Measurement and analysis of capital, productivity and economic growth

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Chapter 7

Summary and Conclusions

Understanding the sources of economic growth has been a major subject in economics, as economic growth is essential to improve standards of living and to reduce global income inequality. Previous literature has clearly distinguished between the role of accumulation of resources through investment and the role of assimilation which is related to the productive use of such resources, in attaining economic growth. Accumulation and assimilation may be measured as the contributions of capital and multifactor productivity (MFP) to economic growth. In order to accurately measure the relative importance of these factors, it is imperative to have accurate measures of capital input. Appropriate measures of capital should take account of the differences in the efficiency of various types and vintages of capital assets. However, when quantifying the contribution of capital and MFP, most studies use a crude measure of aggregate capital input which does not take these differences into account. This issue has gained renewed interest because of the increasing heterogeneity of capital assets, as newer forms of capital such as information and communication technology (ICT) equipments have been introduced into the production process. This thesis has attempted to examine these issues in the measurement of aggregate capital input for analyzing the sources of economic growth. In particular it examined the various ways of measuring aggregate capital input, and the sensitivity of measures of capital accumulation and MFP, to these alternative assumptions. The specific issues on capital measurement addressed in this thesis include:

- accounting for asset heterogeneity by distinguishing various asset types and examining the sensitivity of MFP and capital accumulation measures to alternative models of capital aggregation (chapters 2 and 3)
- estimating lifetimes of various capital assets and examining their differences across industries (chapter 4), and
- examining the endogeneity of capital retirement decisions (chapter 5)

Using improved measures of capital input, the thesis also studies the proximate and ultimate sources of growth. In particular, the thesis

- quantifies the relative importance of capital accumulation and multifactor productivity growth (MFPG) in driving world economic growth and cross-country differences in economic growth (chapter 2), and

- examines the sources of cross-country differences in the adoption of embodied technology in terms of cultural differences between countries (chapter 6).

This chapter provides a summary of the major contributions of this study.

Though the theory and measurement of capital has a long tradition, most empirical studies, particularly those done in the context of cross-country growth analysis, still use measures of capital stock that does not take into account the differences in asset composition. This is predominantly because of the lack of appropriate data suited for growth analysis. In chapter 2 of this thesis, we provided some important modifications to the capital measures for about 150 countries in the Penn World Tables, taking account of the heterogeneity of capital assets across countries and over time. Subsequently, we have examined the bias in the contribution of capital to output growth when the standard measure of capital stock is used. This has been accomplished by using a growth accounting approach, which helps one to decompose output growth into contributions of inputs and MFPG. An important result from this analysis is that it is of major importance to take account of the capital composition while measuring capital input for economic growth analysis. Standard capital stock measures assign a common weight to all asset types, implicitly assuming that the contribution of different types of capital to production is the same. This is an unrealistic assumption as evidence shows that the contributions of certain components of capital, such as ICT equipment, to economic growth are larger than that of other components. Our growth accounting results indicate that the use of standard capital stock measures causes a downward (upward) bias in the contribution of capital (MFPG) when the share of equipment increases in capital stock. This would give the wrong impression that the country is doing well in terms of productivity, which need not be actually the case. Our new data on capital services will append the current Penn World Tables (PWT). It can be used to examine a number of issues in a cross-country context, such as comparative productivity studies at regional or global level, the relationship between ultimate and proximate causes of economic growth, and the empirical validity of alternate growth theories.

Subsequently, in chapter 3 we have examined the sensitivity of measured capital services to various assumptions used in capital aggregation procedure, using more elaborate data for European Union (EU) countries and the United States (US). This was done by calculating rental prices under various model assumptions regarding rate of return, capital gain and corporate taxes and using them to calculate the contribution of capital in a growth accounting framework. The sensitivity analysis suggests that the potential impact of including corporate tax in the measurement of capital services on the measured contribution of capital to output growth is quite small. Hence, any empirical analysis on the role of capital accumulation in EU countries is not very sensitive to the exclusion of corporate tax rates from the calculation of capital services. The sensitivity analysis also suggests that while the choice of a specific rate of return can have some impact at the industry level, mostly for service industries, it is quite trivial at the aggregate level. Hence, the way one chooses to aggregate across various asset types in terms of capital composition and the choice of external versus internal rate of return models is of greater empirical importance than the inclusion or exclusion of corporate taxes and capital gain. This result, however, is not to belittle the possible impact of tax policies and cross-country tax differences on *ex ante* investment behaviour.

