Dissertation

The Use of Conditional Convergence Between Economies to Estimate Steady State Incomes Within Economies

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Abstract

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This dissertation introduces a panel data method to estimate country-specific steady state levels of output in an augmented Solow growth model. The use of panel data permits the estimation of a country-specific effect which can explain the surprising result that many developing economies are above their steady states. These empirical results also confirm that the augmented Solow model can explain the present cross-country income *divergence* of developed and developing economies. Another application finds evidence that the post-Soviet economies began their transition toward markets with initial conditions of overcapitalization. Finally, when the results are sufficient, there is also the possibility of describing an entire period of growth and gaining insights into future periods. This is shown with the OECD economies.

In Islam (1995), panel data is first used to estimate the parameters of the Solow growth model. The following year, Cho and Graham (1996) published a small paper which illustrates a simple way to compute steady state levels of per capita income by using the results of cross-sectional convergence tests. This dissertation simply combines these two methods with the result that the interpretations are more satisfying. In sum, we find that countries can begin a period of development above or below their steady states and that countries converging from above should be considered to be overcapitalized. This implies that development through investment can only succeed when there is convergence from below the steady state. Above the steady state, total factor productivity is too low to sustain the relatively high levels of capital.

The organization of the dissertation is linear with an introduction preceding the second chapter's literature review and the development of a theoretical and empirical model in the third chapter. The applications of the method then follow. Chapter 4 uses a worldwide sample to compare the result to other work and to show that this fundamental model of growth theory can explain the observed increasing levels of international inequality. Chapter 5 takes a look at the transition economies. In addition to finding evidence of overcapitalization, this dissertation finds a positive correlation between growth and the privatization of small business under transition. Additionally, there is a negative impact of price liberalization under the conditions of repressed inflation experienced by many Soviet-era planned economies. Chapter 6 uses a sample of OECD economies to obtain a significant deterministic, technological growth rate. This is possible because the countries are similar enough to make the assumption that they have the same growth rate more realistic. This enables an understanding of steady states after the initial period and leading into the most contemporaneous period of the sample.

Keywords: macroeconomic analyses of economic development; institutions and growth; measurement of economic growth; cross-country output convergence; models with panel data; government policy; socialist systems and transitional economies: political economy, property rights; socialist institutions and their transitions

JEL Classification Numbers: O11, O38, O43, O47, C23, G18, P26, P36

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CHAPTER 1

Introduction

In a very literal sense, the study of cross-country income convergence has been one-sided in its focus on convergence from below steady states while mostly disregarding convergence from above. The traditional Solow and Ramsey-Cass-Koopmans class of models predict conditional convergence using various standard assumptions, the most critical of which is the diminishing marginal product of capital, yet many have left another assumption unstated: with conditional convergence, for cross-country incomes to merge, it has to be assumed that developing economies are further below their steady states than developed economies.[1] If a number are also above their steady states, no such claims can be made.

It turns out that the term "convergence" carries two meanings in the literature. With conditional convergence, one sense of the term refers to the evolution of a country to its own particular long-run steady state. Theory predicts this should be true in the conditional sense, holding constant the differences in investment, human capital, technology, and institutions so that income growth is entirely determined by the diminishing marginal product of capital. This has been described as "within convergence" (Islam, 2003). The other use of the term refers to the equalization of cross-country per capita incomes. So, if worldwide income convergence is to occur, even if it's partial and in the conditional sense, the developing economies would need to have a level of per-worker output which is further below where it would be in the long run, given their level of available technology, investment, etc. The problem with standard tests of conditional convergence is that they find evidence of income convergence regardless of whether a country is above or below its steady state. The model

[1]This need not be an assumption if it is shown to hold by estimating country-specific steady states. The point here is that when the location relative to the steady state is left unaddressed, then it has to be an unstated assumption if the interpretation is that cross-country convergence has occurred.

predicts, and the empirical results herein show, that there is actually a wide variation in the initial positions relative to unique steady states and that this variation explains why there is conditional *divergence* among cross-country incomes. That is, as countries converge to their own unique steady states, many of the developing economies see their incomes fall or stagnate while the developed economies grow at a faster pace.

The field of growth convergence is well-known and well-researched, but the work presented here shows that there are still some avenues left unexamined. These additional contributions begin by using the results of the traditional forms of empirical convergence to compute steady state incomes. Instead of stopping the analysis once sample-wide parameters are estimated, this work continues by using those parameters to make country-specific predictions of the initial steady states. The results paint a richer portrait of convergence by providing estimates of each country's position relative to its unique steady state. This position contains important information and predictions for development. If below its steady state, a country may be able to grow through the use of investment, but if above, as are many African developing nations and, very recently, many OECD nations, then investment only serves to increase the amount that output must fall in order to get to the steady state. At first glance this seems unlikely, especially with respect to developing economies, but with a slightly different perspective of things, one can see that financial investment is only important if a country has adequate institutions. The initial studies of convergence (Mankiw, Romer, and Weil, 1992; Barro and Sala-i-Martin, 1992) assumed that economies have identical production functions, and in this context it is unreasonable to think that developing economies would be above their steady state and, in essence, have too much capital. The use of panel data allows this assumption to be relaxed and changes the result into something more in line with our modern understanding of economic growth. It appears that outside of this present research, panel data has not been used in the estimation of the steady states of a convergence growth regression.

Along these lines, is the acknowledgment that steady states are partially determined by institutional factors through their impact on total factor productivity (TFP). Therefore, being above the steady state simultaneously implies that a country is overcapitalized *and* does not have the quality of institutions and technology needed to maintain its level of capital per worker. That is, overcapitalization is tantamount to having poor TFP. Better institutions would raise TFP and make the labor force productive enough to maintain the high level of capital. There are other factors such as R&D which can affect TFP and are theoretically within our control as in Romer (1990), but the rate of institutional change may be more of a policy choice than the rate at which new technology is developed. In the context of transition and developing economies, that claim may be even more valid. The methods developed here allow for direct tests of these institutions and help in understanding which institutions are important to improving the context that many developing countries find themselves in. The implications are then that stability and sound institutions are not simply good policy, but good financial investments.

Finally, the results imply that the Solow model can be used to predict the actual observable outcomes of cross-country divergence. The method developed here offers another viable alternative to the club convergence and distributional approaches which emerged when it was thought the Solow and RCK models were inadequate. But, as it turns out, a proper interpretation of Solow-type convergence is perfectly compatible with the "twin peaked" type of global development which has been observed over the period of interest. Such observations are illustrated theoretically and empirically.

This introduction proceeds by further describing the motivation with more background to the problem at hand. A brief summary of the literature review is then followed by a detailed description of Chapter 3, the chapter which develops the structural model used to estimate country-specific steady states. A summary of Chapters 4, 5, and 6 then follows. These are applications of the method to, respectively, a worldwide sample, a sample of economies transitioning to capitalism, and a sample of OECD economies which can be used to practice potential forecasting methods. This introduction also gives a brief discussion of the conclusion and possible extensions.

1.1. Background and Motivation

Theoretical analyses have always done a complete job in describing convergence from both sides of the steady state, perhaps because the existence proofs often require this type of analysis. But in the transition to an empirical analysis, things tend to become one-sided. As one example, Barro and Sala-i-Martin (2004) present a detailed theoretical description of the Solow growth model's transitional dynamics from all sides of the steady state, but when it comes time to discuss the empirical analysis of convergence, the authors state,

> "The main idea is that an economy grows faster the further it is from its steady state."

Such statements regarding speed and the distance from the steady state are common to the literature.[2] It is indeed true that if a country's per worker output is below its steady state, then the further it is from this steady state level of output, the faster it would grow. But it's also true that if a country's output is *above* its steady state, then its growth will be more *negative* the further away it is from its steady state.

[2]See for instance, Caselli, Esquivel, and Lefort (1996); Karras (1997); Aghion and Howitt (1998); Foley and Michl (1999); Cole and Neumayer (2003); Basile (2008); Derbyshire, Gardiner, and Waights (2013)

To gain insight into both sides of convergence, Cho and Graham (1996) use cross-sectional data to estimate country-specific steady states, but they have to assume common total factor productivity (TFP) due to the nature of the data. In order to address this issue, we merge this approach with the panel data methods developed by Islam (1995) so that we can estimate country-specific TFPs and then use the results to explain cross-country patterns of development. Once production functions are allowed to vary across economies, convergence from above is simply due to the fact that total factor productivity is too low to sustain the existing level of capital.

This analysis leads to a further recognition of two types of convergence and divergence: a country's convergence to its own unique steady state and the occurrence of cross-country income convergence. These exist as separate phenomena, where cross-country income convergence is dependent on the way in which countries converge to their own steady state (Islam, 2003). As an example, we can define cross-country divergence as occurring when developing economies grow at a slower rate than do developed economies. This occurs as developing countries converge to their own unique steady states from above while developed economies converge from below. This can be tested for, as will be shown.

Thus, the concept of conditional convergence contains more detail than is typically thought. It is generally understood that when two countries have different steady state values, convergence to their own steady state can result in a level of continual inequality which otherwise wouldn't occur if they had the same saving, depreciation, and labor force growth rates. If the countries are all below their steady states, their per worker incomes will all grow, and maybe even partially converge, to get to this point. But the transition to this balanced growth path may also be a scenario in which high income countries start below their steady states and the others start above. Then there is cross-country income divergence on the way to their balanced growth paths. That is, income differences might worsen as countries converge to their own steady states. These are very different outcomes, and this paper develops a method to determine which one is predicted by the classic studies of convergence. Since these basic principles of the Solow model are also found in modern macroeconomic general equilibrium models, a deeper understanding of the empirical predictions may also aid in understanding the simulated transitional dynamics which are commonplace amongst these types of models.

The empirical results in this paper show that lower income countries, particularly ones in Africa, began this period of modern development above their steady states; this can explain their slower growth. The use of panel data permits an interpretation which makes sense of these results, but such an outcome seemed surprising at first light when Cho and Graham (1996) presented their findings using only cross-sectional data. How could developing economies possibly be converging from above and therefore have too much capital? So in the rare cases in which convergence from above is mentioned, it may often be accompanied by a statement of disbelief or denial of the Solow or RCK model.

> "...the transitional component of growth rates in the poorer countries ... turns out to be negative. In other words, these countries appear to have been initially above their steady states and to be converging from above by reducing their capital stocks per effective worker. This raises a troubling question: with such extremely low incomes, how did they get above their steady states? These observations suggest that the good fit of the model is to a large extent illusory" (Ros, 2001).

However, if the assumption of identical production functions is dropped, then the result of convergence from above quickly becomes explainable, expected, and brings the Solow and RCK models of cross-country growth fully in line with the reality of an emerging bimodal global income distribution. Panel data permits country-specific production technologies which are essential to making any sense of the result. Once production functions are allowed to vary across economies, then convergence from above is simply due to the fact that steady states and total factor productivities are too low. This is the approach of this present work and it appears to be an innovation in the sense that we have not found any other research which develops a method with the specific intent of empirically estimating unique steady states within a dynamic panel study of convergence.

The Solow growth model predicts a negative relationship between the levels of income per worker and their subsequent growth rates, regardless of whether the resulting growth rates are positive or negative. That is, regardless of whether there is convergence from below or above, the relationship between growth rates and initial incomes will always be estimated to be negative. The negative relationship is due to the fact that as incomes rise from below their steady states to above, growth rates fall, reach zero as they cross their steady states, and then become negative. Along this entire path, the positive change in incomes is associated with decreasing growth rates. However, along this same path, the implications for development policies change drastically. Any knowledge of a country's initial position relative to its steady state helps explain the nature of its subsequent development. If an economy is converging from below, then investment in capital is an effective way to grow the economy, and for these developing economies, the traditional international financial investment strategies engaged by the IMF and World Bank would be effective. Above the steady state, things are different. There, financial investment is not likely to improve growth in the long run. The marginal productivity of capital is lower when above the steady state. This position not only describes overcapitalization but also describes a country with poor determinants of total factor productivity (TFP). If a country's TFP is too low to support higher levels of capital investment, then these traditional financial investments are inefficient and the funds would be more wisely invested into the provision of public goods and the protection of property rights. Any increase in capital only serves to increase the eventual fall which must occur in order to get back to the long-run steady state, but any improvement in total factor productivity would grow the economy or at least reduce the output fall and the amount of disinvestment of capital stock as the country falls back to its low steady state.

This is consistent with the modern understanding of the role that institutions play in the development process. Institutions have few effects outside of the country in which they are enforced and they are typically predetermined by some past event, so they can be used to explain the disparities in long-run growth. Such factors have been shown to be incredibly important in, for example, Acemoglu and Johnson (2005) and Eicher and Schreiber (2010). Perhaps it is this newly acquired understanding of the fundamental determinants of growth which make this paper's often overlooked interpretation of convergence seem so evident.

These insights could also help create a bridge between the estranged fields of economic growth and economic development. Cross-country regressions tend to not be the favored method among development economists, but the argument that specific types of institutions can have similar impacts within a wide variety of countries doesn't seem too unreasonable. For example, instability is likely to have similar consequences for growth, regardless of a country's idiosyncrasies. Also, the tradeoff between allocating economic activity between the production of capital and the production of final goods is something universal to all levels of human development. Additionally, it's clear that economies share at least a portion of their technology. On the other hand, countries are obviously unique, so instead of discussing convergence of all countries toward a common steady state, the methods herein allow for a rough estimation of a country's position relative to its own unique steady state. Striking a new balance and understanding by paying attention to all sides of development could lead to different development policies. For instance, using the method and results established herein, we observe that many African countries were indeed above their steady states and the capital investment strategies of the IMF and World Bank over the period of interest would have been predicted to have had little effect. In fact, the policies could help explain why these countries have remained overcapitalized relative to their own low steady states whereas the better policy would have been to use the funds to improve institutions and ensure stability.

In the empirical growth literature, if it is mentioned at all, the estimation of country-specific steady states is tangential or heuristic.[3] The lack of attention could be due to the history of convergence as the study of "catching up" which forces the researcher to focus only on convergence from below. It could also be due to the fact that at first glance, the results seem to run counter to the cross-country predictions of the Solow growth model. However, under closer inspection, one quickly discovers that individual countries converging from above can lead to cross-country *divergence* and this is compatible and expected when using the model.

1.2. Chapter 2: Survey of the Literature

This section briefly summarizes Chapter 2, a review of the literature used throughout the dissertation. Given the nature of this dissertation, the literature is varied but largely connected. The convergence literature has followed a clear path which dates back into the history of modern economics as the question of whether countries are seeing their incomes become more or less equal has always been a central concern of growth and development. It is thus natural for the literature review to follow the historical-logical approach by tracing the history of the subject and describing how it naturally evolved into its present forms.

[3] See for example, (Bernard, 2001; Chen and Fleisher, 1996)

The empirical analysis has progressively introduced cross-country variation to the study of convergence. The initial empirical studies began with a concept of "unconditional" convergence as in Baumol (1986). Here, there wasn't much of a connection made to the Solow model, but the concept does not address the variation in population growth rates, investment (savings) rates, and total factor productivity. The "conditional convergence" of Mankiw, Romer, and Weil (1992) allows for variation in population growth rates and investment rates. The panel version is introduced by Islam (1995) who also allows for country-specific total factor productivity. Later Arnold, Bassanini, and Scarpetta (2011) use the Pesaran, Shin, and Smith (1999) mean group estimator to allow for different growth rates in total factor productivity. Some of the most complete variation is found in Pedroni (2007) where the parameter estimates on human and physical capital are allowed to be unique to each country. The capital intensities are allowed to vary with respect to each country, along with total factor productivities.

A review of the transition literature is also to be found in this chapter. The emphasis is on the role of capital during the transition and the theories which explain the output fall during the transition to capital. There is also an overview of the cross-country empirical research on the sample of transition economies. Institutional measures are also used in the application to transition economies.

1.3. Chapter 3: Developing the Model and the Empirical Methods

This chapter lays out the theory and methodology of calculating the unique steady states that underlie a convergence regression. The first section of the chapter discusses the theory behind convergence from above and below and how it pertains to comparing different economies. A graphical approach is used to explain how the within-country convergence can lead to cross-country patterns of development which fit reality. The theory shows how the observed cross-country divergence can be explained. Steady states have already been computed in Cho and Graham (1996), but only in the context of cross-sectional data which forces the conclusion to refer to identical cross-country production functions. As such, the interpretation was less than fulfilling and the method hasn't been extended until now. The method is then simply combined with the panel data methods of Islam (1995) in order to get estimates which permit a more realistic interpretation. In brief, the parameters are estimated in the panel data growth regression and then used to compute the steady state which has been derived analytically.

In the standard panel analysis, the growth rates of total factor productivity (TFP) are assumed to be common to all the economies, although the levels can vary. In order to allow more variation and to incorporate variables which could shift the growth rates of TFP, a simple variant of Mankiw, Romer, and Weil (1992) is derived which allows for the inclusion of various measure if institutions which could affect growth of TFP. These models are then applied to particular samples in the later chapters.

1.4. Chapter 4: Application to a Worldwide Sample

In this chapter, a worldwide sample of 78 countries is used to derive steady states and compare them to a country's initial position. Here we find evidence that the locations are indicative of cross-country divergence. The selection is due solely to data availability as 4 data sources are used for the worldwide sample. These are the Penn World Tables 7.1 and 8.0, the Barro-Lee Education Dataset, and the PolityIV political indexes. The results show that

African nations are disproportionately represented in the economies who are starting above their steady states. This can be explained by their lower level of total factor productivity and the concomitant difficulties in maintaining the level of capital stock per worker which they started out with. Results also indicate that there are several countries well *below* their steady states: Japan, South Korea, and Argentina, for example. These countries grew rapidly. On the other hand, Congo Kinshasa, Nepal, Zambia, and Senegal are the furthest above their steady-states, indicating a level of total factor productivity too low to support the initial level of capitalization.

Actual estimates of the total factor productivity support this conclusion. Institutional variables are used as instruments in the Blundell and Bond (1998) "system GMM" estimator which helps address the issues of endogeneity while giving interesting results themselves when used as right-hand-side variables. A measure of autocracy is consistently negatively and significantly related to levels of per capita output. Interestingly, fewer restrictions on an executives power are significantly related to levels of output. But it appears the executive who also faces frequent challenges from various political challengers is also going to be associated with growth.

1.5. Chapter 5: Application to a Transition Economies

There is a lot of anecdotal discussion of overcapitalization of former communist countries. Managers had incentives to expand their productive capacities beyond what was necessary, resulting in overcapitalization and underproduction of consumer goods. Testing these countries' initial steady states may confirm this hypothesis. Data from the EBRD is used along with the Penn World Tables 7.1 to estimate the unique steady states of the former communist transition economies. The Polity IV variable *autocracy* is also used. The results show that traditional convergence is significant but education rates are not significant in this sample. The insignificance of education could be due to data availability and missing variables rather than specification. Small-scale privatization is a robust result associated with growth while price liberalization is strongly and significantly negatively correlated with growth. The explanation for the latter result is that price liberalization resulted in hyperinflation in the first decade of transition. Afterwards, the reforms had more success.

The main result is that, as expected, the majority of the transition economies are above their steady states, indicating overcapitalization. Total factor productivities are estimated, but they are too small relative to the other explanatory variables to be significantly different from zero. Given the changes in institutions during this time period, it may not be too surprising that the estimated values for total factor productivity have too much variability to be considered to be significant. However, the steady state values, which include the TFP estimates, are mostly significant. Moreover, 21/28 transition economies are above their steady state in 1995. This result provides empirical evidence using a standard growth model that the post-Soviet transition economies were overcapitalized at the onset of the transition. This is another explanation of an output fall of incredible proportions.

1.6. Chapter 6: Application to OECD Economies and Forecast

The OECD group of economies are more likely to rapidly share technology either via direct transfer and exchange of ideas or through trade. For this reason, the assumption of a common deterministic growth trend becomes more realistic and may be used to project steady state estimates coming out of the initial level. Estimates indicate that the majority of OECD economies begin below their steady states in 1980. This is a period of recession, so the potential for growing out of it is high. By 1985, the majority of the economies are above, indicating slower growth in the near future. This is, however, immediately following a period of economic recovery and expansion. In 1990, 1995 and 2000, the economies are mostly below as they emerge from recession and into a long and sustained expansion where arguably, the steady state itself is shifting outward. By 2005 and 2010 the economies are above their steady states, indicating slower growth in the future.

In order to gain insights into why there are movements above and below the steady states we compute the distance that an economy is above or below its steady state, and regress this output gap on various types of capital. It turns out that capital investments into nonresidential properties and ICT technology help explain why a country may move above a steady state.

1.7. Chapter 7: General Conclusions and Possible Extensions

It may be noted that much of the success of the method is that computing steady states in this way is essentially the computation of a predicted value. What is unique here is that the variation around this predicted value shows patterns that are predicted by theory. The method is direct and easy to implement. In fact, the most difficult part of the process is finding estimates of the augmented Solow model which are significant enough to justify the use of the theory. Given that convergence with the Solow model has been estimated numerous times in the literature, it is a relief to know the extension here is more easily implemented than what already exists in a large body of work. Although, in a panel setting, our choice of using a time trend is the source of the difficulty in finding estimates. The choice of sticking with the time trend instead of abandoning it for time dummies was made in order to remain truer to the model despite time dummies aiding in the control of heterogeneity due to business cycle shocks.

One main extension to the theory presented herein is to allow for not only variability in the level of TFP but also in the deterministic growth rate of TFP. That is, there should be variation in the adoption and creation of the non-excludable technology trend. Although both a unique trend and a common one should be used as in Lee, Pesaran, and Smith (1997). Other extensions include the application to regional economies in the US. If a panel including state-level or county-level measures of physical and human capital investment could be assembled along with incomes, then measures such as election results and tax and expenditure rates could be used as proxies for institutions. Such research would be time consuming in the assemblage of the data, but if enough years were collected, the results could be used to give insight into local development.

