to be able to discriminate across industries with respect to the two technology diffusion channels. For some industries, the absorption of industry purpose technology from the leading industry abroad is important. Investment in R&D has a positive impact on these industries' speed of absorption. Without R&D, they would fall further behind the foreign leader industry. For other industries, R&D investment has a positive impact on the speed of absorption of general purpose technology from the domestic technology pool. Without R&D, they would fall behind the domestic technology frontier.

Chapter 6 provides a summary and derives some implications for Western economies today, and discusses some possibilities for future research. The appendices present the used data and their sources, some test results on data properties, and alternative estimation results.