A common assumption used in the literature on measurement of capital input for productivity analysis is that of a constant asset lifetime over time and across countries. This assumption is necessitated by our fragile knowledge of actual asset lifetimes. In fact, the introduction of newer vintages of capital due to rapid technological change may reduce the lifetime of existing capital assets. Firms may opt to discard their assets well before the end of the asset's physical lifetime due to technological obsolescence. In chapter 4, we have estimated the average service lifetime of capital assets, through an analysis of firm level data for actually observed capital stock and discards by Dutch manufacturing firms. Using firm level data from two different surveys — capital stock and discard surveys —, we have estimated a Weibull survival function. By using most available information on discard behaviour of each vintage of capital assets to the Weibull estimation, we approximated the survival probabilities of each asset at each specified age, in order to calculate the average service life of capital assets. In doing this, we use an average survival rate of three different vintages at a given age, and thereby estimate lifetime of capital more accurately than previous studies, which use survival rate for only one vintage. This has led to a significant improvement in the empirical results in terms of model fit. Our results indicate a notable variation in lifetimes of capital assets across industries. This cautions against the reliability of results on sources of economic growth if a common depreciation rate is assumed across industries. When our new estimates are compared with existing estimates for other countries, we also observed that the lifetime of capital assets vary across countries. This observation calls for better measures of cross-country asset lifetime and depreciation estimates.

Given the differences in lifetimes of capital, it is imperative to know what is driving differences in asset lifetimes over time, across industries and countries. We have examined the determinants of capital discards in chapter 5. Currently there is no empirical framework readily available from the literature to examine the determinants of capital discards. This thesis, therefore, applies an eclectic approach, which combines insights on discard behaviour of firms from alternative viewpoints in the literature. We have estimated a probit model which specifies the probability to discard an asset as a function of output, input prices and innovation indicators. Firm level data for this purpose has been compiled from five different surveys on Dutch manufacturing, viz. capital stock survey, discard survey, investment survey, production survey and community innovation survey. At the outset, we observed significant cross-firm variation in discard rates, suggesting that the relative roles of various factors that affect discard decisions vary from firm to firm. We find that technological innovation, measured in terms of introducing a new production process, plays a positive role in driving discard decisions of machinery assets. The introduction of a new product drives computer discards. However, for both these asset types as well as for transport equipment, the predominant determinant of discard decisions is the average age of the asset. In the case of computers, the role of age in discard decisions could be the result of obsolescence because of rapid technological changes in computer producing industry. Furthermore, computer discard decisions have bearing on the technological specificities of firms: high-tech industries are found to be more sensitive to technical change in computer production. However, in the case of machinery discard it is not clear whether it is obsolescence or wear-and-tear that dominates. For transport equipment, we attribute the age effect to mere physical wear-and-tear along with the effect of leasing practices. Leasing is particularly important for transport equipment.

Surprisingly, we find no support for a possible shift to a more labour-saving technology in light of increasing wage rates. Discard decisions are not found to be affected by growth in wages. We attribute this to the possible rigidities in the Dutch labour market that may make labour-capital substitution less cost-effective at least in the short run. Thus, our analysis confirms that capital investment and discard decisions are endogenous decisions by firms, determined by innovation, technological specificities of firm and wear-and-tear.