CHAPTER 2

Review of the Literature

In many respects, it's not possible to avoid the subject of history when surveying the literature on growth convergence. In fact, growth convergence and any empirical study of income dynamics is actually the study of historical occurrence. Additionally, not only has the research evolved over time but the concept itself has changed and received a vast array of contributions. It is therefore apt to survey the literature from a *historical-logical* style as in Islam (2003) in which the discourse over history leads to a feedback with the theory itself. Given the length of time over which convergence has been studied, the evolutionary interplay between the researchers and theory helps organize the review.

The literature review is divided into three sections with the first two covering the convergence literature and the last section reviewing some of the relevant transition economy literature. The convergence literature is divided into two stages. There is a long history leading into the cross-sectional and panel data empirical analyses of convergence. By the 1990s, the use of cross-country growth regressions could be described as being on the cutting edges of economics, and within empirical macroeconomics, only the development of time series methods could have been seen as more prominent. Due in part to its incredible popularity in the period following the 90s, the use of cross-country regressions had a sense of falling back to earth associated with it in the post-90s. This latter period helps divide the literature into two sections: a nascent period in which excitement and interest may have led to the acceptance of restrictive assumptions, and a period of maturation in which the problems with the assumptions are recognized and addressed. This contemporary period is one in which either the original methods are applied to more localized regions and specific economic sectors, or more advanced methods are used to address some of the most restrictive assumptions, if not all of them.

The transition literature covers both theoretical and empirical analyses. Theory helps develop the testable hypothesis that post-Soviet transition economies began the process of liberalization and privatization in a state of overcapitalization. There is also a body of cross-country empirical work which examines the growth of transition economies. Some of this literature uses the same institutional index as is carried out in Chapter 5.

Before proceeding, in case there is any question, it should be clarified that this literature review applies to the entire dissertation. In the subsequent chapters, the literature may be referred to but a detailed discussion will be restricted to this chapter as much is possible.

2.1. Convergence Literature: 1952–1998

This period starts with Gershankron's 1952 work on the subject and comes to a close with the back-and-forth between Pesaran and Islam in the 1998 *Quarterly Journal of Economics*. Baumol (1986) is often given credit for introducing the statistical notion of convergence. In this work he also uses a quote from Veblen to describe how studying economic history is integral to our understanding of the economy today: "...the study of economic history is not simply a manifestation of 'idle curiosity'." That is, in its use of initial states, the study of convergence is really the timeless study of how the past affects us today. Baumol's work thus manages to cite Veblen, Marx, and Gershenkron, but strangely enough, not Solow, even though it would eventually be Solow's model which would be employed in the modern analysis of differential growth rates. In fact, Gershenkron and Solow were writing during the same moments of time with little knowledge of how their work would meet in the future. So perhaps it's best to start a survey there.

Gerschenkron (1952) and Solow (1956) were producing work on convergence during the same epoch of economic thought with Gerschenkron as the economic historian and Solow as the creator an MIT brand of representative agent macroeconomics. Gerschenkron's "advantages of backwardness" concept was used to describe the industrial revolution and Germany's adoption of existing British technology during the German "catching-up process." The role of technology in the Solow model was clearly specified in 1956 but there wasn't much of an application of the model to cross-country differences. In fact, Solow appeared very hesitant to use his growth model to explain differences between countries. In his 1970 textbook on the subject, Solow begins a section on Kaldor's stylized facts, yet before getting to the last of them, he comments,

> "The remaining 'stylized facts' are of a different kind, and will concern me less because they relate more to comparisons between different economies than to the course of events within any one economy" (Solow, 1970).

This present research is an attempt to apply the modern empirical growth methods in a manner which is more consistent with the one described by Solow. That is, the concern here is convergence *within* a single economy to its own unique steady state. This appears to be the same concern of most who study the subject, so it seems convergence as a concept has come full circle in that we have returned to paying attention to the individual economies within the data. The start of this process came after many rich empirical methods made use of the cross-country panel datasets put together by the likes of Summers and Heston (1988) and Maddison (1982). Prior to the 1990s and Summers and Heston dataset, the lack of the availability of data adjusted for purchasing power had hindered much of the possible empirical work on the subject.

Baumol (1986) and Abramovitz (1986) were also working in the same epoch and again the work was a dissimilar analysis of the same subject. Abramovitz began to develop the concept of conditional convergence with an emphasis on institutions while Baumol laid the foundations of the empirical analysis in testing for absolute convergence. Baumol found that in a cross section of countries, there is a negative relationship between an initial level of per capita output and its subsequent growth. Such a relationship implies that less developed countries should grow faster, or catch up, to developed ones. Later on, such a concept would be described as absolute β-convergence. However, many important conditioning variables were left out of Baumol's analysis and would be included later in the study of conditional convergence. It's the conditioning on country-specific information which takes us further from the notion that countries would ever really converge. Meanwhile, Abramovitz supplemented the study of this process with a description of institutional differences in the form of "social capability." Such a contribution is best summarized in the following.

> "...we expect the developments anticipated by that (convergence) hypothesis will be clearly displayed in cross-country comparisons only if countries' social capabilities are about the same."

Thus came the next round of convergence studies which set out to find *conditional* convergence, however measures of institutional differences would still be missing. β-convergence now would become conditional on country-specific levels of saving, population growth, and human capital. This stage would also likely prove to be the most influential as Mankiw, Romer, and Weil (1992) (MRW from here on) and Barro and Sala-i-Martin (1992) came at a time when data availability and computational ability were reaching present levels, and as macroeconomics was entering a state of crisis. With the explicit theoretical underpinnings of the Solow and RCK models, the papers were some of the first structural forms of convergence tests. Their goal, however, was to simply determine whether or not the correct specification of the macroeconomic production function should exhibit a diminishing marginal product of capital. However, the methods developed and the insights gained into the conditions of growth would propel empirical studies of economic growth into the next decade.

This work influenced the development of the methods of cross-country growth regressions which in turn began to offer a wide variety of perspectives on income convergence. Having emerged as a mainstay of empirical macroeconomics, the tests and the concept itself began to evolve in the face of these new methods. Convergence has an explicit time series component to it, so the next logical step is to include such information. Islam (1995) developed the fundamental methods to test for convergence which is also conditional on TFP by using panel data to estimate country-specific effects. Much of the transition to panel data involves a substantial amount of programming in order to compute different averages of variables over a 5-year time period. Such averages are then associated with the growth rates which lead up to the most recent year of each 5-year period. The averaging helps remove the short-run business cycle impacts on real GDP. If enough 5-year periods are assembled, then panel data estimation is made possible. The results indicate a faster rate of convergence due to the inclusion of more country-specific information in the estimates. In fact, in using panel methods, the assumption of identical production functions had been abandoned. The faster rate was being determined after holding the unique factors of production constant and showed that cross-country income convergence was otherwise possible if it weren't for these fundamental differences. Islam is therefore one of the first to observe that conditional convergence calls for greater involvement in the development process, not less, and that such involvement should be geared toward enhancing institutions which are now considered to be one of the "fundamental causes of growth" (Acemoglu, 2008). What also remained problematic is the well-known issue of dynamic panel bias (Nickell, 1981). Islam employed a minimum distance estimator to some success, although other methods were being made available at the time. It's highly likely that the country-specific effects are correlated with one or more of the regressors which makes for biased OLS estimation. Fixed effects estimators can include the country-specific effect but often do so by first-differencing the data. This introduces the dynamic panel bias because the error term comes from a differenced term in which one error is differenced from an error term which comes from the same period as the lagged dependent variable. To deal with such an issue, GMM estimation methods were employed, most notably by Arellano and Bond (1991) and Blundell and Bond (1998). Caselli, Esquivel, and Lefort (1996) adopted this estimation method along with the Kiviet (1995) correction for dynamic panel bias. The results gave rates of convergence faster than in OLS and a change of sign in the estimation of the impact that education has on growth. The sign change on education in going through different estimators isn't uncommon. Gaps between male and female education rates are seen as a sign of "backwardness" especially when there is a negative coefficient on female education rates (Barro, 1996). Caselli, Esquivel, and Lefort (1996) find the opposite result in the direction of male and female education and note there may be confounding relationships between lower education and higher fertility among women. The strange behavior of education coefficient isn't the most salient feature of the panel data studies. What was most impactful is that, given unique total factor productivity (TFP) levels and growth rates, the theoretical relationship between convergence to a *common* steady state had been broken. Absolute β-convergence had lost much of its meaning, at least among cross-country national incomes and in a world-wide sample.

Lee, Pesaran, and Smith (1997) possibly did the most toward showing how panel studies minimize any concept of cross-country β-convergence. Their stochastic Solow model permits an AR1 process with country-specific technology and a country-specific constant. There is no longer the need to assume a common growth trend. The estimator developed in Pesaran, Shin, and Smith (1999) allows for the estimation of growth in TFP which is unique to each country. When this method is not used, they show that if the growth rate of technology is specified to be the same for all countries, as is done in the prior work on panel data, then omission of the differential rates in the empirical estimation will ensure that an MA process will enter into the error term due to heterogeneity of growth rates in TFP and the first differencing in the panel estimator. The results show even faster rates of convergence to a steady state, but each country has their own rate. After allowing for the heterogeneity, the proper interpretation of conditional convergence had finally arrived: countries converge to their own unique steady states and then grow at their own unique deterministic rates. However, in this give-and-take Islam (1998) hits on a key idea which we'll return to shortly: there is an "underlying tension between the *within* and *across* dimensions of the concept of convergence." We would expect countries to have at least some common trend even though overall growth rates may be different. But even if the concept of empirical β-convergence has become hollow, the usefulness of the concept of convergence and empirical methods which were developed haven't gone away. The study of convergence has now moved on to studying "growth clubs," continuous distributions of income, and somewhat surprisingly, endogenous growth.

There are several general ways in which convergence emerges from this period. While it has become a dubious claim to say that all countries across the globe share a common point of income convergence, it still may be valid to argue that groups of countries converge to a steady state which is unique to that "club." Durlauf and Johnson (1995) develop the notion of growth clubs through an empirical analysis in which countries are selected and classified based on various determinants of growth. The authors use cross-sectional regression methods but the specification of subsamples allows for estimation of entire production functions unique to the growth club. This allows for different estimates of capital and labor shares which offers a more accurate estimation of the specific parameters of the Solow model, however country comparison becomes less direct.

The most direct empirical approach to estimating convergence (or lack thereof) is given by Quah (1997) in his nonparametric estimation of income distributions and their probability of changing over time. Quah's results show a bi-modal, or "twin peaked," distribution emerging over the last several decades. Such distributional change is consistent with the notion of club convergence and illustrates some income convergence within each peak.

Another way in which convergence is studied today is through the use of estimators such as Pesaran's pooled mean group estimator which allow for increased cross-country variation (Pesaran, Shin, and Smith, 1999). There are now estimators which allow for cross-sectional varying parameter estimates. We'll take a look at those in the next section.

2.2. Convergence Literature: 1998–The Present

One of the great ironies of convergence theory is that it was initially made popular as a test which could show whether the neoclassical growth model should be preferred to an endogenous growth model. But as it turns out, some forms of endogenous growth make predictions of conditional convergence, and given club convergence, the neoclassical model makes the same predictions of a lack of absolute convergence that endogenous growth theory does. One way endogenous growth theory can predict convergence is to include a type of cross-country technology transfer into the standard model which is already has deterministic growth in TFP. Explaining the growth in productivity allows for cross-country differences in R&D while the technology transfer allows for a catch-up effect. Howitt (2000) does just this in his presentation of the Schumpterian growth model with transferable technology. He derives an equation very similar to MRW but the inclusion of productivity-enhancing R&D allows for a more reasonable share of capital to complement the expected rates of convergence.

Panel data methods have been developed to specifically incorporate both country-specific heterogeneity and common trends. Such data includes information on country-specific effects and growth trends so that the MRW identifying assumption becomes unnecessary. Phillips and Sul (2007) develop a time-varying common factor model which incorporates a country-specific effect that can vary over time as a complement to a common deterministic growth trend. The authors use the model to develop a simple and direct test for convergence over time and a clustering algorithm to combine regions into convergence clubs. Such methods paint a complete picture of cross-country growth process by permitting both non-excludable factors of growth along with any unique and excludable components of growth.

There are several other types of convergence research which employ search algorithms to determine growth clubs. Moral-Benito (2012), and Sala-i-Martin, Doppelhofer, and Miller (2004) use Bayesian averaging to determine which countries belong in which clubs. Other research is designed to address the problem of interdependence between cross-sections, perhaps due to trade. Costantini and Destefanis (2009) use cointegration and the "continuous-updated fully modified" estimator of Bai, Kao, and Ng (2009) to estimate in the presence of dependent cross sections. Other contemporary estimation methods also involve ways to allow for variation in the parameters along with the cross-sectional interdependence. Common correlated effects estimators first derived by Pesaran (2006) and applied by Bhattacharjee, de Castro, and Jensen-Butler (2009), Eberhardt and Teal (2009), and Fleisher, Li, and Zhao (2010) can accomplish estimation under these least restrictive set of assumptions.

When it comes to an acknowledgment of the estimates that put some countries above their steady states, there may be a total of three papers written specifically on the subject of calculating steady states within the convergence setting, with the last two being working papers: Cho and Graham (1996), Mathunjwa and Temple (2006), and Hollanders and Ziesemer (1999). Okada (2006) has an interesting paper which uses the theoretical relationships to calculate steady states using the commonly assumed shares of capital and then runs a convergence analysis on the sub-samples. In comparison, this present research empirically estimates the steady states and then notes the importance of the interpretation of different TFPs in a panel setting.

Today, conditional β-convergence is tested in well-defined contexts but remains active. Rodrik (2013) tests for cross-country convergence in the manufacturing sectors of 118 countries. Such an analysis adds another layer to convergence theory: instead of focusing on similar regions, different economic sectors may be determined to be technologically similar. Rodrik is observing unconditional convergence at this point, and shows that sectors may converge in absolute terms. Also, data availability continues to be less of a problem. Now regional convergence in China is an area of active research (Andersson, Edgerton, and Opper, 2013). Andreano, Laureti, and Postiglione (2013) look at convergence in the MENA region. Work is also still carried out on the "advantages of backwardness" (although this present research shows that it's convergence from above which is likely for those in poverty). Ravallion (2012) shows that, by also assuming convergence from below, there should be a reduction in poverty rates of the least developed nations.

2.2.1. The Transition Literature

Theory would predict that the incentives in place during the Soviet era of planned economies would lead to an overallocation of resources into investment and that this capital would still be present during the initial stages of transition. The first part of this section will take a look at the theory and anecdotes of overcapitalization during the transition. The European Bank for Reconstruction and Development (EBRD) has maintained an index tracking the changes in regulatory institutions and enforcement of property rights for over two decades. Empirical work which includes the index will be presented here. Lastly, the literature which also studies growth convergence in transition economies will be touched on. This last section is brief due to the limited amount of work on the convergence of transition economies.

In "Transition and Institutions," the authors treat Russia as a late reformer, noting that the Russian transition toward privatization and liberalized prices can be characterized as "inconsistent shock therapy" (Cornia and Popov, 2001). Being a late and inconsistent reformer is one thing, but Kolodko (2000) clarifies the difference between "market-oriented reform and a transition to market economy." A transition to a market economy involves a restructuring of political institutions along with economic institutions. Decades later, few transition economies outside of Eastern Europe have completed this process. Interestingly, much of the reform process could have found its catalyst in the overallocation of capital and consequent shortage of consumer goods.

Overinvestment had been a steady problem, but slight reforms to the planning system may have only worsened it. The pre-transition attempts at reform were designed to compensate for the overallocation of capital by freeing up the flows of investment. "Typical of bureaucratized central management, such drives (toward the reform of the 1980s) had previously led to overinvestment, with all the adverse consequences for performance, especially widening imbalances and lower productivity" (Kolodko, 2000, p. 16). Kolodko is referring to the soft budget constraints in which the centralized version of lending led to a continual accumulation of capital. Vladimir Popov, a research fellow at UNU/WIDER during the transition and Head of the Research Sector at the Russian Academy of National Economy might extend this claim to say that all centrally planned economies were subject to overinvestment. "The Soviet economy, however, was more defense and investment oriented than other socialist economies" (Cornia and Popov, 2001, p.31).

János Kornai contrasts investment in the context of a planned economy to that of more western economies:

> "The allocators do not search for an entrepreneur waiting to step forward with a proposal for innovation. Flexible capital markets are unknown. Instead, the rigid and bureaucratic regulation of project activities takes place. And to devote capital resources to activities with possibly uncertain outcomes is unconceivable" (Kornai, 2012).

So the problem overinvestment under communism is two-fold: investment is rarely used for risky investments as in market economies so it is accumulated by large industries which may not need so much, and any incremental reform is likely to exacerbate the problem by leading to easy lending practices on the part of the central bank. These lending practices are often described as soft budget constraints and form the cornerstone of János Kornai's work on chronic shortages. In his book, *Economics of Shortage* (Kornai, 1980), Kornai formalized many of the descriptions of how capital and consumer goods were being misallocated under centralized planning. At first glance, the link between lending and overinvestment is straightforward: purchases of physical capital can occur at a higher rate when financing comes with ease. But the question remains: why don't planners recognize the inefficiency and correct the problem? The answer lies in the perpetual pressure among socialist planners to maintain full employment. As a firm manager, capital purchases may make your workforce more productive and it certainly gives current employees something to work with. As a planner, the production of capital should lead to more employment too. This leads to a state of chronic shortage in which there is sufficient demand but insufficient provision of consumer goods.

In order to conduct an empirical analysis of capital during this period, we'll need to be able to control for the incredible changes in institutions which are occurring during the entire set of observations. The EBRD Transition Indicators serve as measure of these institutions (EBRD, 2012). The indices give measures of large-scale and small-scale privatization, price liberalization, governance and enterprise restructuring, the trade and foreign exchange system, and competition polices. One of the first papers to find linkages between the indices and growth was Sachs (1996). Sachs uses a cumulative index to find a positive relationship between the institutional changes and growth. Several other empirical studies find similar results. Christoffersen and Doyle (2000) use an unbalanced panel data set to regress GDP growth on exports, inflation, and the EBRD cumulative index. The index is highly significant and positively correlated to GDP per capita growth. Hernández-Catá (1997) regresses real GDP growth on the EBRD indices, inflation, a speed of restructuring variable, and various dummies including war, ruble zone and regions. His results show a negative, robust, and significant relationship of price liberalization to GDP growth for the years 1990 to 1995. Godoy and Stiglitz (2006) acknowledge that, "cross section analysis can at best be only suggestive," but they attempt to compensate for this by employing instrumental variables. This work also attempts to determine the effects of the speed of privatization by employing the difference of the 2000 and 1991 EBRD privatization indices. The OLS regression shows that the speed of privatization has a negative effect while the level of the privatization index is insignificant. Two-stage OLS provides similar results. Havrylyshyn (2003) find a negative relationship between the transition indices and growth, but only in the first year; the correlation is positive thereafter.

Overall, the empirical work covered here provides slightly mixed results but with most finding a positive impact on growth. The reason this mixed relationship occurs is because of the U-shaped growth process during the transition. Many countries began to stabilize after 1995, and this is when the sample begins in the empirical results of Chapter 5. Using this year as the start of the sample is due to availability, but it may put the focus in the upward portion of the U-growth.

The above uses of the EBRD indices are conducted to study growth, but not necessarily convergence in income levels. There are some papers which do study convergence using some of the same countries in our sample, but there are few. Rapacki and Próchniak (2009) look at 27 of the 28 transition economies used in Chapter 5. They also focus on the 1990–2005 period and are mainly concerned with absolute (i.e. unconditional) β convergence and convergence in variance. Without the use of the conditioning variables, the authors find some periods of β convergence. Outside of this study of convergence, there is another that is descriptive and looks at the impact of FDI on certain sectors of Eastern European economies (Sohinger, 2005). The other related work is composed of time series methods. Estrin, Urga, and Lazarova (2001) test for cointegration and use a Kalman filter test for convergence among 26 of the transition economies. Kočenda (2001), and Kutan and Yigit (2004) use versions of Augmented Dickey-Fuller regressions to test for convergence among Eastern and Central European economies. Tsanana and Katrakilidis (2013) use Lagrange Multiplier (LM) unit root tests for convergence among the Balkans and an interesting paper by Yorucu and Mehmet (2014) exploit institutional variation on the island of Cyprus, part of which belongs to Turkey and is also included in our sample of transition economies. Turkey is an interesting case as it is one of the more advanced reformers and wasn't part of the Soviet Union or Eastern Bloc.

In sum, the convergence literature is broad. This is likely due to the fact that convergence is the study of income dynamics between national economies so will always be of central importance to macroeconomic development and comparative economics. Of course, convergence came to prominence as the more traditional empirical side of the study of economic growth, and it certainly has a role in that field, but it will always be a central question to development and comparative studies of international economics.

The next chapter will introduce the method to test for country-level positions relative to their steady states and to determine which side they will converge from. This adds yet another layer to the study of convergence.

CHAPTER 3

Theory and Empirical Methods

3.1. Convergence Theory from Above and Below

In much of the convergence literature, the relationship between the empirical results and the conclusion that there is cross-country convergence in incomes is usually explained in a brief and intuitive manner. In order to take some steps toward a more rigorous analysis, this section attempts to more precisely describe how the conclusion of cross-country income convergence emerges from the empirical analysis. To fully understand the link between theory and empirics, we need to break down the notion of convergence in order to get to its theoretical and empirical core. In so doing, the fact that countries have unique production functions must also be addressed. This section takes on such a task.