The thesis has also examined the sources of economic growth and divergence in economic growth between countries both in terms of proximate and ultimate causes. This was done by using the standard growth accounting approach to analyse economic growth during the last three decades as well as for periods of country-specific growth accelerations and decelerations (chapter 2). In doing this, we have used our new measure of cross-country capital service data presented in chapter 2 along with measures of output and employment from the PWT 6.2. The results strengthen the prevailing view that factor accumulation cannot explain much of the cross-country variation in economic growth for the 1970s and 1980s. This is also true for the 1990s, which is striking given that the 1990s is a period of growing integration, globalization, international trade and increasing proliferation of ICT capital. Nevertheless, compared to the previous periods, the importance of capital accumulation has increased significantly in the 1990s, possibly due to the increasing share of ICT capital. MFPG is the major driver of economic growth in most of the world's fast growing countries as well as during episodes of growth accelerations in individual countries.

The co-variance of capital accumulation and MFP growth rates has increased during the 1990s. This seemingly suggests the importance of technology embodied in capital, but could also be a reflection of disembodied knowledge creation by firms necessitated by accumulation of capital assets such as ICT. Increasing FDI flows that would bring managerial efficiency and advanced technology across national boundaries could also cause such growing co-variance. The results imply that poorer countries cannot achieve faster growth without adopting better technologies. But, as existing evidence suggests that frontier technologies are becoming highly capital intensive (Los and Timmer, 2005), this covariance would also suggest the need for increasing capital accumulation in poor countries, in order to boost productivity and economic growth. Thus the research brought two major findings, namely (1) the importance of MFPG in driving growth divergence, and (2) the strengthened relationship between MPFG and capital accumulation.

Our cross-country growth accounting analysis shows that technological change does not appear to occur at the same rate everywhere. Several studies have argued that in a world characterised by slow technology diffusion, large MFPG differences can prevail (e.g. Howitt, 2000; Klenow and Rodríguez-Clare, 2005). We, therefore, also looked into several ultimate factors that make countries less receptive to technological change, including the roles of cultural factors along with education and income variables in driving the difference in ICT adoption rates across countries. While the role of the last two factors are widely accepted in the literature, even countries of similar income conditions are often seen to differ much in terms of their adoption rates. In Chapter 6, we use a regression approach to examine the determinants of ICT adoption, where we regress two measures of ICT adoption – per capita ICT spending and per capita computers - on Hofstede's well-known cultural indicators.

Our results suggest that differences in ICT adoption can be explained, to some extent, by the differences between countries in terms of their socio-cultural attitudes. For instance, economies with a culture of high-power distance are less receptive to a new technology compared to countries with low power-distance. Similarly, countries which are risk-averse or highly collective are slow in adopting a new technology. This would indicate that a stringent hierarchical structure may deter countries from adopting technologies faster, and thereby act as an impediment in achieving faster economic growth. For instance, such hierarchy may affect the quality of institutions, which reduces the speed at which economic activity can increase. Thus these results complement existing evidence on the determinants of technology adoption and suggest that technology spillovers do not automatically take place, depending only upon a country's economic or educational capacity. Cultural ambience is important as well. This may indicate that the cultural constraints on the adoption of better technologies may partly explain the productivity gap between countries, as it can affect the speed at which technology diffusion occurs.

In this thesis we have attempted to improve the measurement of capital. In doing so, we had to confine ourselves to a narrow concept of capital, including physical assets such as machinery, transport equipment and construction assets. A broader concept of capital would also include human capital and intangibles. In chapter 2 we have used a crude measure of human capital, which indicates no significant differences in our final conclusions on the relative importance of capital and MFP in driving growth differences. But more research is required to derive an international database on human capital. Especially, the interaction between human and physical capital accumulation deserves further study. This is of particular importance as evidence suggests that the human capital plays an important role in enhancing ICT investment. In addition, we have considered only tangible assets. Intangible assets are often argued to be important in accounting for a country's performance. In particular most developed countries have a substantial and increasing share of intangible investment. Earlier literature has shown that ignoring this aspect may lead to underestimation of capital contribution (Abramovitz, 1993; Basu et al, 2002; Corrado et al, 2006). Clearly, the challenge for improving the measurement of capital will be around for some time to come.