To begin with, take the two forms of unconditional convergence:

$$y_t = b_0 + b_1 y_{t-1} \quad \text{and} \quad \Delta y_t = b_0 + b_1' y_{t-1} \tag{1}$$

The two are algebraically and empirically equivalent convergence equations where the second form comes from subtracting y_{t-1} from both sides of the first, so that $b_1' = -(1 - b_1)$. Both are forms of a partial adjustment model. If b_1 were greater than one, then this would imply that incomes diverge: a higher initial level of output would result in an even higher level of output in the future. But given the diminishing returns to capital in the Solow model, one would expect b_1 to be positive but less than one. It's more intuitive to consider the second form and observe that if b_1 were positive and less than 1, then b_1' would be negative. The larger the y_{t-1}, then the smaller Δy_t and countries would converge. This would be true even if y_{t-1} were so large that Δy_t would be negative; at this point a country would be converging from above. Therefore, with convergence, b_1' is estimated as having a negative value regardless of which direction the country is converging from and despite the two directions having incredibly different implications for development. The finding of a negative b_1' (or positive b_1) is due to the fact that standard tests of convergence are really indirect estimates of the slope of the curve in Figure 3.1. Figure 3.1 describes why we would expect some form of convergence. The figure shows the standard transition equation, given by $\dot{k}(t) = sA(t)k(t)^{\alpha} - (n + g + \delta)k(t)$ which describes the evolution of capital stock per worker and where n, g, and δ are the labor force growth rate, the technological growth rate, and depreciation. The level of capital intensity is determined by α, as is indicated in Figure 3.1. Due to the fact that $\alpha < 1$, diminishing returns will set in and the growth rate of capital should turn negative. Linearization around the steady state puts the focus on this negatively sloped portion of the transition equation.

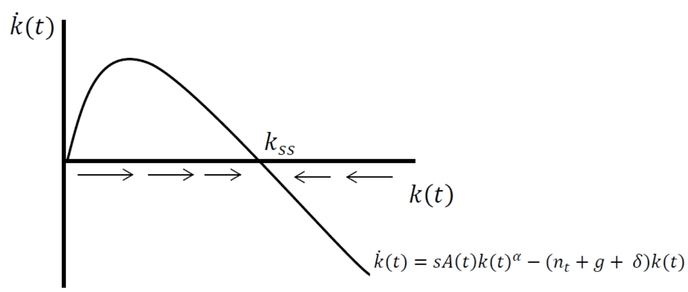

FIGURE 3.1. The Solow Transition Equation: Capital Accumulation (or Capital Disinvestment)

What also needs to be clear is what a convergence regression actually does with respect to Figure 3.1. If there is an observation which has a low level of capital per worker and a high growth rate, then this observation will contribute to a negative correlation as is illustrated. Likewise, a country with a high level of $k(t)$ and low, possibly negative, growth rate will also contribute observations which support the notion of convergence. In the panel setting of conditional convergence, this occurs only after controlling for differences in investment, population growth, education, and TFP, all of which determine the position of the transition equation and k_{ss}, the steady state level of per worker capital. This explains why conditional convergence is easier to find than absolute: it controls for the differences and obtains the convergence result when a country is heading toward its own *unique* steady-state, regardless of whether this is from above or below. However, the direction from which a country is converging gives information essential to the formulation of development policy.

When there are differences in TFP, the position of the transition equation is dependent on $A(t)$, the level of TFP, which is in part established by the fundamental determinants of growth. Then it can be seen how a country may find itself above its steady state. If there is a political event which leads to a fall in $A(t)$, then we would expect a fall in the $\dot{k}(t)$ curve and the existing level of capital per worker would be above the new k_{ss}. Disinvestment would then ensue. Such an outcome is illustrated on the following page in Figure 3.2. There is now a lower curve indicated by $\dot{k}(A^l(t), k(t))$ where $A^l(t) < A^h(t)$. Figure 3.2 also illustrates a key prediction of the Solow model. If two countries start with a similar level of capital stock per worker, but one country has lower TFP, then there will be cross-country income *divergence* between the two. Here, one can observe why conditional convergence is more easily detected than unconditional: k' can be associated with either positive or negative growth, so you must condition on the factor that determines the position of the steady state in order to find the negative relationship. There are numerous ways in which a country may be converging from a position above its steady state as is shown in the low-productivity case. Transition economies may find themselves in such a position following a period of poorly planned investment. Persistently inadequate institutions along with foreign investment could also keep $k(t)$ above k_{ss}. Rodriguez and Sachs (1999) note that a natural resource curse could also lead to such a position for a developing economy if wealth and power is centralized, consumption is low, and revenues are directed into too much investment. It's also likely that a nation with overbuilt housing stock may be in such a position. This would be the case in countries like the US, Spain, and Ireland leading up to and following the 2007-2009 recession, especially if the financial collapse is interpreted as a negative technological shock.

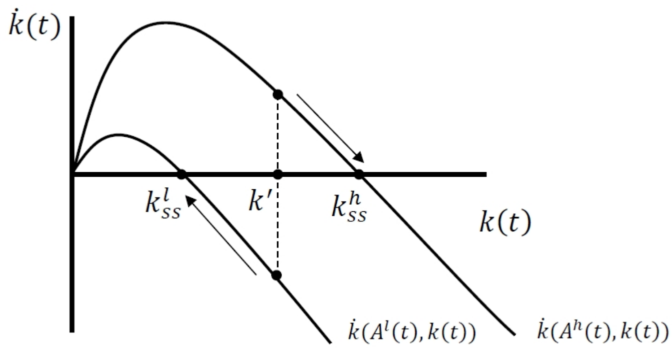

FIGURE 3.2. Economies with Low and High Productivities

Given this, convergence from above implies that there is overcapitalization, but this term only has meaning relative to the level of total factor productivity. If there were a higher level of TFP then the level of capital per worker would no longer be too high. On the other hand, convergence from below implies a country can develop through financial means and has a high enough level of TFP to sustain capital accumulation. By this argument, an overcapitalized economy is the same as one which has too low of factor productivity. In the end, overcapitalization and insufficient TFP are just two sides of the same coin.

Yet another perspective is given in Figure 3.3. There a developed economy would have $y(A^h(t),(k(t))$ as a production function while a developing economy would have $y(A^l(t),(k(t))$ because of productivity differences. Their respective steady states might be k^h_{ss} and k^l_{ss}. Normal convergence would occur if the developed economy was also below its steady state at, say k'', such that it would grow rapidly at first but slow down as it approached its own steady state. On the other hand, convergence from above would occur if the developing economy with low productivity somehow found themselves at k'. At this point, the economy does not have the level of TFP that is required to maintain this high level of capital. So, in the long run, output in the economy will fall and the economy will converge to its steady state from above.

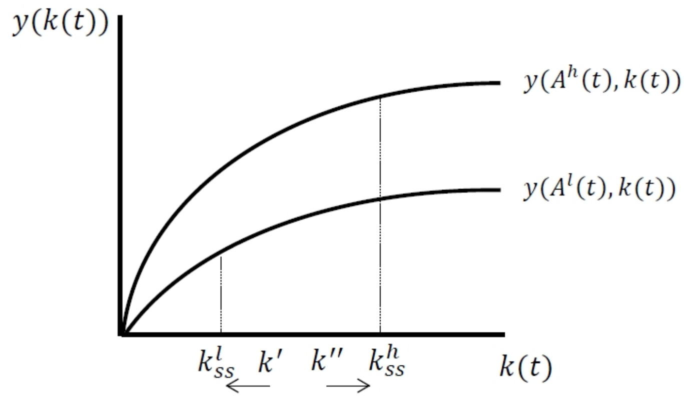

FIGURE 3.3. A Developing and Developed Economy

Despite these clear implications, very few theorists have chosen to write on the subject. Cho and Graham (1996) are the first to notice the empirical reality of convergence from above, but afterward the authors chose to write little more on the subject. They correctly note that,

> "With this result, one may find hardly any grounds for policies such as the World Bank's investment in these poorer countries *with the intent of pushing them towards their steady states*." (Emphasis added)

But the authors forget about the other side of the story: investment may be ineffective when above the steady state, but this is only because TFP is too low to sustain it. One possible reason this conclusion wasn't put forth is the fact that TFP is considered to be constant across countries in the cross-sectional studies of MRW and Cho and Graham (1996). However, panel data permits a very different interpretation of the results, one which allows for countries to have different production functions. Thus, with more complete results in hand, the interpretations are very different, and we find that the World Bank would be a wise investor if it worked with an institution like the UN to improve institutions by, say, ensuring election security, rule of law, fair and equal access to economic institutions, and the maintenance of peacekeeping forces. This present research hopes to make clear that peacekeeping, equity, and ensuring clean elections aren't just good public policy, but sound financial investments.

3.2. A Panel Data Method for Estimating Steady States in a Convergence Analysis

The main methodological difference between calculating steady states in a panel data setting and doing so in a cross-sectional setting as in Cho and Graham (1996) is that panel data contains multiple time periods, as opposed the change between only two periods. Rates of change are computed over multiple increments of time and then used to define the first time period of full observations as the initial period in which $t = 0$. From there, the method simply recovers the parameter estimates and allows t to grow in a linear fashion. Although, it's worth noting that in Islam (1995) the specification of the time trend is nonlinear. In this present work, the model is put into discrete form before the final substitution which results in a linear time trend. This is done in order to remain more consistent with the original form of the model.

Nazrul Islam developed the methods to estimate convergence within panel data (Islam, 1995) and then elaborated on the nature of estimating country-specific "within convergence" with such methods (Islam, 2003). What is unique in the dynamic panel setting is the ability to estimate country-specific total factor productivities. Without panel data, there is an implicit, if not explicit, assumption that countries have the same production technologies.

Differing productivities are essential to make much sense of the results in which developing countries are above their steady states.

Islam's method and the one herein is based on MRW. Much of it is familiar, but the following still includes details to illustrate the link to convergence theory. In the following section, other parts of the model will be discussed more fully in order to make clear that the addition of an institutional parameter does not affect other variables. There are essentially two parts to the development of the method. One part is to linearize the model and then find a solution to the resulting differential equation. In per worker terms, in order to find the solution, you will also need the per worker value of the steady state at $time = 0$, which is the other part of the derivation. The fact that $gt = 0$ at this point allows for substitution of this initial steady state in order to solve the differential equation. The initial steady state can then be substituted again to introduce human and physical capital investment and population growth rates for the subsequent empirical analysis.

The traditional aggregate production function has labor augmenting technology and is homogeneous of degree 1:

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} (L(t)A(t))^{1-\alpha-\beta} \tag{2}$$

where $K(t)$ is capital stock, $H(t)$ is a stock of human capital and $L(t)$ is the stock of labor hours. $L(t) = L(0)e^{nt}$ determines the rate of growth of labor, $A(t) = Ae^{gt}$ gives a level of TFP with growth rate g, while the transition equations for $K(t)$ and $H(t)$ are given later in efficiency worker terms. As is, the above production function does not result in a steady state in the mathematical sense, since it will grow at a rate determined by the growth of $A(t)$ and $L(t)$. So, equation (2) needs to be formulated in order to control for the growth due to gt and nt and also to then use that result to log-linearize around an "effective worker" steady state. The solution is to rewrite equation (2) by subsuming $(L(t)A(t))^{-\alpha}$ into $K(t)^{\alpha}$ and $(L(t)A(t))^{-\beta}$ into $H(t)^{\beta}$. Both sides are then divided by $L(t)A(t)$ to get

$$\hat{y}(t) = \hat{k}(t)^{\alpha}\hat{h}(t)^{\beta} \tag{3}$$

$$\dot{\hat{k}}(t) = s_k\hat{k}(t)^{\alpha}\hat{h}(t)^{\beta} - (n+g+\delta)\hat{k}(t) \tag{4}$$

$$\dot{\hat{h}}(t) = s_h\hat{k}(t)^{\alpha}\hat{h}(t)^{\beta} - (n+g+\delta)\hat{h}(t) \tag{5}$$

where s_k and s_h are the rates of saving/investment into physical and human capital. The transition equations, $\dot{\hat{k}}(t)$ and $\dot{\hat{h}}(t)$ describe the path of convergence that physical and human capital will take when they are away from the steady state. The goal is then to determine the transitional dynamics of $\hat{y}(t)$ w.r.t. $\hat{k}(t)$ and $\hat{h}(t)$. But $\hat{y}(t)$, $\hat{k}(t)$, and $\hat{h}(t)$ are all nonlinear so in order to study motion toward the steady state, a linear approximation is needed. After a first-order Taylor expansion and substitutions described in Section 3.3.1., one obtains Equation 6:

$$\frac{\dot{y}(t)}{y(t)} = g - \lambda(\ln\hat{y}(t) - \ln\hat{y}^{*}) \tag{6}$$

where λ is the coefficient of convergence which is to be estimated empirically and gives the speed at which a country convergences to its own unique steady state.

At this point it's worth noting that the above form has the left hand in per worker terms. Here, theory shows that a country may encounter a negative impact on their per worker growth rate from being *above* their steady-state level of output but still have an overall positive level of per worker growth as long as $g > \lambda(\ln \hat{y}(t) - \ln \hat{y}^*)$. From a more practical standpoint, if a country is above its steady state, it can still grow but only from g, the non-rival, non-excludable technology. If this occurs, increases of investment into the country will only serve to increase the amount by which per worker GDP should *decrease* in order to return to its steady state. To be precise, if investment was constant, g may be large enough to grow the steady state and move the steady state closer to the actual level of output, but the key feature to note at this point is that overcapitalization is a state in which the level of capital stock, and therefore output, is too high for the existing the level of TFP. The economy is simply not productive enough to maintain its stock of capital per worker. If the TFP were higher, then a country would have a higher steady state level of output and be closer to its actual, high level of capital stock per worker.

To finish this part of the modeling, we'd like convert Equation 6 so that all terms are per-worker and then solve the differential equation. Converting into per worker terms is straight forward given that the $A(t)$ terms cancel out given that $y^*(t) = A(t)\hat{y}(t)$ so that we have,

$$\frac{\dot{y}(t)}{y(t)} = g - \lambda(\ln y(t) - \ln y^*(t)) \tag{7}$$

where $\ln y^*(t)$ is the per-worker steady state, also known as per-worker output along the balanced growth path. In this form, improvements to TFP would have a weighted impact on actual output with $(1 - \alpha - \beta)$ being the weight (as can be seen in Equation 9), but the increase in $A(t)$ would also have a full and direct impact on the steady state. Thus, if output was above the steady state, improvements in TFP raise the steady state faster than output and take us closer to a long-run equilibrium.

To solve this equation, we use a coefficient of integration, then integrate by parts using Equation 18, the initial per worker steady state determined in the next section. The solution gives:

$$\ln y(t) = gt + e^{-\lambda t} \ln y(0) + (1 - e^{-\lambda t}) \ln y^*(0) \tag{8}$$

3.2.1. Per Worker Steady State Values

Keeping with the per worker specification of the variables is important for empirical analyses as data isn't really available in efficiency terms but it is available in per worker or per capita terms. Steady-state variables written in per worker terms grow at the same rate as $A(t)$, so the term "steady state" may not be well-used here in the per worker sense and is sometimes referred to as balanced growth. The following derivation is the same as is in Bernanke and Gürkaynak (2002).

Along the balanced growth path, the variables in per worker terms, $y(t)$, $k(t)$, and $h(t)$ all grow at the same rate, g when total factor productivity is defined as $\dot{A}(t)/A(t)$. The per worker version of the model is given by:

$$y(t) = A(t)^{(1-\alpha-\beta)} k(t)^{\alpha} h(t)^{\beta}$$

(9)
$$\dot{k}(t) = s_k y(t) - (n+\delta) k(t)$$

$$\dot{h}(t) = s_h y(t) - (n+\delta) h(t)$$

Then the growth rate of per worker output is

(10)
$$\frac{\dot{y}(t)}{y(t)} = (1-\alpha-\beta)\frac{\dot{A}(t)}{A(t)} + \alpha\frac{\dot{k}(t)}{k(t)} + \beta\frac{\dot{h}(t)}{h(t)}$$

It has been shown that along the balanced growth path $\frac{\dot{y}(t)}{y(t)} = \frac{\dot{A}(t)}{A(t)} = \frac{\dot{k}(t)}{k(t)} = \frac{\dot{h}(t)}{h(t)} = g$ (Barro and Sala-i-Martin, 2004). Thus,

(11)
$$g = (1-\alpha-\beta)g + \alpha\frac{\dot{k}(t)}{k(t)} + \beta\frac{\dot{h}(t)}{h(t)}$$

and

(12)
$$g = (1-\alpha-\beta)g + \alpha s_k A(t)^{(1-\alpha-\beta} k(t)^{\alpha-1} h(t)^{\beta} - \alpha(n+\delta)$$
$$+\beta s_h A(t)^{(1-\alpha-\beta)} k(t)^{\alpha} h(t)^{\beta-1} - \beta(n+\delta)$$

which is rearranged to get

(13)
$$g = g + \alpha[s_k A(t)^{(1-\alpha-\beta} k(t)^{\alpha-1} h(t)^{\beta} - (n+g+\delta)]$$
$$+\beta[s_h A(t)^{(1-\alpha-\beta)} k(t)^{\alpha} h(t)^{\beta-1} - (n+g+\delta)]$$

From here it can be seen that either $\alpha = \beta = 0$ or $s_k A(t)^{(1-\alpha-\beta)} k(t)^{\alpha-1} h(t)^{\beta} = (n+g+\delta)$ and $s_h A(t)^{(1-\alpha-\beta)} k(t)^{\alpha} h(t)^{\beta-1} = (n+g+\delta)$. Given the latter argument, the per worker steady states are then

$$k^*(t) = \left[\frac{A(t)^{(1-\alpha-\beta)} s_k^{1-\beta} s_h^{\beta}}{(n+g+\delta)}\right]^{\frac{1}{(1-\alpha-\beta)}} = A(t)\left[\frac{s_k^{1-\beta} s_h^{\beta}}{(n+g+\delta)}\right]^{\frac{1}{(1-\alpha-\beta)}} \tag{14}$$

and

$$h^*(t) = \left[\frac{A(t)^{(1-\alpha-\beta)} s_k^{\alpha} s_h^{1-\alpha}}{(n+g+\delta)}\right]^{\frac{1}{(1-\alpha-\beta)}} = A(t)\left[\frac{s_k^{\alpha} s_h^{1-\alpha}}{(n+g+\delta)}\right]^{\frac{1}{(1-\alpha-\beta)}} \tag{15}$$

Also, to find $y^*(t)$

$$\begin{aligned} y^*(t) &= A(t)^{(1-\alpha-\beta)} A(t)^{\alpha} A(t)^{\beta} \left[\frac{s_k^{\alpha} s_h^{\beta}}{(n+g+\delta)^{(\alpha+\beta)}}\right]^{\frac{1}{(1-\alpha-\beta)}} \\ &= A(t)\left[\frac{s_k^{\alpha} s_h^{\beta}}{(n+g+\delta)^{(\alpha+\beta)}}\right]^{\frac{1}{(1-\alpha-\beta)}} \end{aligned} \tag{16}$$

So, in the end we have

$$\begin{aligned} y^*(t) &= A(t)\hat{y}^* \\ k^*(t) &= A(t)\hat{k}^* \\ h^*(t) &= A(t)\hat{h}^* \end{aligned} \tag{17}$$

Here the per worker steady states (i.e. balanced growth variables) will grow in proportion to $A(t)$ where $A(t) = Ae^{gt}$ and A is time invariant.

Observe that when the per worker steady state of output is evaluated at an initial period where $t = 0$ we have: $y^*(0) = A\hat{y}^*$. We can then find the log of $y^*(0)$ to get,

$$\begin{aligned}\ln y^*(0) = \ln A + \frac{\alpha}{(1-\alpha-\beta)} \ln s_k + \frac{\beta}{(1-\alpha-\beta)} \ln s_h \\ - \frac{\alpha+\beta}{(1-\alpha-\beta)} \ln(n+g+\delta)\end{aligned} \tag{18}$$

Equation (18) will produce the final results of this present endeavor. Notice that there is no time dependent component to it, but the parameters can be estimated empirically by using this standard convergence model in discrete form (presented next) and then computing the values and variances of the initial steady state per worker income. Comparing this result to actual per worker incomes gives us information about where countries are relevant to their steady states in the initial period of the sample. This gives insights into the subsequent patterns of growth.

3.2.2. Moving Into a Discrete Form for Empirical Analysis

The next steps are to 1) specify the empirical model and 2) show how such a model can be used to calculate per worker steady states. The first part is covered by Islam (1995) in his classic paper on the dynamic panel estimation of convergence. A short paper by Cho and Graham (1996) is also used to help derive per worker steady states. What follows is a combination of the two which permits the panel estimation.

There isn't necessarily a direct link between the theoretical model and a discrete estimable form. As was mentioned, the main issue is that in reality and in the data, there is no $time = 0$ from which to calculate the initial values of the variables. Also, rates of change can be calculated over smaller increments instead of over the entire period of the sample. Incremental differences and averages help control for some heteroscedasticity due to short run business cycles. Islam's direct approach is to designate five-year time intervals and assign the earliest period of full observations to the theoretical $time = 0$ in the Solow model. A similar change of notation is made here, but instead of beginning in terms of efficient workers, we start in per worker terms using Equation 8 and Equation 18. In these two equations, we assign $\tau = t_2 - t_1$, to indicate the initial period. This is illustrated in Equation 19 which is a discrete form of Equation 8. We use an increment of five years, so that if the first year is 1965 then $t_1 = 1965$ and $t_2 = 1970$. We can then define a time trend, use it for t in gt, and define the theoretical $time = 0$ as t_1, or 1965. From there, the per worker steady state will grow at a rate g and gt will then grow with the per worker levels of output at the specified time trend. In the actual estimation a discrete unitary trend is chosen. Also, the designation of $y^*(\tau)$ is used in the final term to show that the measures of saving, human capital investment, and population growth are averages taken between t_2 and t_1, or whichever period is relevant.

$$\ln y(t_2) = gt_1 + e^{-\lambda\tau} \ln y(t_1) + (1 - e^{-\lambda\tau}) \ln y^*(\tau) \tag{19}$$

For this initial steady state where $t_1 = 0$, we have from Equation 18:

$$\begin{aligned} \ln y^*(\tau) = \ln A + \frac{\alpha}{(1-\alpha-\beta)} \ln s_k + \frac{\beta}{(1-\alpha-\beta)} \ln s_h \\ - \frac{\alpha+\beta}{(1-\alpha-\beta)} \ln(n+g+\delta) \end{aligned} \tag{20}$$

Substituting Equation 20 into Equation 19 gives[4]:

$$\begin{aligned} \ln y(t_2) &= gt_1 + e^{-\lambda\tau}\ln y(t_1) + (1-e^{-\lambda\tau})\ln A \\ &+(1-e^{-\lambda\tau})\frac{\alpha}{(1-\alpha-\beta)}\ln s_k + (1-e^{-\lambda\tau})\frac{\beta}{(1-\alpha-\beta)}\ln s_h \\ &-(1-e^{-\lambda\tau})\frac{\alpha+\beta}{(1-\alpha-\beta)}(n+g+\delta) \end{aligned} \tag{21}$$

In order to make the final change to a dynamic panel model we can specify the country-specific effect, the time trend and append a purely stochastic error term. This gives the following familiar empirical model.

$$y_{it} = \gamma y_{i,t-1} + \sum_{j=1}^{3}\beta_j x_{it}^j + \eta(t-1) + \mu_i + v_{it} \tag{22}$$

where we have

$$\begin{aligned} & y_{it} = \ln y(t_2); y_{i,t-1} = \ln y(t_1);\ \gamma = e^{-\lambda\tau} \\ & \beta_1 = (1-e^{-\lambda\tau})\frac{\alpha}{(1-\alpha-\beta)};\ \beta_2 = (1-e^{-\lambda\tau})\frac{\beta}{(1-\alpha-\beta)}; \\ & \beta_3 = (1-e^{-\lambda\tau})\frac{\alpha+\beta}{(1-\alpha-\beta)} \\ & x_{it}^1 = s_k;\ x_{it}^2 = s_h;\ x_{it}^3 = (n+g+\delta) \\ & \eta = g; \mu_i = (1-e^{-\lambda\tau})\ln A \end{aligned} \tag{23}$$

[4]As an aside, conceptually, we can distribute $(1-e^{-\lambda\tau})$ through each of the last four terms of Equation 21 and then collect like terms to get: 1) $gt_1 + \ln y^*(\tau)$ (which is equivalent to next period's $\ln y^*(\tau)$), and 2) $-e^{\lambda\tau}(\ln y(t_1) - \ln y^*(\tau))$ which is due to convergence as defined in Equation 7 with λ now equal to $-e^{\lambda\tau}$.

This is the same form as is in Islam (1995), except for the way that the time trend is specified. It has been derived slightly differently, and while the $\eta(t-1)$ notation may be a bit clumsy, this specification indicates that the linear time trend grows with each subsequent five-year increment (i.e $t = 1, 2, 3, ...$). As is commonly ignored, a time trend within each increment would result in a constant when regressing the five-year increments in a panel (e.g. $(t_2 - \lambda t_1)$) would be constant for each observation). The parameters can be estimated with any number of methods, but the preferred estimator is the system-GMM estimator described later. The main advantage is that the estimator not only addresses the time series issues, but allows for institutions as traditional instruments along with the system-GMM autoregressive instruments. As was shown in the previous section, to recover Equation 20, the initial steady state level of per worker output, we can simply omit $\eta(t-1)$, $\gamma y_{i,t-1}$ and υ_{it} from the right hand side of the empirical model and then dividing the result by $(1-\gamma)$. This method is equivalent to defining the steady state as a point where $y_{i,t} = y_{i,t-1} = y^*(t)$, then solving for $y^*(t)$ and setting $\eta(t-1) = \upsilon_{it} = 0$. $\eta(t-1) = 0$ comes from assigning an initial $(t-1) = 0$. The following steady states can then be calculated for $t = 2, 3, 4, ...$ as is consistent with the per-worker steady state. During the estimation, the first year of complete observations (including lags) can be designated as the year in which $time = 0$. After that, there is a deterministic growth trend so that $time = 1$ followed by $time = 2$ etc. Calculating steady states in this manner is also how long-run values are calculated in the partial adjustment model. For instance, long-run propensities to consume may come from the estimation of a consumption function in a partial adjustment model. Here, the long-run values are the capital and human capital shares of output.

3.3. A Simple Extension of the Augmented Solow Model for Dynamic Panel Analysis

This is an extension of the model presented in MRW. The objective here is to add a time-independent institutional component to total factor productivity. The institutional component enters into the model as a parameter, but much like the saving and education rates in the classic convergence papers, the values of institutional indicators will vary in the data. The variation of any of these parameters has always been explained as a shock. Rather than adding any sui generis ambiguity, including an institutional parameter allows for differences in total factor productivity to come from two sources: one from an initial level of country-specific total factor productivity and another from a country-specific measure of institutions which may face unspecified shocks. There is still a common growth trend to all countries, but having an institutional shift parameter can mimic sporadic and instantaneous changes which may also impact the long-run growth rate.

If such a shift parameter is missing, this is tantamount to specifying all economic growth (including that due to protection of property and equality of access) as progressing along a time trend common to all countries. Also, when including a shift parameter, in order for the simple specification used here, the trend must be independent of time. Given this, it seems reasonable that institutional characteristics aren't common to all countries and, as for institutions following a progressive time trend, one may only need to consider the history of ancient Greece to know that democracy isn't permanent or the history of the Russia to know that private property rights may come and go, and then come back again. That is, it's not likely that every economic system is presently on a progressive deterministic path toward, say, a market-based representative democracy. Allowing for both a technical trend and an additional country-specific determinant of total factor productivity gives flexibility and realism which is otherwise missing in the standard model. Others (e.g. Lee, Pesaran, and Smith (1997) and many DSGE models for that matter) specify technology as following a completely random process. Here it's sufficient to manually separate the linear growth trend from the country-specific factors which we may have estimates for and allow the empirical estimation to simulate differential growth rates through a shift parameter. This side-steps the need to specify a data generating process for TFP much in the same way that saving rates and education are treated as parameters in the MRW model.

Conceptually and empirically, given the additive specification, many of these types of institutional parameters can be included as long as they are assumed to be independent of time. In what follows, the potential z are such institutional factors and are likely to be excludable forms of economic technology, such as regulation of property rights, ease of market entry, or other laws which ensure equal and efficient access to a country's economic institutions. They are said to be excludable because they can only affect the country in which they are enforced and are thus distinct from time-dependent forms of non-rival and non-excludable technology. The traditional non-excludable forms of technology are innovated or adopted at a rate which takes the familiar gt form where g is the growth rate of these forms of technology. Addressing both excludable and non-excludable forms of technology in the specification of total factor productivity seems to make sense as the both are likely to be present in the actual growth process. In the following, a standard analysis of the Solow model is carried out in order to show that the addition of z does not affect the rest of the model and results in a convenient form in which to append institutional variables to the augmented Solow model.

3.3.1. An Extension of the Augmented Solow Model

Total factor productivity is extended by adding z to its rate of growth. As stated above, the additional variable is likely to be institutional in nature and can be adjusted by policy-makers in an attempt to impact the level of total factor productivity and the level of output. The policy decision is not modeled and is assumed to be independent of time. The goal here is an ex-post empirical analysis given that we have knowledge of past z. Let ρ be the percent change in total factor productivity in response to a change in z, whichever measure z may be. Note that in what follows ρz can also be a multiple of vectors such that $\rho z = \rho_1 z_1 + \rho_2 z_2 + ... + \rho_n z_n$, allowing for a multitude of such measures. The ρ can be estimated empirically and they determine the relative impact of each productivity shock. Then total factor productivity can be given by

$$A(t) = Ae^{gt+\rho z} \tag{24}$$

Here g is a common rate of growth attributable solely to nonrival transferable technology and is commonly thought to be 2%. Following MRW and Islam, $g = 2\%$ is assumed for $(n + g + \delta)$, but is also estimated as a growth trend by the coefficient on t. Time t is a variable indicating how many periods have passed since an initial period. A is the country-specific effect which represents initial and constant idiosyncratic characteristics of the level of productivity. This specification allows the deterministic time trend, gt to be separated from other types of technology (e.g. institutions) which are not dependent on time and may be nontransferable and unique to a specific economy.

The new TFP specification still gives a production function with two transition equations stated in efficiency terms, only now there is a ρz term. Equation 24 grows at a rate determined by gt and is essentially shifted by ρz. As long as linearization is carried out in efficiency terms (i.e. where $\hat{y}(t) = Y(t)/(A(t)L(t))$, any impact that z has on the steady state $\hat{y}(t)$ is offsetting and leaves the steady state in efficiency terms as a constant. The addition of ρz also does nothing to increase "break-even" levels of investment which are still given by $(n + g + \delta)$.

The essential steps of the derivation are as follows. First note that $\ln y(t) = \ln A + gt + \rho z + \alpha \ln \hat{k}(t) + \beta \ln \hat{h}(t)$, where $y(t)$ is per worker output now that the $A(t)$ term has been expanded and rearranged to the other side of the equation. Given that z is independent of time, the derivative of $\ln y(t)$ w.r.t. time is then

$$\frac{d \ln y(t)}{dt} = g + \alpha \frac{\dot{\hat{k}}(t)}{\hat{k}(t)} + \beta \frac{\dot{\hat{h}}(t)}{\hat{h}(t)} \tag{25}$$

or

$$\frac{\dot{y}(t)}{y(t)} = g + \alpha \frac{\dot{\hat{k}}(t)}{\hat{k}(t)} + \beta \frac{\dot{\hat{h}}(t)}{\hat{h}(t)} \tag{26}$$

It should be noted that the left-hand of the equation is in per worker terms while the right-hand is in efficiency terms. This allows $\dot{\hat{k}}(t)/\hat{k}(t)$ and $\dot{\hat{h}}(t)/\hat{h}(t)$ to be estimated with a first-order multivariate Taylor expansion around a constant, the steady state. The strategy to obtain the estimate is to rewrite the earlier Equations 4 and 5 (except now with ρz) in terms of $\ln \hat{k}$ and $\ln \hat{h}$. Then the linearization can be around $\ln \hat{k}^*$ and $\ln \hat{h}^*$ instead of the original variables. Starting with capital stock, the first order expansion w.r.t. to $\ln k$ and $\ln h$ is

$$
\begin{aligned}
\frac{\dot{\hat{k}}(t)}{\hat{k}(t)} &\approx s_k e^{-(1-\alpha)\ln \hat{k}^*} e^{\beta \ln \hat{h}^*} - (n+g+\delta) \\
&-(1-\alpha) s_k e^{-(1-\alpha)\ln \hat{k}^*} e^{\beta \ln \hat{h}^*} (\ln \hat{k}(t) - \ln \hat{k}^*) \\
&+\beta s_h e^{-(1-\alpha)\ln \hat{k}^*} e^{\beta \ln \hat{h}^*} (\ln \hat{h}(t) - \ln \hat{h}^*)
\end{aligned} \tag{27}
$$

$Ae^{gt+\rho z}$ is still subsumed into $\hat{k}(t)$, $\hat{k}^*$, $\hat{h}(t)$, and $\hat{h}^*$ such that the steady states in efficiency terms are constant. Noting that $s_k e^{-(1-\alpha)\ln \hat{k}^*} e^{\beta \ln \hat{h}^*} - (n+g+\delta) = 0$, and the same linearization is carried out for $\dot{\hat{h}}(t)/\hat{h}(t)$, the two can be substituted back into Equation 26 to obtain

$$
\begin{aligned}
\frac{\dot{y}(t)}{y(t)} &= g + \alpha[-(1-\alpha)(n+g+\delta)(\ln \hat{k}(t) - \ln \hat{k}^*) + \beta(n+g+\delta)(\ln \hat{h}(t) - \ln \hat{h}^*)] \\
&+\beta[\alpha(n+g+\delta)(\ln \hat{k}(t) - \ln \hat{k}^*) - (1-\beta)(n+g+\delta)(\ln \hat{h}(t) - \ln \hat{h}^*)]
\end{aligned} \tag{28}
$$

This eventually reduces to

$$
\frac{\dot{y}(t)}{y(t)} = g - (1-\alpha-\beta)(n+g+\delta)(\ln \hat{y}(t) - \ln \hat{y}^*) \tag{29}
$$

which is the same as Equation 6 but here we see that $\lambda = (1-\alpha-\beta)(n+g+\delta)$. From here, we can carry out the exact same empirical exercise as before, only now we have a ρz term coming from $A(0) = Ae^{\rho z}$ in the initial steady state as is shown in Equation 30:

$$
\begin{aligned}
\ln y^*(t_1) = \ln A + \rho z &+ \frac{\alpha}{(1-\alpha-\beta)} \ln s_k + \frac{\beta}{(1-\alpha-\beta)} \ln s_h \\
&- \frac{\alpha+\beta}{(1-\alpha-\beta)} \ln(n+g+\delta)
\end{aligned} \tag{30}
$$

This initial steady state equation is substituted into the solution of Equation 29 to get an equivalent of Equation 21 which now contains the ρz term in addition to gt. The resulting empirical model is then the same as Equation 22 except now with an additional $\beta_j x_{it}^j$ term for the ρz addition.

3.3.2. Interpretation of Estimation

It might be suspected that the structural model could drive the results which will be presented in the following chapters. This concern could be very general and therefore difficult (if not impossible) to address, or it could be much more specific. For instance, the results of Chapter 4 illustrates a pattern in which developing economies are above their steady state and developed economies are below theirs. There may be a general sense that the pattern is due to the structure of the empirical model, or there could be a more specific insight that the assumption of a common g could be creating the outcome. It is this latter suspicion which will be addressed here.

To begin, in many of the applications, the interest is the initial period of observations in which $time = 0$ as defined by theory and in the data. Thus, $gt = 0$ in this initial period, so all TFP evolution prior to this point will be caught by A, the country-specific fixed effect. This part of the TFP estimation is allowed to vary by cross-section, so there shouldn't be a concern that a common g could affect the estimation and calculation of the *initial* steady states.

After the initial steady states, the gt term is needed for calculation of the subsequent steady states. So what if the common g forces an average value for the entire sample, whereas a developing economy, because it grows more slowly, would have a g which would be lower than the average? To show this, take Equation 31, where g_i is country specific.

$$\begin{aligned}\ln y_i^*(t) = \ln A + g_i t + \frac{\alpha}{(1-\alpha-\beta)} \ln s_k + \frac{\beta}{(1-\alpha-\beta)} \ln s_h \\ - \frac{\alpha+\beta}{(1-\alpha-\beta)} \ln(n+g+\delta)\end{aligned} \tag{31}$$

If $g_i < g$, as with a developing economy, then $\ln y_i^*(t) < \ln y^*(t)$, where $\ln y_i^*(t)$ indicates a steady state estimated using a country-specific growth rate. This implies that using the country-specific g_i would place developing economies further above their steady states, not closer to them. Conversely, using the common g gives a larger estimate of the steady state for developing economies, thus making them seem closer to their steady states, not further above. That is, the method used here makes countries appear more similar, which is quite the opposite from "driving" the results.

Lastly, if there is a bias in the coefficients due to the common g, the bias would again be towards the average and not away from it. In this instance, using a common g would mean a country-specific component, say g_i again, would be left in the error term. Since it's likely that country-specific growth rates would be positively correlated with a country's investment and population growth, then the coefficients used to calculate the steady states would be upwardly biased. In this case, the developing economies would be closer to their steady states, not further above them. This again contradicts the notion that the structure of the empirical models drives the results and interpretation.

3.4. Concluding Remarks

While a lot of material was presented in this chapter, it should be noted that there isn't much being done which differs significantly from the existing body of literature. The estimation of steady states using panel data in a Solow convergence setting appears to have first occurred in this dissertation. Despite this fact, the methods are a simple combination of Islam (1995) and Cho and Graham (1996). Outside of some slight personalization, little is done as an innovation outside of combining these two papers. However, the result is important as panel data allows for country-specific TFP and productions functions. The consequences are drastic in that the results can explain subsequent patterns of observed economic development. And as was seen, adding an additional parameter to the total factor productivity in the Solow model should not result in additional complications. In sum, much effort was made to keep things simple yet obtain consequential results.

In the following chapters, the methods developed here will be applied to a worldwide panel data set, a panel data set of just OECD economics, and another group of countries chosen to examine the growth consequences of radical institutional change occurring during the transition from planned economies to market-oriented ones.

CHAPTER 4

Application to a Worldwide Sample

4.1. Introduction

In this chapter, the previous methods are applied to a sample of worldwide economies. The worldwide sample is chosen for comparison to the work of the original research on convergence (Mankiw, Romer, and Weil, 1992; Islam, 1995; Caselli, Esquivel, and Lefort, 1996). The sample was chosen by these original researchers based on availability of data and the purposeful exclusion of oil exporting economies. Advantages of using this sample include the representation of changes to the worldwide income distribution and the inclusion of greater variation in the unexplained characteristics. The major disadvantage comes from the assumption of a deterministic growth rate common to all countries in the sample. There is good reason to believe that countries can adopt The wider the variation, the less likely it is to hold. This assumption is made less strict by the inclusion of country-specific shifts in the growth rate.

Before presenting the results, this chapter gives a brief overview of the data and then discusses several estimation issues which arise in this present context. Data come from various standard sources. There are also several issues in which there isn't much guidance and the researcher must use judgment in deciding which way to estimate the regression equation. The element of time adds an additional set of estimation options while simple tasks such as taking averages can turn into an art form during this type of analysis.

The results presented in this section illustrate that the augmented Solow model can be used to explain and predict the observed cross-country *divergence* which occurred in the decades following 1965. By using the standard convergence result and parameter estimates, the steady state is calculated and compared to the actual level of output in the first period of the sample, which is 1965. Little is demanded of the results, as the emphasis here is on determining one of two positions: above or below the steady state. If a country has a level of output higher than it's steady state, then it may spend a lengthy amount of time growing at a rate slower than the common deterministic growth rate. That is, it will grow more slowly, or even negatively, in order to get to its long run steady state. It's shown that many of the countries starting in this position are African developing economies. Countries who are below their steady state are expected to grow more rapidly than the deterministic rate. In this sense, the augmented Solow model is explaining the observed outcomes and the fact that there is cross-country divergence should not be seen as contradictory to the model. In fact, it is predicted and explained by the model. In the past, confusion may have occurred by the emphasis on *convergence* within an economy, however, such convergence can occur from above or below the steady state.

The chapter is organized as follows. First it discusses the data in greater detail, addresses the several estimation issues that arise, presents the regression estimates and consequent steady state estimates, and then an interpretation of the results.

4.1.1. Data Description

The data come from several sources. The Penn World Tables versions 7.1 and 8.0 from Heston, Summers, and Aten (2012) and Feenstra, Inklaar, and Timmer (2013), respectively, are the primary sources of data. These sources provide measures of real GDP, population, and investment as a share of GDP, all in real terms adjusted for purchasing power. Given the challenge of estimating a labor force and to remain consistent with the Mankiw, Romer, and Weil (1992) and Islam (1995) papers, per capita GDP is used instead of per worker GDP. "Output-side" real GDP at current PPPs (in mil. 2005 US$) is used for the measure of output. The Solow model specifies a saving rate to be used. Due to data limitations and given the long run theory of saving and investment, we can use a measure of investment as a percentage of GDP to capture the savings rate. Investment in physical capital is given by the "share of gross capital formation at current PPPs" in the Penn Tables 8.0. Data on education come from the Barro-Lee dataset (Barro and Lee, 2013) and out of the several choices of available measures, we used the percent of adults over 25 who have attained some secondary school. Completion rates are available, but given the high number of students who fail to complete a certain level of education, it is reasoned that the percent of students who attained some secondary school education would be a better measure of investment into education than the subset of students who complete secondary schooling. Other research uses enrollment figures, but secondary school completion rates give a better measure of the effectiveness of education. The augmented Solow model predicts that the coefficients will be positive on investment, negative on population growth, and positive on human capital.

In Section 4.2.2, the model will include measures of institutions. The various measures will be treated as exogenous and lagged values will be used as instruments in addition to being regressors as specified by the model. For this worldwide sample, indexes will come from the PolityIV database (Marshall et al., 2010). The first two sources are well known and Polity IV is a widely cited database of political institutions with its most well-known use found in Acemoglu and Johnson (2005). The particular PolityIV variables used here are *Autocracy*, *Duration*, *Exec Reg*, *Exec Open* and *Participation*. Countries scoring higher on the *Autocracy* index do more to "sharply restrict or suppress competitive political participation." *Duration* is simply the number of years in which a particular political system has been in place. *Exec Reg* is the "regulation of chief executive recruitment" and a country scoring higher has an executive who comes into power through legal statute as opposed to use of power. *Exec Open* is the openness of executive recruitment and refers to the determination of eligible candidates for such a position. Finally, *Participation* is the "competitiveness of participation" and refers to the amount of alternative policies and opposition to the ruling party that may be present. Table 4.1 and Table 4.2 summarize the variables.

TABLE 4.1. Summary Statistics: 1965

Variable	Mean	Std. Dev.	Min.	Max.
PC Real GDP (US$)	5013	5605	355	27572
Pop Growth	2.2%	0.9%	0.1%	4.4%
Investment Rate	17.4%	9.9%	1.8%	40.5%
Ed Attainment Rate	11.5%	12.4%	0.19%	54.3%
Autocracy	3.497	3.361	0	9.200
Duration	15.974	26.72	0	154
Exec Reg	2.449	0.607	1	3
Exec Open	3.549	1.092	0	4
Participation	3.753	1.023	1	5

TABLE 4.2. Summary Statistics: 2010

Variable	Mean	Std. Dev.	Min.	Max.
PC Real GDP (US$)	12670	14236	257	58153
Pop Growth	1.5%	1.0%	-1.3%	3.7%
Investment Rate	20.9%	7.3%	5.3%	4.2%
Ed Attainment Rate	36.2%	18.1%	3.1%	72.7%
Autocracy	1.047	1.665	0	7
Duration	31.728	36.813	0	199
Exec Reg	2.598	0.496	1	3
Exec Open	3.546	1.186	0	4
Participation	3.22	1.224	1	5

It's difficult to formulate a hypothesis with regard to the direction of the relationship of GDP to the various measures of political institutions. On the one hand, this is problematic, as it would be advantageous to find support for a specific theoretical prediction, but the only one made so far is with regard to significance, not direction. So far, predictions have been made with regard to significance, not direction. On the other hand, for a variable such as *Autocracy*, one may find very different predictions depending on which theory is being applied, so flexibility is desired. *Autocracy* might promote growth if the leader is a benevolent dictator, but could hurt growth if the dictator was exploitative. *Exec Reg*, *Exec Open* and *Participation* should all be positively related to growth. According to Acemoglu and Johnson (2005), "good institutions are those that provide security of property rights and relatively equal access to economic resources to a broad cross-section of society" Acemoglu, Johnson, and Robinson (2005). All three of these institutions should assist in ensuring equality of access to the economy.

Much of the reason that cross-country growth regressions emerged as the trendy subject of the 1990s was because of the Penn World Tables and the data they made available. Following Mankiw, Romer, and Weil (1992), it became clear that human capital is essential for growth. Barro and Lee (2013) now provide a standard source for such data. Once the data has been assembled, estimation could proceed.

4.1.2. Estimation

There is a large underlying mechanical aspect to estimating a dynamic panel with 5-year averages. It's assumed that by averaging over several years one can help control for business cycle shocks. Growth rates are computed over a five-year range in order to better approximate the long-run rate of growth. To complement the growth rates, five-year averages of saving rates (i.e. investment), population growth, and secondary school completion rates are computed.

Then there are the mechanics of taking averages and growth rates. This requires a bit of programming given that different datasets are used. Without any guidance from theory, any one of the several methods of finding growth rates is equally acceptable for computing population growth. However, there is theoretical guidance in determining growth rates of per capita income, so log-differences are used to compute the growth rates of per capita real GDP while $n = (population_t/population_{t-1}) - 1$ is used to compute annual rates of population growth which are then averaged across the desired time frame. Saving and education rates are also averaged over five years as well as the institutional variables. The *prior* five years are used in each average so that the right hand variables are explaining the gap between $y(t_2)$ and $y(t_1)$ in what is essentially a partial adjustment model.

Neither Islam (1995) nor Caselli, Esquivel, and Lefort (1996) use a time trend despite the fact that one is specified in the model. Instead, the authors use time dummies to control for the time-specific effects, but these two methods of control are not equivalent. Excluding a time trend means that more trend-variation will be caught by the error term which could in turn affect estimation of the coefficient and variance on $(n + g + \delta)$ as worldwide n has been on a steady and continuous decline since the 1960s. On the other hand, including a time trend appears to make it less likely to find a significant relationship between $(n+g+\delta)$ and $y(t)$. Ideally, the model should include both a time trend as a matter of theory and time dummies as an empirical method to control for time-specific heterogeneity coming from international macroeconomic shocks. The value of the time dummy must be added back into the intercept to compute TFP. If several dummies must be dropped due to collinearity, then a consistent specification might only include a time trend, which is done here in the worldwide sample. This will make robust estimation of $(n+g+\delta)$ more difficult, but the end goal is overall significance of the initial steady state and not the significance of each individual variable as it is in Islam (1995) and Caselli, Esquivel, and Lefort (1996).

The augmented Solow model can also be estimated in an unrestricted or restricted form. As can be seen in the structural model which is to be estimated,

$$\begin{aligned} \ln y(t_2) = gt_1 + e^{-\lambda\tau}\ln y(t_1) + (1-e^{-\lambda\tau})\ln A \\ +(1-e^{-\lambda\tau})\frac{\alpha}{(1-\alpha-\beta)}\ln s_k + (1-e^{-\lambda\tau})\frac{\beta}{(1-\alpha-\beta)}\ln s_h \\ -(1-e^{-\lambda\tau})\frac{\alpha+\beta}{(1-\alpha-\beta)}(n+g+\delta) \end{aligned} \tag{32}$$

the coefficient on $(n+g+\delta)$ can be expanded through $(n+g+\delta)$ and then share similar parameters as in the coefficients on s_k and s_h. In brief, the coefficients on $(n+g+\delta)$ can be split into two terms with each respective term to be equal, but in opposite sign, to that on investment and human capital. Transforming the variables by subtracting $(n+g+\delta)$ from investment and the other $(n+g+\delta)$ (after expansion) from human capital will present a restriction which can be tested. Both specifications are presented, however because the specification contain the same information, the two results bear little distinction in the final calculation of the initial steady states. That is, the estimated coefficients of the restricted and unrestricted forms lead to only slightly different results, but the general outcome remains.

A dynamic panel specification introduces several well-known empirical issues into the estimation. A pooled OLS estimator will omit any country-specific effects, and if there are country-specific effects present in the data, they will end up in the error term. OLS estimation will then suffer from omitted variable bias as such effects are likely to be also picked up by the right hand side variables, especially, the lagged dependent variable. One could account for the country-specific effects in a fixed effects estimator but this doesn't alleviate the problems caused by the endogeneity. Typically, fixed effects within estimation is used by differencing the time-averaged variables. However, this serves to introduce a time-averaged error term which will again be correlated with the lagged dependent variable (since the lagged error term present in the differenced error term is also found in the lagged dependent variable) (Nickell, 1981).

To address endogeneity and the consequent biased estimation, the "system-GMM" estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998) is the preferred estimator. System-GMM estimation uses a system of lagged levels as instruments in addition to the lagged differenced values found in the GMM estimator of Arellano and Bond (1991). Such an estimator has been shown to be consistent and unbiased for a dynamic panel with more cross sections than time observations. The challenge in using such an estimator is that all combinations of lags can be used as instruments so there tends to be a proliferation of instruments and over-fitting if the estimator is used without caution (Roodman, 2009b). Overfitting cannot be easily detected by unusually large R^2 because in a dynamic panel (with a lagged dependent variable) a large R^2 is to be expected.

An additional assumption to the classical GMM identifying assumptions is that the lagged *changes* in the instruments are independent of current *levels* of the error terms. In the present setting, one could think of a context in which this may be problematic. For instance, one cost of using the augmented Solow is that government expenditure isn't accounted for and is instead left to the error term. It's fairly accepted that government spending should have a short-run impact on growth. So, upon incurring a recession (a negative change in real GDP), the government may react with exogenous spending which would find itself as a shock present in the error term, thus violating the assumption if this is systematic because past changes in a regressor will be present in the levels of the error terms. However, the timing is unlikely to work in such a way that it systematically violates the assumption made in system-GMM estimation. A past recession may lead to present government spending, but assuming the recession is still ongoing in the present while there is spending, and that the government will end its spending in the following period when the recession has subsided, the assumption will not be violated. In the final period, a past recession will be followed by the end of government spending (and the end of recession), which offsets the initial period where the past recession led to the start of government spending. The observations including past changes and present levels will be offsetting and not likely to lead to significant correlation. Unfortunately, there is not enough data on government spending to test this, but given this likely sequence, the assumption should hold.

While much of the discussion on system-GMM revolves around the GMM-style instruments, the estimator does allow for additional purely exogenous instruments, much in the same way that an IV estimator does. To this extent, the institutional variables in the latter sections of this chapter may be treated as additional exogenous instruments. One theoretical justification for doing so can be found in Acemoglu's *hierarchy of institutions* (Acemoglu, Johnson, and Robinson, 2005). The theory suggests that changes in institutional measures should lead to changes in economic outcomes, with any reverse causation coming from lags of economic outcomes. A more detailed description and diagram can be found in Figure 5.4 of Chapter 5. Here it suffices to say that the measures of political institutions will be used as additional instruments, both in lags and in lagged differences. Such an approach is also take in Eicher and Schreiber (2010) using the same estimator and the same theory to justify the use of institutions as instruments.

There may be heteroscedasticity present due to short-run business cycle impacts, even after averaging over 5 years. For this reason, robust standard errors are used and the Hansen J test is used (as opposed to the Sargan test) in order to establish whether the instruments are valid. The Hansen J should help identify a model in which the instruments are valid, however, while the test is robust to heteroscedasticity, it is weakened by too many instruments. Thus the worldwide panel estimation uses 54 instruments for 85 cross-sections while the OECD panel estimation uses 29 instruments for 24 cross-sections. The test performed for the OECD sample may be slightly weakened but it is still within a normal range. The Arellano-Bond tests for AR(1) and AR(2) are also used to test for unit roots in the errors. It's expected that the first differenced error terms will have a unit root in AR(1) due to a common term, but not after, so valid estimation requires that the null hypothesis of no autocorrelation is rejected in AR(1) but is not rejected in AR(2). The null hypothesis of valid instruments is not rejected in the Hansen J tests. Estimation is implemented using the `xtabond2` Stata package written by Roodman (2009a).

In order to add back in the country-specific effects and compute the unique steady states, we need to get estimates of the fixed effects which were differenced out during the System GMM estimation. In order to do so we follow the procedure outlined by Caselli, Esquivel, and Lefort (1996) and take time-averages of the error terms as follows. Equation 22 can be rewritten as:

$$\hat{\mu}_i + \hat{\upsilon}_{it} = y_{it} - \hat{\gamma} y_{i,t-1} + \sum_{j=1}^{3} \hat{\beta}_j x_{it}^j + \hat{\eta}_t \tag{33}$$

then we can compute

$$\hat{\hat{\mu}}_i = \frac{1}{T}\sum(\hat{\mu}_i + \hat{v}_{it}) \tag{34}$$

In practice, one can include a constant in the estimation and its value represents the average country-specific effect. If so, the $\hat{\hat{\mu}}_i$ can be added to the constant in order to finally obtain an estimate of the term $(1 - e^{-\lambda\tau}) \ln A_i$ which is found in Equation 21.

In what follows, pooled OLS and fixed effects (within estimator) estimation results are presented for reference and comparison to the preferred system-GMM estimate. The general hypothesis of this present research is that developing economies will be converging from above while the developed countries will converge from below their idiosyncratic steady states. If this is the outcome, it is seen as evidence that the simple augmented Solow model has specified a selection of variables and basic theoretical framework which affords a reasonable explanation as to why many developing economies are above their steady state, whereas before there was still some question. Confirmation of this hypothesis is explained by the fact that convergence from above is due simultaneously to overcapitalization and underinvestment into TFP.

4.2. The Worldwide Panel: 1965 - 2010

The first set of results come from a sub-sample of MRW's "NONOIL" worldwide group of countries described in the introduction. After combining datasets and restricting countries to the original 98 from MRW, the limitations from availability of the education variable only permit a sample of 85 countries. Most countries are available for every year from 1965 to 2010, although 5 countries are missing in 1965 only.

These results have already been eluded to: they indicate that the majority of countries above their steady state are the ones who are considered to be developing but are diverging lower from the median of worldwide incomes. Further applications illustrate that this is no artifact of the method being employed, but rather the outcome of the international patterns of development examined by the Solow growth model and with the Solow growth model's choice of variables. But before presenting the estimations of country-specific steady states, we should examine what is being used to derive them. That is, we should make sure that this version of the traditional convergence analysis is in line with the general results of the literature.

Table 4.3 presents these results which are interesting in themselves, even though the goal is to use the coefficients and standard errors to estimate an initial steady state level of per capita GDP. In any convergence regression, the most notable feature is the coefficient on y_{t-1}. This coefficient is equivalent to $(e^{-\lambda t})$ and establishes λ, the speed of convergence, a measure of how much the growth rate of per capita GDP declines as a country accumulates (or disinvests) capital (Barro and Sala-i-Martin, 2004). For example, $\lambda = 0.05$ indicates that 5% of the annual gap between actual per capita GDP and its steady state value will diminish per year. At this rate, the time in which it would take a country to converge half-way to its steady state would be 13.86 years[5]. This seems to be a reasonable and GMM estimates of λ range from 0.01 to 0.101 as in Caselli, Esquivel, and Lefort (1996) (CEL from here on). While our estimates fall within that range, the System GMM speed of convergence is slower than those of CEL, although we include a time trend and CEL use a different type of GMM estimation.

[5]Given Equation 8, $\ln \hat{y}(t_2)$ will be halfway between $\ln \hat{y}(t_1)$ and $\ln \hat{y}^*$ when $e^{-\lambda t} = \frac{1}{2}$ so that solving for t gives $t = \frac{\ln 2}{\lambda}$.

Table 4.3. Convergence Regressions Using a Worldwide Sample: 1965 - 2010

	Pooled	Fixed Effects	GMM Unrestricted	GMM Restricted
	y_t	y_t	y_t	y_t
y_{t-1}	0.981***	0.749***	0.930***	0.942***
	(0.014)	(0.029)	(0.023)	(0.016)
$(n+g+\delta)$	-0.133*	0.0129	-0.323*	–
	(0.074)	(0.147)	(0.187)	–
s_k	0.0653***	0.0702**	0.102***	–
	(0.017)	(0.029)	(0.025)	–
s_h	0.0233*	-0.0784**	0.0551***	–
	(0.014)	(0.031)	(0.015)	–
$s_k-(n+g+\delta)$	–	–	–	0.0996***
	–	–	–	(0.023)
$s_h-(n+g+\delta)$	–	–	–	0.0597***
	–	–	–	(0.016)
time t	-0.00879***	0.0260***	-0.00393	-0.00414
	(0.003)	(0.007)	(0.004)	(0.004)
cons	-0.0173	2.397***	-0.176	0.150*
	(0.182)	(0.539)	(0.389)	(0.085)
λ	0.046***	0.348 ***	0.058***	0.062***
	(0.000)	(0.018)	(0.000)	(0.000)
N	764	764	676	676
R^2	0.9793	0.7636	–	–
Hansen J	–	–	0.161‡	0.153‡
$AR(1)$	–	–	0.010‡	0.007‡
$AR(2)$	–	–	0.949‡	0.926‡

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

† $N = 647$ due to use of 3 lags as predetermined instruments

‡ p-values

As in CEL, the unrestricted and restricted System GMM estimation produce very similar results so the restricted form is used to calculate steady states with greater levels of significance as the constant is significant in those specifications. With enough time observations, further work may omit the constant so that the entire country-specific effect will be represented by the mean of the cross-sectional error terms.

At 0.10, CEL's estimates of the capital shares in the GMM setting are so small and so far enough away from the accepted 1/3 standard that the authors find it as evidence against the Solow growth model itself. But the authors use a panel GMM method which has been shown to contain biases (Blundell and Bond, 1998). The main difference between CEL's methods and the ones used here are the choice of instruments. Here we use lags of output starting at 2 lags as "GMM style" instruments and a combination of lags 1-3 of output, saving, human capital, and $(n + \delta + g)$ as "IV style" instruments to obtain a capital share of output at 0.47 and a human capital share of 0.26 in the restricted model. The unrestricted gives a capital share of 0.42 with the same share of human capital. While a bit high, the physical capital contribution to output is much more realistic than CEL's 0.10 estimate. With half-lives of 48 and 58 years, the rates of adjustment are very slow. However, such slow rates of convergence over the 1965 to 2010 period may be realistic. Developing economies who are above their steady states are predicted to grow in proportion to the world-wide deterministic rate. The steady state could grow even faster as it takes on any increase in TFP directly. On the other hand, if the economy is facing continual negative shocks in the from of say, political turmoil and international or internal conflict, then convergence may be slower as the steady state will not grow faster than actual output. This is consistent with the hypothesis that some countries have yet to fall far enough given their low levels of TFP and that the best policy is then to find ways of improving TFP but not investment.

4.2.1. Convergence From Above and Below

At this point most studies on convergence leave to discuss other topics, perhaps relative total factor productivities, or other estimates of convergence without acknowledging that the significant convergent coefficient came about from the countries in the dataset converging from both above and below. Many will have a subsequent discussion as if all countries were converging only from below, but this is simply not the case. Following the methods just described, we calculate the steady state values of per capita GDP in the initial period. This tells us where each country was starting during the convergence process. All countries come from a sample in which there is significant convergence behavior; the question is what kind of behavior? Tables A.1, A.2, and A.3 in the appendix report the values (in logs) of each country's initial per capita real GDP, steady state, the resulting output gap, and the standard errors of the estimated steady state, all sorted by the distance to their own unique steady state. Each steady state is statistically significant. In order to visualize the underlying pattern, Figure 4.1 illustrates which countries are above the steady state and which ones are below. Contrary to the interpretation of λ, the steady states here are unique. λ tells us the average speed of convergence for all countries after controlling for country-specific effects. Here we add those effects back into the estimate of the steady state and can now see where each country is relative to their own steady state. The $45°$ line indicates the set of points in which the actual per capita GDP would be equal to the steady state level. Observations above the line indicate levels of per capita GDP which are above their steady states.

The pattern which emerges tells the story of the development patterns which emerged coming out of the last half-century. In 1965, Japan (JPN), South Korea (KOR), and Botswana (BWA) were set embark on a period of impressive growth. Brazil (BRA), Argentina (ARG), and Greece (GRC) were also ready to to converge from well below their steady states as estimated in the augmented Solow growth model. The countries had high total factor productivities and, as implied by the model, relatively low levels of capital stock

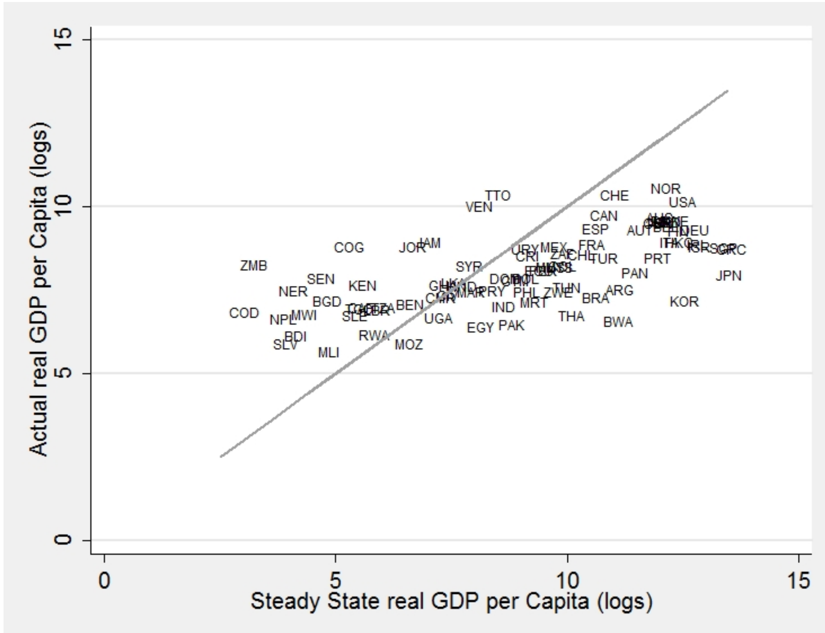

Figure 4.1. Per Capita GDP Relative to the Steady State, Worldwide 1965

capital stock per worker. The institutions and other fundamental determinants of growth give capital a very high marginal product and the countries' growth rates remained above the world-wide average for this period of development. On the other hand, Congo Kinshasa (COD), Zambia (ZMB), Bangladesh (BGD), Senegal (SEN), Congo Brazzaville (COG), and Niger (NER) all were well above their steady states. The amount of capital per worker in these countries was not productive enough no be maintained and had to fall or stagnate over this period of development.

Much of the pattern can be explained by differences in TFP. In some ways, this shouldn't be surprising as whatever can't be explained by investment, human capital, and population growth will be caught by the residual. But this is the empirical reality of the concept of total factor productivity: it's composed of a wide array of country-specific factors which affect growth. Current empirical growth literature is working hard towards explaining this black box, but as for the current role of TFP here, the goal is to simply explain why some developing countries were above their steady states. The trend is clear: sorting the sample by distance from the steady state and then taking averages of quintiles, we calculate that the 20% of countries furthest below their steady state have a log TFP of 4.14, followed by 3.42, 2.90, 2.73, and finally 1.63 among the countries furthest above their steady states. The falling TFP in relation to the distance from the steady state is a strong indication that the countries who are furthest below their steady state are so because of higher TFP.

To illustrate the relationship between growth and distance from the steady state, we present Figure 4.2 where the horizontal axis represents the output gap in which the more negative the value is, the further a country is below its steady state in 1965. The growth rates in the vertical access indicate the average annual rates from 1965 to 2010. The gray region marks the 95% confidence interval. Worldwide and over time, there appears to be a very tight fit between the steady state output gap and subsequent growth rates, an indication that the estimated initial steady states are descriptive of economic growth when they are

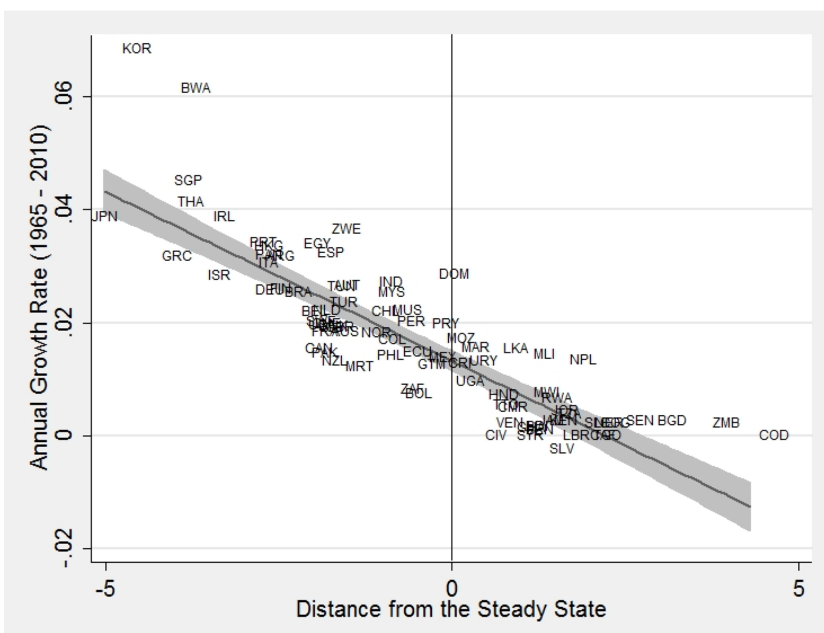

FIGURE 4.2. Subsequent Growth Rates Following a Location Above or Below the Steady State

compared to the actual initial levels of output. What we see is that the further below the steady state, the faster the subsequent rate of economic growth. The augmented Solow model explains this with the relationship of capital and education investments relative to productivity. If a country is below its steady state, it will accumulate physical and human capital while growing faster than the rate of deterministic technological growth.

4.2.2. The Worldwide Panel with Institutions: 1965 - 2010

In this section, we'll try to tease out some of these factors by using measures of institutions, but for now total factor productivity is a bit of a black box. The advantage of this panel data method is to make the black box unique to each country. The comparison of country-specific TFP at least tells us where to look when in search of countries that have something unique to their total factor productivity. Estimation will be similar to the previous sections, except now we have added ρz, a set of institutional parameters into Equation 18.

$$\begin{aligned} \ln y^*(t_1) = \ln A + \rho z + \frac{\alpha}{(1-\alpha-\beta)} \ln s_k + \frac{\beta}{(1-\alpha-\beta)} \ln s_h \\ - \frac{\alpha+\beta}{(1-\alpha-\beta)} \ln(n+g+\delta) \end{aligned} \tag{35}$$

Here we use the PolityIV measures of political institutions which include indicators of autocracy, duration of the current regime, the amount of regulatory constraints on the executive, the openness with which people can run against or otherwise challenge the current executive, and the amount of political participation which occurs within a given country. While a few countries change positions when ranked by the distance from the steady state, the overall distribution is changed little by the inclusion of these measures of political institutions. What the ρz do give us is insight into what is driving the pattern of declining TFP.

Table 4.4 gives the results which are inclusive of the PolityIV variables. As for the standard results, the speed of convergence is still very long but there's less variation between the restricted and unrestricted versions. With half-lives of 50.6 and 51.2 years, the unrestricted and restricted versions illustrate a long period of transition. The shares of capital and human capital are virtually identical in the restricted and unrestricted case. In the restricted case, capital's share of production, α, is estimated to be 0.42 while human capital's share, β, is right about 0.26 with the remaining share going to total factor productivity. In all these cases, the capital share is above 1/3 but represents an improvement from CEL's estimate of 0.10. Also, the share of human capital sitting at 0.26 is a much more reasonable estimate than the negative values of the CEL estimate. It's possible that the GMM estimator (Arellano and Bond, 1991) used by CEL suffers from the small-sample biases that the System GMM estimator used herein does not. At any rate, these results are seen as evidence in support of using the augmented Solow model for this type of estimation.

The institutional variables give interesting results in themselves. The significantly negative coefficient on *Autocracy* is robust to estimation methods. This indicates that governments with few challenges to executive power are associated with slower growth. However, it appears that executive power in itself may not be detrimental for growth. The negative coefficient on *Exec Reg* supports this assertion through its indication that a coup or other seizures of power may be good for growth. Power transitions, or at least the possibility of them, seem to be important for good institutions. *Exec Open* and *Participation* are

Table 4.4. Worldwide Sample of 78 Countries 1965 - 2010

	Pooled	Fixed Effects	GMM Unrestricted	GMM Restricted
	y_t	y_t	y_t	y_t
y_{t-1}	0.982***	0.773***	0.934***	0.935***
	(0.015)	(0.030)	(0.022)	(0.021)
$(n+g+\delta)$	-0.126*	-0.0148	-0.149	–
	(0.076)	(0.135)	(0.147)	–
s_k	0.0645***	0.0738***	0.0855***	–
	(0.016)	(0.027)	(0.024)	–
s_h	0.0172	-0.0790***	0.0516***	–
	(0.013)	(0.025)	(0.017)	–
$s_k-(n+g+\delta)$	–	–	–	0.0862***
	–	–	–	(0.021)
$s_h-(n+g+\delta)$	–	–	–	0.0522***
	–	–	–	(0.019)
Autocracy	-0.00836**	-0.0108**	-0.0135**	-0.0134**
	(0.004)	(0.005)	(0.006)	(0.005)
Duration	-0.000292	0.00105	-0.000104	-0.0000906
	(0.000)	(0.001)	(0.000)	(0.000)
Exec Reg	-0.0364*	-0.0609**	-0.0507*	-0.0511*
	(0.019)	(0.029)	(0.028)	(0.028)
Exec Open	0.0147*	0.0231*	0.0186*	0.0187*
	(0.008)	(0.012)	(0.011)	(0.011)
Participation	0.00204	0.0137	0.0198	0.0189*
	(0.009)	(0.010)	(0.014)	(0.010)
time t	-0.0113***	0.0203***	-0.00458	-0.00465
	(0.002)	(0.006)	(0.004)	(0.004)
λ	0.004	0.051***	0.014***	0.013***
	(0.003)	(0.008)	(0.005)	(0.004)
N	829	829	647†	647 †
R^2	0.9799	0.8086		
Hansen J	–	–	0.245‡	0.212‡
$AR(1)$	–	–	0.008‡	0.010‡
$AR(2)$	–	–	0.882‡	0.882‡

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

† $N = 647$ due to use of 3 lags as predetermined instruments

‡ p-values

indicators of how easy it is to challenge an executive's power; they are both positive. While the indicators tend to have only a small impact on the estimated growth rates, they do tell a story: strong executives who easily face challenges and checks to their power are the ones who are in charge of your average rapidly growing economy.

The distribution of countries' locations relative to their steady states is presented in Figure 4.3. As can be seen, there is little difference between the estimates which include institutions and those that do not. The main difference comes in how we treat total factor productivity: keep everything as part of the black box or find indicators of TFP in order to obtain estimates which will then be added back into the black box. The results here indicate that what has been developed is a method to test for and experiment with various measures of institutions in order to open up total factor productivity.

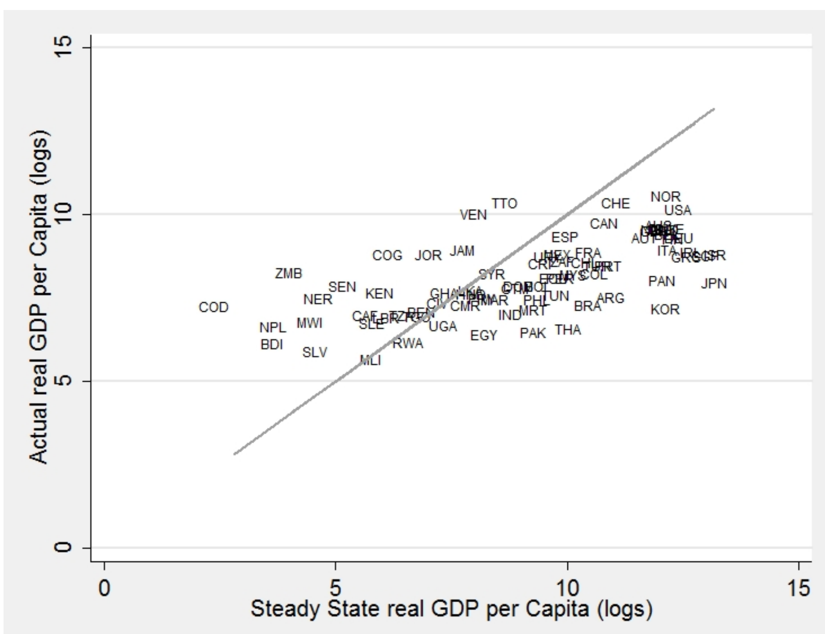

FIGURE 4.3. Initial Per Capita GDP Relative to the Steady State

The distribution is similar to what we saw before, only now there may be more flexibility in interpreting what is happening within the variation of TFP. Now we can simply refer back to the indicators themselves once a low TFP is estimated, and then look for the reasons why a country scores high in authoritarianism, for example. The common theme is still that the developing African states constitute the clear majority of the countries beginning the modern stage of development above their steady states. El Salvador (SLV) also starts above the steady state, yet the remainder are mostly African states (most notably Congo-Kinshasa (COD), Congo-Brazzaville (COG), and Zambia (ZMB).

The country with the fastest growth seems to be South Korea (KOR), but shares the spotlight with Japan, Panama, Argentina, and Brazil. Botswana unfortunately drops out because of lack of data. The estimation of the steady states confirm some of the patterns observed in the cross-sectional study of Cho and Graham (1996) with developing nations converging from above and the developed countries converging from below. The hypothesis that Venezuela is converging from above is also verified, lending credence to a version of the natural resource curse (Rodriguez and Sachs, 1999).

In order to get a clearer picture of these countries' steady states, total factor productivity inclusive of institutions is also estimated and reported in the appendix. As is predicted, total factor productivity is lower for the countries which are further above their steady states, although the relationship is not monotonic and has more variation than without institutions. Computing averages of quintiles after sorting by distance from the steady state again gives insights into the role of TFP. The 20% countries who are furthest below their steady states have an average total factor productivity (in logs) of 5.46, the next 20% have an average of 4.92, followed by 4.53, 3.88 and finally an estimate of TFP standing at 2.69 for the countries who are all above their steady states. All but 6 of the 78 total factor productivities are significantly different from zero.

The indexes used herein were constructed based upon actual events so that looking for explanations of macro-level growth in these instances isn't more complicated than describing the sources of the data which were used to get the estimates in the first place. Of note is the fact that the coefficient on *Exec Reg* is significant and negative, indicating that more regulation of executive power is associated with less growth. It also might be added that this is a fairly robust result. What drives it are not the African economies. As one would expect, those economies do have less regulation of recruitment of chief executives and they are associated with less economic growth, but that part of the sample is being outweighed by the Latin American countries and South Korea. Until he left power in 1988, Chun Doo-hwan was dictator of South Korea following a coup d'état, yet oversaw an impressive economic expansion. *Autocracy* gives a robust result. It also appears as if having more rival parties able to participate in the political process is associated with higher per capita GDPs. Together these results describe an executive with broad powers, but one also who faces many legitimate challenges, is associated with more economic growth.

One country in particular is worth discussion, although the estimate is insignificantly different from 0. Congo Kinshasa actually has a negative value of $\ln A(t)$. At first glance this seems unlikely, but solving for $A(t)$ gives $A(t) = 0.60$ so that about 60% of what is produced becomes part of national output. One quick glance at Congo's history tells a story of a US supported dictator, Joseph Mobutu, taking power in 1966 and subsequently turning Congo Kinshasa into a kleptocracy. After the cold war, the US lost interest in Mobutu leading to his loss of power and a subsequent civil war. By 2009 5.4 million people had died in the conflicts and surviving women and children were subjected to personal atrocity (Butty, 2010).

4.3. Comparison to a More Conventional Method

Estimating the initial steady state of a country can be done in several different ways. The type of data chosen often restricts the researcher to a particular method. Time series methods in the form of growth accounting may be the most commonly used way of estimating steady states and the capital and labor shares. Cross-sectional methods can also be used to estimate the steady state but rarely are, while herein was presented a method to do so with panel data. However, there is a simpler and more direct way to achieve such estimates. We could simply estimate Equation 18 directly as in a growth accounting study but with panel data. Actually, doing so does have a slight change on the distribution, but the general conclusions are the same. Figure 4.4 presents those results while Table A.7 in the appendix shows the full estimation. The most distinguishing feature is that there is a wider distribution of steady states, but it's still the developing nations who are overrepresented among the overcapitalized nations while Korea, Japan, and Argentina look like they are about to have a good period of development.

Should such an estimator be preferred due to its simpler form and methods? The fixed effects (within estimator) is now a valid method since there is no longer a lagged dependent variable as a regressor, and thus it has an advantage in estimating the country-specific effects. But there are several reasons why the method developed in the previous sections should be used in this context. First, using the panel data method developed herein allows for the inclusion of an additional control variable, the lagged level of per capita real GDP. It's known that education, saving rates, and even population growth are all dependent on past values of per capita GDP so that omitting the variable could cause biased estimates. Having a lagged dependent variable also puts the empirical model into the partial adjustment form.

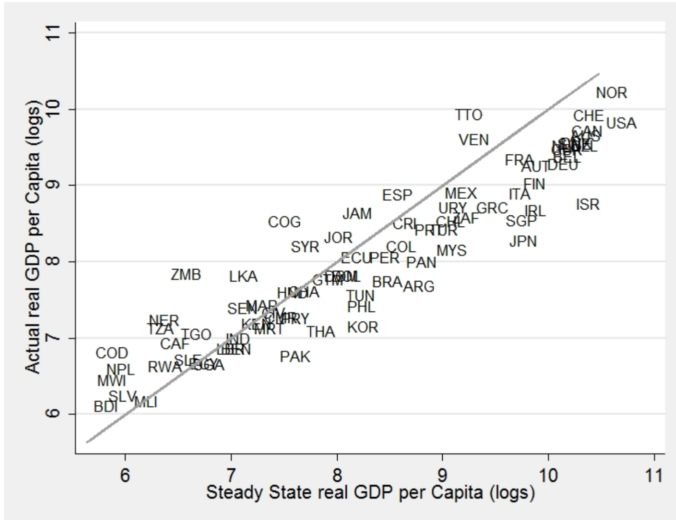

FIGURE 4.4. Direct Estimation of the Worldwide Sample

Secondly, the inclusion of a lagged dependent variable in the original method changes the specification from a static one into a dynamic one. Since the Solow model is dynamic, it seems that the proper specification of an empirical model should also be dynamic. What should be explained is the change in the dependent variable from one period to the next, not a static estimate of it. Lastly, the purpose of this paper is to give greater insight into convergence analysis. A complete picture of what was estimated is only gained if those same results are used to determine the position of a unique steady state.

CHAPTER 5

An Application to Transition Economies

In this chapter, the methods developed in Chapter 3 will be applied to the former communist transition economies to examine whether there is support for the commonly accepted view that the economies were overcapitalized as they began the process of privatization and liberalization. The transition economies referred to here include the members of the former Soviet Union, other Central and Eastern European countries, and Mongolia. The transitioning economies of southeast Asia are not included due to issues of data availability. A complete list of the countries in the sample is given in Table 5.1.

Table 5.1. Transition Economies by Region

Region	**Countries**		
Baltic States	Latvia	Lithuania	Estonia
Central and Eastern Europe	Belarus	Bulgaria	Croatia
	Czech Republic	Hungary	Moldova
	Romania	Poland	Russia
	Slovakia	Slovenia	Ukraine
Southeastern Europe and Anatolia	Albania	Bulgaria	Macedonia
	Montenegro	Moldova	Serbia
Caucuses	Armenia	Azerbaijan	Georgia
Central Asia	Kazakhstan	Kyrgyzstan	Tajikistan
	Turkmenistan		

There are two main reasons to believe that there would be overcapitalization in this context. First, anecdotal evidence from the former financial ministers and advisers of the centrally planned economies typically tells the story of overallocation of resources into capital at the expense of consumer goods. The other reason to expect overcapitalization is that, as first discussed by Harvard economist, János Kornai, soft budget constraints were very common among the transition economies. According to this theory, we'd expect overcapitalization to occur due to the loose financing practices of central banks. As a result, the typical situation of these economies is for them to have repressed inflation due to a combination of excess demand and price controls, which is reflected in a state of chronic consumer shortages. In the next section, we will explain the link between consumer good shortages and overcapitalization as being due to a production cycle common to many planned economies.

To test the general hypothesis that we'd expect to find these economies to be overcapitalized, we need to determine whether they are above or below their steady states at the onset of the transition. The finding that most countries were above their steady states would indicate a level of capital which is too high given their levels of total factor productivity. Of course, studying the long run growth of these economies during this period is made difficult by the constant institutional changes that they are undergoing. In order to address this issue, time dummies are used along with indices of economic institutions provided by the European Bank for Reconstruction and Development. These aren't simply controls, though. As used by Eicher and Schreiber (2010) and in accordance with theory (Acemoglu, Johnson, and Robinson, 2005), the indices are also used as traditional instruments in addition to the GMM-style lagged right-hand side variables.

The next section more fully discusses the reasons for believing that these economies would be above their steady states at the onset of the transition to market-based economies. It also describes the *hierarchy of institutions* as the theoretical justification for using institutions as instruments. Section two then describes the data and the countries in the sample. The third section presents the regression results and illustrates that the clear majority of economies are indeed above their steady states as the transition got underway. The last section then briefly concludes.

5.1. Central Planning and Over-Allocation of Capital

It is the anecdotal evidence of planned economies' overinvestment into capital which led to the development of the methods presented in this chapter and earlier ones. In the lead up to the privatization and price liberalization of the 1990s and 2000s, the former economies of the USSR were often described as having obtained a level of capital above that which is optimal. Cornia and Popov (2001) provide a comment to this effect: "All centrally planned economies were over-industrialized at the expense of the service sector, especially at the expense of trade and financial services, which were relatively underdeveloped" (Cornia and Popov, 2001, p. 31). Kolodko (2000, p. 11), the Polish Deputy Premier and Minister of Finance during the transition, has a more descriptive account:

> "Stalinism had caused fundamental changes in Eastern European economies after the Second World War. It engineered essential adjustments in economic structures, mainly through rapid industrialization and the establishment of the groundwork for additional expansion, especially in heavy industry. The new structures, because of overindustrialization and underdevelopment of the service sector, gradually become rigid and inflexible, and they were unable to keep pace with the quickly rising aspirations of populations for a better quality of life."

Meanwhile, János Kornai, is a bit more succinct in his description: "Central planning is not miserly with the resources devoted to capital formation. The share of investment carved out from the total output is typically higher than in capitalist economies" Kornai (2012, p. 29).

Kornai also describes a type of production cycle akin to the business cycle of market economies, which can explain why during lean times, capital was still being accumulated (Kornai, 1992). Planners had multiple incentives in acquiring too much capital: it was a manner by which you could increase worker productivity (albeit marginally), thereby justifying further employment, and it also came about as plant managers began to hoard capital in expectation of the cyclical trend of higher production quotas following the lower ones.

This production cycle worked in several stages. Desires for economic expansion led to investment in physical capital. Overinvestment would result in a shortage of consumer goods in certain sectors. Planners would then react by slowing down investment into capital goods and shifting production into consumer goods. Before this can occur, there is much forced saving on the part of the consumer who has adequate income and faces low managed prices, but can't find available products until production is fully redirected. The cycle "closes" as shortages dissipate and consumers reap the rewards of past investment. Eventually, the cycle would renew after the shortages evaporate and neglect of capital investments into energy or infrastructure would renew the concern for capital investment. In an effort to build another economic expansion, planners again establish quotas which would increase the stock of capital. However, during the expansions, capital was typically hoarded by managers so that the firm would be ready for the subsequent attempt at expansion following yet another slowdown. These factors came together to generate a workforce which had virtual 0% unemployment, but with this came the outcome of full-employment with chronic consumer shortages as demand stemming from the well-employed consumer often outpaced production (Kolodko, 2000).

A related theory which also gives reason to expect overcapitalization is due to the easy lending practices that many central banks had with the largest producers. The term "soft budget constraint" is often used to describe the ease with which managers could get loans. Often, the loans were used to purchase more physical capital than was optimal. This observation not only led to one of the most well-known economic theories to emerge from the study of the transition but also helps explain why we would expect there to be overcapitalization. Providing many fruitful and lasting insights, János Kornai's study of soft budget constraints has now found itself well-represented outside of the transition literature, and in both mainstream and heterodox economics. It has inspired applications to the present financial bailouts in capitalist economies (See, for instance, Qian and Roland (1998), Du and Li (2007), Pettersson-Lidbom (2010), Fink and Stratmann (2011), or Crivelli and Staal (2013)).

Kornai (1986) coined the term "investment hunger" to describe how a soft budget constraint could lead to overcapitalization during the Soviet era as production managers sought to meet lofty quotas and expand the economy. The endless hunger was quickly fulfilled by successive lines of credit from the central bank. There was no need to be constrained by the availability of resources. Managers could expand output to meet quotas by employing more capital and hiring any available employee. These large firms had little concern for the failure of their investments as any loss could be offset by a steady flow of government financing. As mentioned earlier, as part of a production cycle, the only outcome of this hunger for investment under a soft budget constraint would be the routine shortage of consumer goods. In some of the original work on the subject, Kornai (1980) refers to this as a state of *chronic shortages*, and it is quite possibly the main reason that there was a transition to capitalism.

There are no viable estimates of these planned economies' aggregate capital stock. Any imputation of its value would be purely experimental and even this would need to be conducted using data collected by managers who had strong incentive to hide their reserves of capital stock from detection. Even over the most recent couple of decades, estimating capital stocks through the perpetual inventory method would depend on having reliable estimates of depreciation rates which are likely varying over time as Soviet-era capital is replaced with new capital stock with better known depreciation rates. Without reliable data, there aren't many ways in which to test the implication of overcapitialization in the model of *chronic shortages*. Kemme (1989) gives a good description of literature which presents evidence of shortages in the pre-transition economies, but not overcapitalization. Without direct measures of capital, and given the long run nature of capital stock, one option which has now become available is to use macroeconomic growth theory to test if economies converge from above their steady state levels of per capita income. According to the augmented Solow model, we may be able to get an estimate as to whether these economies began their period of transition starting from above their steady states. If so, this may be interpreted as an empirical validation of the descriptions of the Soviet-era planned economies' relationship to capital. Also, given the frequently changing institutions, including measures of economic institutions doesn't simply offer a unique fold to traditional Solow growth theory, but is required in order to control for changes which are certain to affect long-run growth. To this end, indices of privatization, price liberalization, and other factors of transition, are employed to control for and get estimates of the importance of each factor to long-run growth.

5.1.1. The Output Fall

If we are to study growth during this transition, the U-shaped dynamics of real GDP should be briefly mentioned. The initial decline in real GDP after the onset of the transition was so large that the term "output fall" is often used in favor of "depression" given that the decline in output was nothing less than a complete collapse for most of the transition economies. Figures 5.1, 5.2, and 5.3 illustrate the scale of the output fall by graphing real GDP as a ratio of its 1990 level. While the specific countries may be difficult to discern in the figures, the general trend of 40% to 60% drops in GDP by 1995 is evident, with Azerbaijan and Georgia experiencing the largest drops. What the figures also illustrate is that 1995 seems to be a point from which economies begin to return to growth and stabilize a bit after the drastic changes in price regulations and firm ownership. As can be seen, all but a few

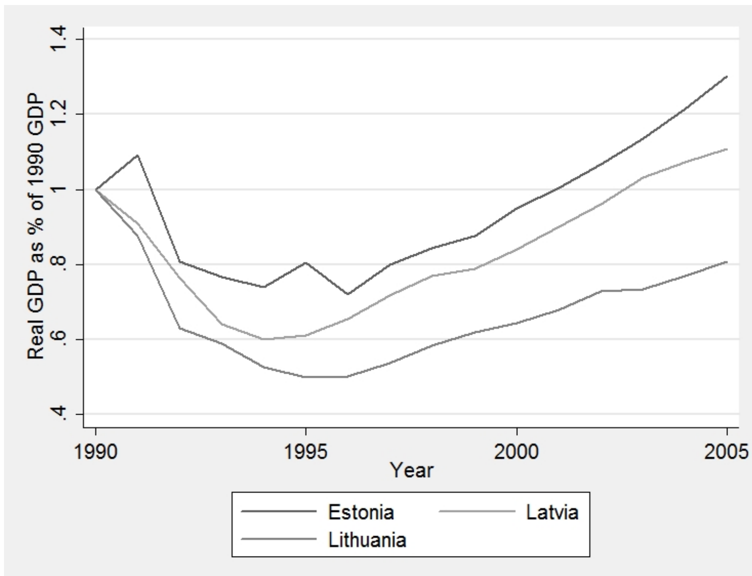

FIGURE 5.1. Baltic Economies' Real GDP as % of 1990 GDP

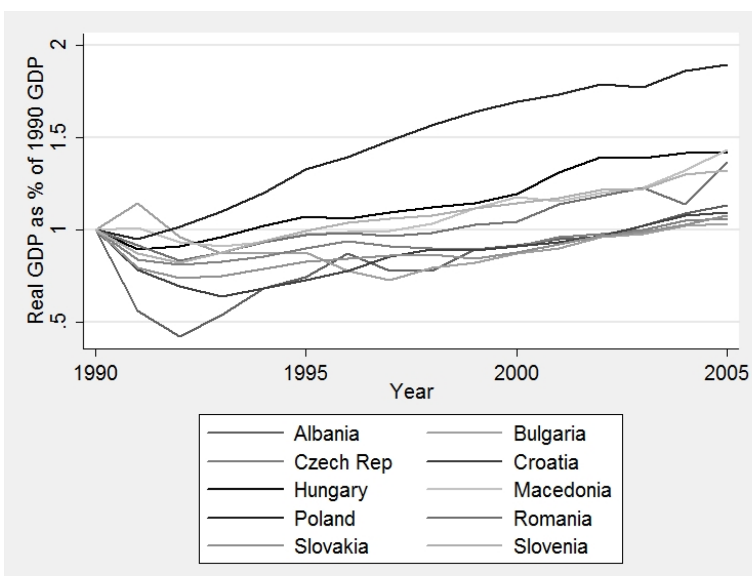

FIGURE 5.2. Central and Eastern European Economies' Real GDP as % of 1990 GDP

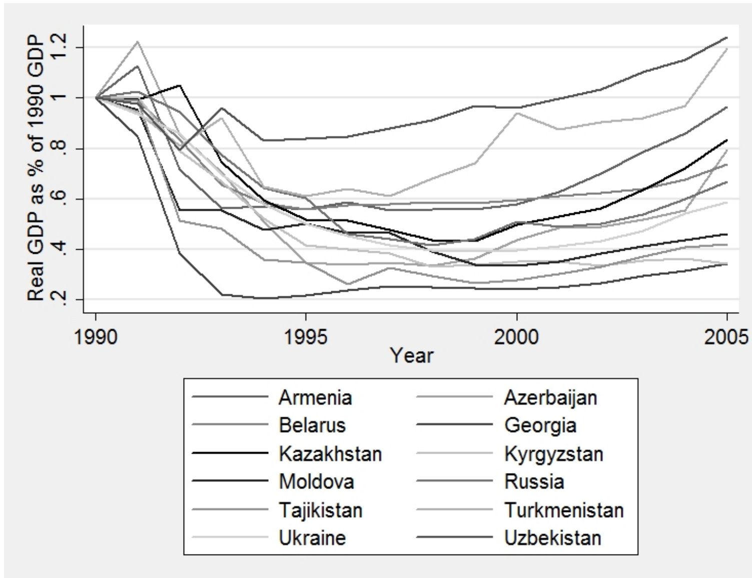

Figure 5.3. Former Soviet Union Economies' Real GDP as % of 1990 GDP

Eastern European economies were beginning a recovery by 1995. Close to half of the former Soviet economies are starting a recovery around 1995.

The goal in estimating the steady state is to isolate the impact of capital. A lot of theories of the output fall refer to disorganization of the production process and radical instability due to large price changes (Åslund, 1994; Blanchard and Kremer, 1997). But, it seems that the impact of capital would be of a more long-run nature than explanations using supply linkages and inflation. We have observations from 1990, but must use those observations as the lagged values, so the first year of full observations is 1995. This post-1990 period is likely to focus on the impact of overcapitalization, and the time-consuming adjustments to the steady state, so the practical requirements and data limitations resulting in the use of 1995 as the first year of data may still give a time frame which is adequate for the study of capital during the output fall. We find that the economies are mostly above their steady states in this period, yet many economies are returning to growth at this period, contrary to a ceteris paribus prediction. So there must be other factors which contribute positively to growth. Institutional change is ongoing and what we are likely seeing from this point is growth in which the gains from institutional transition and TFP improvements are offsetting the negative impact of convergence of capital to lower per-worker levels. The post-Soviet economies may have become more productive yet less capital intensive.

The rest of the chapter will describe these additional institutional variables, discuss a related theory as to why they make for good instruments, present the results, and conclude with a description of the validity of the results and their implications for the theory of *chronic shortages*.

5.1.2. Institutions, Identification, and Estimation Issues

In tailoring econometric methods to theory, it's helpful to focus on the argument that the economy is *embedded* into culture, society, rules and regulations (Polanyi, 1944; Williamson, 2000). Acemoglu's theory of the *hierarchy of institutions* seems to draw heavily from this concept of embeddedness by suggesting that economic outcomes will be dependent upon social and political institutions (Acemoglu, Johnson, and Robinson, 2005). In fact, Polanyi's concept forms a necessary condition for the hierarchy to exist. Polanyi argued that market structures may develop enough power to make an attempt at disembedding themselves from society so that they no longer serve the needs of society. However, Polanyi argues that society reacts to protect itself against the severity and harshness of a pure market system by creating worker protection laws and a social safety net as means to keep markets in the service of society. The *hierarchy* illustrates this by showing that economic institutions are the outcome of political power which is itself determined by existing social and political institutions. Thus both Polanyi and Acemoglu justify the use of institutions as instruments for the variables which establish economic growth. Acemoglu, Johnson, and Robinson (2005) represent a concise version of the theory in the diagram recreated in Figure 5.4.

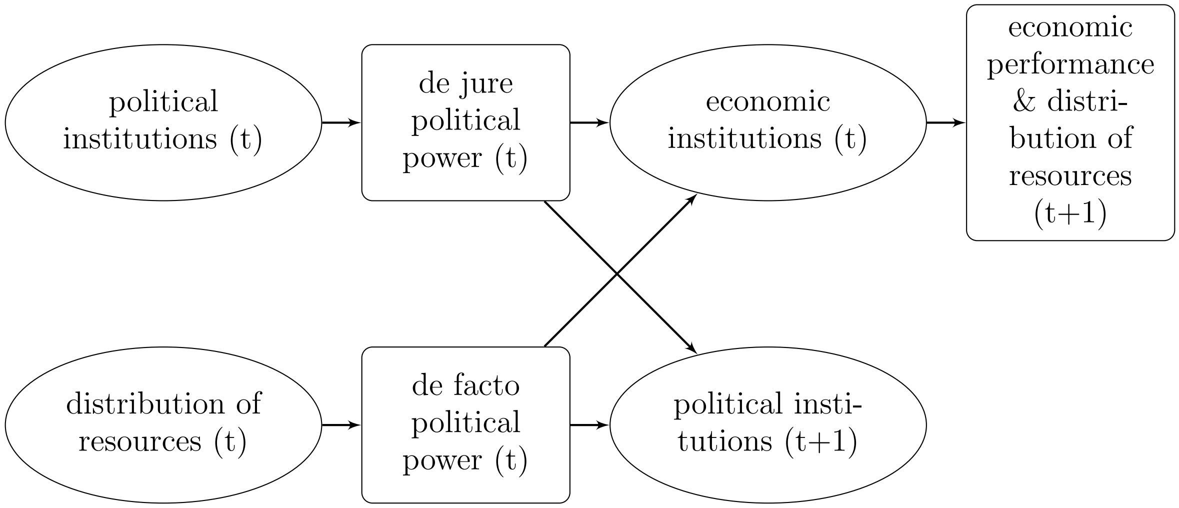

FIGURE 5.4. Hierarchy of Institutions

In the Solow setting, growth doesn't always emerge immediately from institutions. Instead, institutions affect the abilities and incentives of the actors who then determine the level of capital investment, the size of the workforce, and the level of human capital investment. Thus, institutional impacts on growth can be indirect by working through these regressors, as well as being a direct part of total factor productivity. If political institutions and past economic outcomes are omitted from the analysis, it is likely that any change in political and economic institutions will be present in the error term. According to the theory, income distribution may be another omitted variable in the Solow framework which could affect both macroeconomic inputs and output. There's not much which can be done about income distributions: there are too many theoretical and data limitations. As for the remaining components of the model, institutions should be valid instruments as they establish how much actors invest and how fast the workforce grows. However, institutions should not be subject to the same random business cycle shocks which should be present in the error term and therefore can be treated as exogenous. In his work, Daron Acemoglu uses past measures of political and environmental conditions as instrumental variables in a two-stage OLS setting. Similar measures may be experimented with here.

System-GMM estimation is able to incorporate this method into a more complete and general dynamic setting. Thus, as in Eicher and Schreiber (2010) and Falcetti, Lysenko, and Sanfey (2006), this paper utilizes an Arellano-Bond-type GMM estimator to incorporate the *hierarchy of institutions* into a method of determining the differential impact of privatization on the economy. The version used herein is the Arellano-Bover/Blundell Bond system-GMM estimator (Arellano and Bover, 1995; Blundell and Bond, 1998), which utilizes lagged values and lagged differences of a variable as instruments in order to account for the endogeneity present in dynamic panel models. In addition to lagged values of endogenous and predetermined exogenous variables, the estimator also allows for traditional instrumental variables and measures of institutions will be used as such. Using lagged values as instruments for all the variables closely matches the recursive nature of the relationships illustrated above in the *hierarchy of institutions*.

5.1.3. Estimation Issues

As in the other chapters, using a dynamic panel model always presents unique estimation issues. To begin with, unless the cross-sections are fairly indistinguishable, there will often be a country-specific effect which is present in the error term and likely to be related to the right hand side variables. OLS will omit this country-specific effect and as a result, the coefficient estimates will be biased. One solution would be to use fixed effects estimation in order to include the omitted country-specific variable. However, as Nickell (1981) and Kiviet (1995) have noted, regardless of the way the fixed effect is treated in the estimation, the error term will be differenced and therefore it will share information with the lagged dependent variable due to the lagged error term. As such, fixed effects estimation will be biased, especially with regard to the coefficient estimated on the lagged dependent variable. This is particularly problematic in this present work as in order to recover the steady state parameters, we must divide every term by $(1 - \gamma)$ where γ is the coefficient on the lagged dependent variable. These estimation issues offer another reason to use system-GMM: differencing of the data during estimation accounts for the country-specific effect, while the GMM instruments used will ensure that the error term isn't correlated with any of the right hand side variables.

5.2. The Data

The data used in this chapter were assembled from various sources and represent 28 transition countries with most having observations available over the period of 1987-2010. What resulted is an unbalanced panel data set with fewer observations from the earlier periods. The main data sources are from the EBRD (2012), the World Bank Group (2012), and the PolityIV Project (Marshall et al., 2010). Data isn't available prior to 1989, so the first lagged year of per capita real GDP will be 1990, while the first year of full observations is then 1995, given that we are still using 5-year averages and a lag appears as an independent variable.

A result worth noting here is that the method of transition is of little consequence to the result of convergence. It was often argued that the speed and comprehensiveness of the transition process was important to the nature of economic growth under transition. Some authors used the terms "gradualism," and "shock therapy" or "big-bang" to describe the different processes. A literature search brought together citations to create a dummy variable which organizes the countries depending on their transition method.[6] In the end, testing for differences in transition methods gave results which were very sensitive to the number of five-year observations. A paucity of observations after splitting the sample makes it difficult to find statistical significance using system-GMM with several lags, while dummy variables alone are insignificant when included in regressions. In the future, an additional 28 observations will become available and may give higher levels of significance. Thus, the main focus here is on the initial position relative to the steady state and its subsequent success or failure in explaining the output fall during transition.

5.2.1. The EBRD Indexes

The most unique component of the data comes from the EBRD. As a set of controls and instrumental variables, the indices provide a useful measure of institutional change. These are the European Bank for Reconstruction and Development's Transition Indicators (EBRD, 2012) and have been continuously collected and updated since the unofficial start of the transition in 1989. The EBRD produces separate indices for large and small-scale privatization, price liberalization, forex liberalization, and banking liberalization among other measures of institutional change. The EBRD indices take on a value along a scale of 1–4 with 0.33 increments. A level of 1 for the large-scale privatization index signifies that less than 25% of the large-scale industries are privatized. A level of 4+ is indicative of 75% or more of the industries being privatized which is thought to be a level comparable to OECD economies.

[6]Comments found in Sachs (1996), Bunce (1999), Kolodko (2000), Roland (2000), Cornia and Popov (2001), Marangos (2002), Havrylyshyn (2003), Minagawa (2013) gave insights which allowed the following categorization: Shock therapy/Big Bang countries are Croatia, Czech Republic, Estonia, Kyrgyz Republic, Latvia, Lithuania, Mongolia, Montenegro, Poland, Russia, Serbia, and Slovenia. Gradualist countries are Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Hungary, Kazakhstan, Romania, Slovakia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

The small-scale privatization index works along the same lines except without specific percentages associated with each level of privatization. A detailed description of some selected indices can be found in Table 5.2.

The EBRD indices have seen plenty of use in the empirical growth literature. Sachs (1996) produced some of the first estimates of the EBRD indices' correlations to economic growth and others followed. Havrylyshyn (2003) uses a cumulative index to explain growth, as does Hernández-Catá (1997). These earlier studies often show that the negative relationship between a cumulative EBRD index and the transition-period growth. This relationship can be explained by a U-shaped transitional recession and expansion. Because of this U-shaped pattern of growth during the first decade of transition, Popov (2007) uses a cumulative index to divide the sample into pre- and post-1996 periods. He shows that before 1996, the relationship is negative among transition countries but turns positive once economies adjust to their new-found economic freedoms. In fact, what Popov illustrates is that the timing in which studies of these kind are conducted is important and will affect the data and results. Radulescu and Barlow (2002) find that this pattern makes it difficult to find robust results when using a cumulative index over the 1991 to 1999 period.

This literature suggests that the EBRD indices might be valid instruments for the factors which affect economic growth. In fact, Eicher and Schreiber (2010) use an annual set of EBRD indices as instrumental variables in a cross-country growth regression. Of course, the difficulty in cross-country growth regressions has always been the issue of endogeneity. Instruments and "system-GMM" estimation offer a potential way to identify the relationships of interest. Given this empirical relationship, it's likely that institutional variables can be valid instruments. One concern with the validity of such instruments is the possibility of a feedback occurring between economic growth and economic and political institutions. In

Table 5.2. Summary Statistics: Selected EBRD Indices

Variable	**Definition**
Large Scale Privatization	1 – Little private ownership 2 – Comprehensive scheme almost ready for implementation; some sales completed 3 – More than 25 per cent of large-scale enterprise assets in private hands or in the process of being privatized (with the process having reached a stage at which the state has effectively ceded its ownership rights), but possibly with major unresolved issues regarding corporate governance. 4 – More than 50 per cent of state-owned enterprise and farm assets in private ownership and significant progress with corporate governance of these enterprises. 4+ – Standards and performance typical of advanced industrial economies: more than 75 per cent of enterprise assets in private ownership with effective corporate governance.
Small Scale Privatization	1 – Little progress made 2 – Substantial share privatized 3 – Comprehensive program almost ready for implementation 4 – Complete privatization of small companies with tradable ownership rights 4+ – Standards and performance typical of advanced industrial economies: no state ownership of small enterprises; effective tradability of land
Price Liberalization	1 – Most prices formally controlled by the government 2 – Some lifting of price administration; state procurement at non-market prices for the majority of product categories 3 – Significant progress on price liberalization, but state procurement at non-market prices remains substantial 4 – Comprehensive price liberalization; state procurement at non-market prices largely phased out; only a small number of administered prices remain 4+ – Standards and performance typical of advanced industrial economies: complete price liberalization with no price control outside housing, transport and natural monopolies.

Source: EBRD (2012)

particular, during transition, large drops in output would be expected to lead to reversal of institutional changes. In this case, shocks picked up in the error term will be related to the instruments. However, if the model is specified with a lagged level of output as a regressor, then the factors which lead to policy reversals will be included in the model instead of left in the error term, thus alleviating the main concern over the validity of such instruments in this context. In this dissertation, separate measures of large and small-scale privatization, price liberalization, ect. are used along with lagged right-hand side variables as instruments. Such use also finds theoretical support by the *hierarchy of institutions*, a theory to be discussed next section.

5.2.2. Other Sources of Data

As in the earlier chapters, the source for real GDP, population, and a measure of investment all come from the Penn World Tables (Feenstra, Inklaar, and Timmer, 2013). Data on education is not available from the Barro-Lee dataset, however, an effort to collect such data was made in earnest and it comes from multiple sources. Base data come from UNESCO Institute for Statistics. Enrollment in tertiary schools, along with public and private enrollment in secondary schools come from UNESCO (UIS, 2013). The data has many missing values, especially in the early and mid-1990s due to a complete lack of census surveys in Turkmenistan and the breakup of FR Yugoslavia into Serbia and Montenegro. For Turkmenistan, Serbia, and Montenegro, enrollment rates from a UN publication (Berryman, 2000), WDI school-age population figures (Group, 2012), and the UNICEF (2013) TrasMonEE database are used as supplementary sources. Berryman (2000) includes enrollment rates for upper-secondary and tertiary levels of education for the early to mid-1990s. TransMonEE is used to supplement the missing values from 2000s. Even after this construction, there are a number of missing variables. About 10% of the observations are missing for the tertiary data and 15% are missing from the upper-secondary level data. Given the particular use of the data, it becomes important to impute the missing values. If not, the data would skew the results even more given that there are cutoff points used to compute the five-year averages needed for estimation. Most of the missing variables are from the late 90s, so averages taken from above or below a cutoff point in the mid-90s would be skewed in the direction of their respective existing data. So the remaining missing variables are imputed using a time trend which fits the population growth trends in the existing data.

TABLE 5.3. Summary Statistics (Annually): 1990

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
PC Real GDP (US\$)	9353	4434	2641	19338
Pop Growth	0.8%	1.0%	-1.1%	2.6%
Investment Rate	20.2%	10.7%	4.8%	44.2%
Ed Enrollment	82.6%	13.3%	53.4%	100.4%
Large Scale Priv	1.04	0.13	1	1.5
Small Scale Priv	1.41	0.81	1	3
Price Liberalization	1.60	0.96	1	3.35
Autocracy	5.25	0.74	3	7.25

TABLE 5.4. Summary Statistics (Annually): 2010

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**
PC Real GDP (US\$)	12049	6562	2037	25270
Pop Growth	0.1%	0.7%	-0.8%	1.9%
Investment Rate	18.5%	7.5%	2.7%	40.7%
Ed Enrollment	90.9%	14.2%	61.3%	126.7%
Large Scale Priv	3.20	0.78	1	4
Small Scale Priv	3.90	0.53	2.18	4.3
Price Liberalization	4.02	0.47	2.7	4.3
Autocracy	1.6 0	2.99	0	9

Values > 100% are due to repeating grades

Table 5.3 and Table 5.4 describe the data in the beginning of the transition (1990) and the end (2010). Real GDP per capita has increased on average among the transition economies. Population growth has slowed, much like the rates in continental Europe. Investment has stayed the same and education has increased. Education is slightly higher in 2010, but not that far above its already high levels in 1990. Socialist command economies tended to assign very high importance to equality of education. Some of the highest female literacy rates are found in the former soviet socialist republics.

5.3. Results

Of main interest here are the steady state estimates and the countries' positions relative to them, but they are derived from the standard cross-country growth regressions so those results will be discussed first while the steady state results follow in the subsection. The regression results are presented in Table 5.5. OLS and fixed effects estimation are presented for comparison to illustrate the improvement in using system-GMM, especially relative to fixed effects estimation. The coefficient on $(n + g + \delta)$, the break-even level of investment, is insignificant in the OLS estimation, but significant in system-GMM. Much of the difference seems to come from the size of the absolute value of the coefficient, indicating that if the OLS estimates are biased toward zero, then there is likely a fixed effect or other omitted variable which is positively correlated with both output and population growth and is getting picked up by the OLS coefficient on $(n+g+\delta)$. GMM may be accounting for this relationship as it's likely there is a bias from the country-specific effect which isn't present in the system-GMM estimates. With fixed effects estimation, little seems consistent except for a robust estimate on physical capital. The well-known endogeneity issues in using an error term of

Table 5.5. Convergence Regressions Using Transition Economies: 1995 - 2010

	Pooled	Fixed Effects	GMM Unrestricted	GMM Restricted
	y_t	y_t	y_t	y_t
y_{t-1}	0.794***	0.175	0.749***	0.733***
	(0.051)	(0.120)	(0.075)	(0.073)
$(n+g+\delta)$	-0.205	0.103	-0.968***	-0.798***
	(0.189)	(0.167)	(0.353)	(0.261)
s_k	0.272***	0.181***	0.365***	0.369***
	(0.071)	(0.032)	(0.122)	(0.113)
s_h	0.286*	0.381*	-0.195	
	(0.147)	(0.206)	(0.228)	
Large Scale Priv	-0.0459	-0.0730	0.158	0.138
	(0.058)	(0.061)	(0.125)	(0.116)
Small Scale Priv	0.184**	0.0464	0.474***	0.423***
	(0.088)	(0.085)	(0.149)	(0.117)
Price Liberalization	0.0700	-0.00507	-0.725**	-0.715**
	(0.108)	(0.069)	(0.318)	(0.285)
Autocracy	0.0321***	0.00496	0.0769*	0.0566
	(0.011)	(0.018)	(0.040)	(0.042)
time t	0.123***	0.202***	0.0701**	0.0664**
	(0.025)	(0.037)	(0.028)	(0.027)
cons	0.789	7.768***	0.451	1.411
	(0.857)	(1.422)	(1.711)	(1.527)
λ	0.004	0.058***	0.015***	0.012***
	(0.003)	(0.008)	(0.005)	(0.003)
N	112	112	83	83
R^2	0.9060	0.8243	–	–
Hansen J	–	–	0.348‡	0.263‡
$AR(1)$	–	–	0.201‡	0.196‡
$AR(2)$	–	–	–	–

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

† $N = 83$ due to use of lags as predetermined instruments

‡ p-values

first-differences may be at play. Education is significant and positive for both OLS and fixed effects estimation. Under GMM, the coefficient becomes negative and insignificant. This is a strange result, but education has been shown to behave strangely in other research (see, for instance Barro (1996), Caselli, Esquivel, and Lefort (1996), Soto (2002), and Easterly (2003)). It's possible the issue may be due to lack of variability in the in the first-differenced data (Arcand and d'Hombres, 2005). Because of this, and the fact that this present research is more concerned with estimating the steady state, the human capital variable is dropped in the fourth column of results in Table 5.5 and the majority of the discussion will focus on those results. OLS and GMM seem very consistent in their estimation of the lagged values of real GDP. This is important as the coefficient on y_{t-1} and its variance are needed to compute the steady state. The fixed effects estimation of the coefficient on y_{t-1} shows likely dynamic panel bias first discussed in Nickell (1981).

Interestingly, all of the estimates exhibit rapid rates of convergence, ranging from 11.16 to 15.02 years, to the half-way point of their steady states. This may be in line with the rapid economic growth (both negative and positive) which occurred over the period. The estimates of the capital share of income vary depending on the coefficient, but neither one is completely unrealistic. Focusing on the last column, the coefficient of -0.798 on $(n + g + \delta)$ implies a capital share of 0.75 while the coefficient on s_k gives the more direct estimate of investment and results in 0.58 for the capital share of income. These are very high estimates of capital shares. These are similar to the shares of capital that the utility and information sectors, respectively, would obtain on their own in the United States (Acemoglu and Guerrieri, 2008). Interestingly, these shares in themselves provide evidence of high levels of capital investment, although they cannot be interpreted on their own as overcapitalization, which is why positions relative to the steady state are important. In any case, the inclusion of the other coefficient estimates in the ultimate calculation of the steady state will include additional information which contributes to significant estimation of the steady state. In other words, problems present in the point estimate of a coefficient may be less severe when using several such estimates to calculate the steady state.

Unique to this convergence regression is the inclusion of the EBRD indices. These measures of institutional change not only help identify the variables of interest, but also provide insights into the transition process itself. It appears as if large scale privatization is not significantly correlated with economic growth. Estimates not presented here indicate that large scale privatization is *negatively* associated with the levels of output, but now we see that the growth of output is a different creature. There may have been temporary benefits from privatization due to one-time sales of large companies, but those benefits may not be reflected in the subsequent growth of real GDP once a large and disorganized firm is privatized.

Small-scale privatization is another story. The coefficient there is significant and positive. Some of the firms are fairly large, with some countries' measures of "small-scale" being firms of 500 employees or less. Others use 250 employees as a cut-off. None-the-less, the measure does help capture the efficiency benefits of privatizing firms which are not extremely large. It is associated with an immediate positive impact on growth. In moving from fixed effects to GMM, the fact that the variable becomes significant lends credibility to the use of system-GMM.

Even more supportive of the system-GMM estimation is the behavior of the coefficient on price liberalization. The direction of the coefficient on price liberalization isn't very surprising. The fact that the significance and direction of the coefficient switches to what is expected under system-GMM finds much support in the literature. It's a fairly well-known fact that hyperinflation during the process of transition was an immediate consequence of privatizing prices under the state of shortages and repressed inflation. Autocracy isn't significant, perhaps because some countries underwent a complete transition process, including political change, while others merely underwent economic reform and the relationship was randomly distributed in relation to growth and the other reforms which affected growth.

5.3.1. Evidence of Overcapitalization

To explain what happens during this period of transition, the system-GMM estimates presented in the previous section can be used to compute steady-states in the exact same manner as in the previous chapters and as shown in Equation 30, only now the ρz include the transition indices. Variances of the steady states are computed using the delta method.

This main contribution finds significant support for theories of overcapitalization in the onset of transition. Cornia and Popov (2001), Kolodko (2000), and Kornai (2012) have all argued that there was too much physical capital being invested into by centrally planned economies. Here, using the system-GMM results without education as in the fourth column of results in Table 5.5, we find that 21 of the 28 transition economies are above their steady states in 1995. If we include education, then the result is that 24 of the 28 transition economies are above their steady state in 1995. The full estimates, which include education in one set and exclude it in the other, are presented in Table A.8 found in the appendix. The differences which occur due to the inclusion of education still give results which are about what we would expect given the anecdotal evidence of overinvestment during the Soviet era. It's worth noting is that these results indicate a relationship of physical and human capital to what would be their steady state levels, given rates of population growth and institutions.

Given institutions as they were in 1995, a position above the steady state suggests that these economies should continue to fall, but this is not what happened for many. A possible explanation is that institutional change continued while the benefits from past institutional changes began to finally accrue, leading to positive shifts of TFP in the future periods. Thus, losses due to capital depreciation, sales, and replacement were offset by improving institutional conditions.

To illustrate this relationship, we have included Figure 5.5 and Figure 5.6. As in the earlier chapters, the solid line is a 45° line in which the steady state would be equal to the actual level of output. Positions above the line indicate levels of output which are above the steady state. Azerbaijan (AZE), Moldova (MDA), and Georgia (GEO) can be seen to be well above their steady states, and also well below the levels of their 1990 output. In fact, all three are close to 50% of the level of output at the onset of the transition. Armenia (ARM), Serbia (SRB), and Ukraine (UKR) appear to be in better growth positions, although for various reasons. Serbia and Ukraine are both emerging and balanced economies, with Serbia having the higher per capita income and steadier growth. Armenia, on the other hand, has likely seen its economy not only affected by the transition, but a rebuilding effort buoyed by international aid following a devastating 1988 earthquake.

The general pattern for the transition economies is fairly clear: these results are mostly consistent with the anecdotal evidence in the beginning of the chapter. It's likely that overcapitalization presents another important explanation of the output fall. Kornai's study of soft budget constraints and description of chronic shortages can help explain how these economies got to this point and took so long to recover. Physical capital, unlike movements

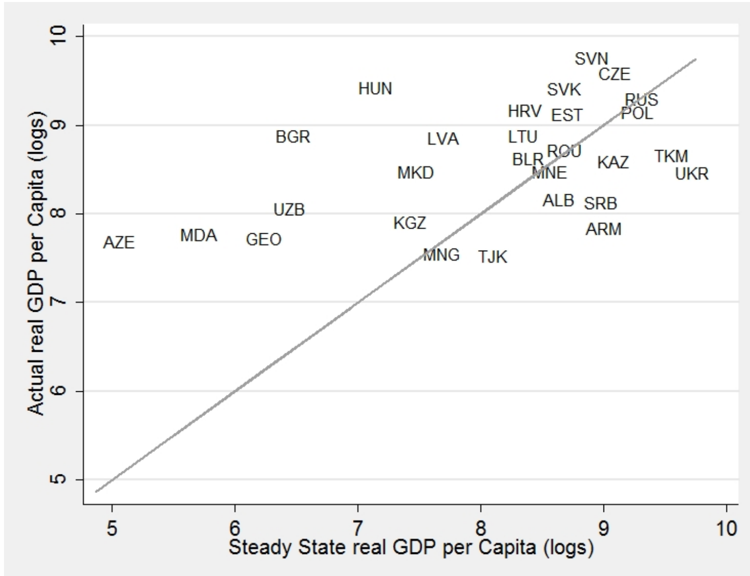

FIGURE 5.5. Transition Economies' Initial per capita GDP relative to the steady state

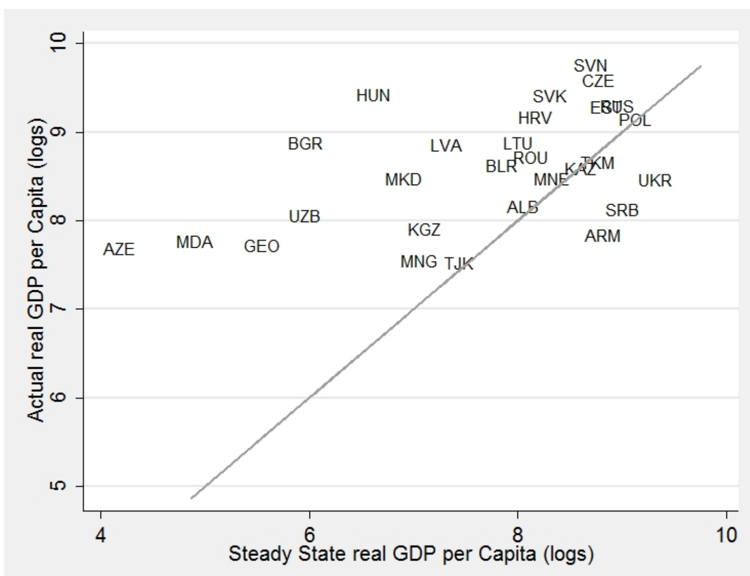

FIGURE 5.6. Transition Economies' Initial per capita GDP relative to the steady state (including education)

of prices, is something real and tangible which takes time to be replaced or scrapped. However, the relationship to the subsequent growth rates aren't as clear here as they are in the applications to the worldwide or OECD samples. Institutions are rapidly changing over this period and so does a country's total factor productivity and steady state. Most of the estimates of total factor productivity are insignificant due to the fact that the constant is insignificant in the regressions. This is unfortunate as TFP carries important information in this context. It's possible alternative estimates may produce a significant regression constant, but in this present analysis there is just too much variability over time. Even so, the estimates of the steady state include additional significant information so that the steady state estimates are all significant at the 5% level.

According to theory, the locations above the steady state let us know that the economies are about to embark on slower than average growth. However, within this sample there are historic changes in GDP growth and institutions. Among the transition economies, the average rate of growth from 1995 to 2010 is 4.2% per year. There are several growth leaders. Azerbaijan experienced a 10.1% average rate of annual growth over this period. At the other extreme, Kyrgyzstan saw an average annual rate of growth in per capita income of -1.8%, and all this is happening during a period in which astounding drops in real GDP have occurred. Given this context, gaining significant empirical insights into the initial period of transition may be all that can be reasonably expected.

5.4. Concluding Remarks

This chapter has attempted to find evidence of overcapitalization at the onset of the transition from the Soviet-era planned economies to emerging market economies. There are plenty of reasons to believe that these economies should have been converging from above their steady states. However, the use of a sample of 28 economies undergoing such radical economic and institutional transition poses several estimation problems. The subsequent growth rates have been erratic. Presently, some of the transition economies have attained the fastest growth rates in the world while others haven't grown at all. Attempting to determine where the steady state is during this period entails estimating a level of potential output which is continually evolving. Not only this, but total factor productivity should be evolving too, as the intent of the transition to a more market-based economy is to obtain productivity-enhancing institutions. This suggests that in addition to short-run changes in nominal variables, there is also an evolution of the long-run steady state.

Despite these challenges, it does appear that the method presented herein can detect initial levels of steady state incomes. If so, this chapter gives a set of interesting results. Fortunately, it is possible to not only control for the movements in the long-run steady state, but also use their exogenous variation as instruments to address the identification issues associated with a panel growth regression. Also, the system GMM estimator can use measures of institutions as instruments along with including them as right-hand-side variables. Doing so gives several results.

First, several of the EBRD indices are significant and impact growth in the direction that one would expect. Price liberalization has a clearly negative impact on growth while small-scale privatization is associated with faster transition growth. After accounting for the presence of these institutional changes, we are able to find significant conditional convergence among the sample of transitioning economies and use those estimates to determine whether the initial levels of output are in one of two positions (above or below their steady states). The minimal requirements made on the results lead to significant estimation of the steady states and affirmation of the observations of Kornai (2012) and others. The majority of transition economies are likely to have begun from an initial position above their steady states. According to the Solow model used to detect it, this is likely due to having too much capital.

There have been many contributions to determining what happened during the output fall. Blanchard and Kremer (1997) model problems with asset-specific capital, Roland and Verdier (1999), look at the consequences of price liberalization, Aghion and Blanchard (1998) and Debande and Friebel (1995) examine how privatization led to the fall in output. The significance of these present results are that we have another explanation for the output fall of the post-Soviet economies: investment needed to be reallocated and capital stock per worker had to come down to a lower level before the economies could grow at their long run rates. We are essentially arguing that the quantity of capital was also problematic. This adds to these list of explanations, of which many may be needed given the sheer scale of the fall in GDP. The option we have just presented is another viable explanation, and uses one of the most standard macroeconomic growth models. Given the universal importance of capital to macroeconomic growth, this could also be one of the safer explanations in the face of a transition to markets which was diversely carried out not only in its speed of privatization and price liberalization, but also in the sequencing of such policies.

CHAPTER 6

Using the OECD Sample to Forecast

In this chapter, we choose to isolate the sample of OECD countries in order to estimate steady state levels of output over the entire sample period rather than only in the initial period. What is new to this estimation is the need for a reliable estimate of g, the growth rate of total factor productivity. In the prior chapters, this wasn't a concern as gt takes on a value of zero in time $t = 0$. The OECD sample offers a group of economies which tend to follow a similar growth path and finding a significant time trend is made easier because of it. There are also theoretical and estimation issues which are addressed by using this sample of countries.

Looking at steady states over various periods of time helps describe the development patterns over the last 3 decades. Also, knowing where the economies are in the most recent period could give insights into the present growth patterns. One would expect that the OECD economies would have started the recent period of development below their steady states, considering that, prior to the 2007-2009 recession and excluding the 1980-1982 recession, the countries are known to have had fairly consistent growth and to have developed and adopted many of the current production technologies. We find that, outside of the periods of recovery from recessions, the trend is for OECD economies to begin the period below their steady states, move toward their steady states, and then in 2005 proceed to go above them and continue to move further above in 2010. The changes appear to be indicative of subsequent 5-year periods and indicate that, outside of any unexpected shock, the present period should be one of slow growth.

A reduced form regression is also run to decompose the movements above and below the steady states. Capital investment into new residential housing may be too sporadic due to financial irregularities to find significance. Nonresidential investment, however, shows the relationship of capital to positions above and below the steady state that we would expect. That is, increasing investment below the steady state will shrink the distance from the steady state while increasing investment above will push an economy further above its steady state.

This chapter proceeds with a quick discussion of the OECD countries as a sample then discusses the estimation issues that the sample addresses. In the third section, results are presented which describe the countries' positions relative to the steady state over time. The fourth section presents a short regression which relates types of capital investment to the movements around the steady state and the final section briefly concludes.

6.1. The OECD Panel: 1980 - 2010

In this present research, where the focus has been on determining whether a country is converging from above or below the steady state, intentionally selecting countries which had fairly consistent growth helps clarify a potential misunderstanding. We would like to illustrate that the method previously developed in Chapter 3 does not simply split up a sample based on an average growth rate, but rather determines each country's location relative to its own steady state strictly through the use of theory and data. That is, it would provide support to this method if the results showed variation in one extreme direction or the other, rather than appearing to simply compute a conditional expectation which splits the sample. The OECD group gives a way to check this because they tend to move together and we'd expect them to all be below their steady states prior to a period of growth.

The group of countries representing the OECD were originally part of the Mankiw, Romer, and Weil (1992) initial study of condition convergence and were mainly selected due to the quality of the available data. The authors chose a selection of countries who had joined the OECD by 1965 so as to avoid selection bias. If they had joined after, then it would be expected that they would have higher growth throughout the sample. After it was used in Mankiw, Romer, and Weil (1992), for comparability purposes, the sample found itself a part of many contributions to standard convergence. Examples can be found in Islam (1995), Lee, Pesaran, and Smith (1997) and Bond, Leblebiciolu, and Schiantarelli (2010). As in this current paper, some authors cite more technical reasons for using the sample (Arnold, Bassanini, and Scarpetta, 2011). We'll discuss these reasons in the following sections while noting here that the similarities between the technology employed by the group of countries helps address several theoretical and empirical issues. For now, it may be worth noting that Barro and Sala-i-Martin (1992) used the states of the United States to use cross sections with similar technologies, thereby addressing some of these same issues and the strategy with the OECD sample can be similar.

Presently, 1980 is chosen as an initial period and this allows for the inclusion of two additional countries to what was in Mankiw, Romer, and Weil (1992), for a total of 24 cross sections in the panel. The main reason for starting in 1980 is due to data availability of the relevant institutional variables, however this is conveniently the beginning stages of what became known as "the great moderation," a period of stability and steady growth. Table 6.1 lists the countries found in the sample. The panel is balanced and each cross-section contains seven 5-year periods, so that there are seven time observation for each of the 24 cross sections.

Table 6.1. OECD Members in the Sample

Australia	Denmark	Greece	Japan	Norway	Switzerland
Austria	Finland	Iceland	Luxembourg	Portugal	Turkey
Belgium	France	Ireland	Netherlands	Spain	United Kingdom
Canada	Germany	Italy	New Zealand	Sweden	United States

The PolityIV indexes are ideal for the worldwide sample, but when analyzing the OECD, many of the political institutions are so similar that the data borne out in the indices are virtually identical. So we use an alternative measure of institutions in the form of the Economic Freedom Index constructed by the Fraser Institute and provided by Gwartney and Lawson (2012). The Economic Freedom Index is a comprehensive measure of various factors which measure the business climate of a country. In brief, the index measures the size of government, legal systems, property rights, sound money, freedom to trade internationally, and regulation. While the correlation and therefore inclusion of some components may be in question (such as the size of a government which scores lower while government-enforced property rights score higher), the cumulative index does perform well in growth regressions.

6.2. Estimation Issues

There are a host of concerns associated with cross-country growth regressions. Many of these can be addressed by choosing a panel of countries which are similar enough to make the assumptions of common production technologies and common TFP growth more reasonable. This is the motivation behind finding "growth clubs" as in Durlauf and Johnson (1995), Canova (2004), and Phillips and Sul (2007) among others. It's especially important to address these issues in this last illustration of possible applications of convergence theory. Additionally, having homogenous production technology also makes the critical assumption of the system-GMM estimator less questionable (Pesaran and Smith, 1995). In one sense, the Solow model does offer a theoretical framework with which to make the assumptions more acceptable, especially when using panel data and allowing TFP levels to vary. Physical and human capital shares may be seen as identical between countries as long as the technologies used to complement them are not. That is, the effectiveness of capital may vary, even thought the income shares do not. This is the approach used here, and the OECD panel of countries appears to closely conform to this.

As discussed in Eberhardt and Teal (2011), there are more econometrically sophisticated ways to deal with some of these issues. Presently, there are dynamic factor methods which allow for, not only country-specific levels of TFP, but country-specific growth rates in TFP and shares of physical and human capital (Pesaran, 2006; Teal and Eberhardt, 2009; Bai, 2009). Here, we don't allow quite as much much flexibility in the estimator, but adopt the strategy of using a sample in which so much flexibility isn't as important as in a one which might also include developing economies. In some ways, the institutional index may also be considered to be a component of the error term, as is specified in a common factor model. Ultimately, what is important is that there is variation between countries in the components which are most important. This should be sufficient as there are also common elements shared between this group of economies.

6.3. Results

For comparison, we'll first examine in detail the regression without the Economic Freedom index and then in the following section, the index will be included and those results will be used to compute steady states for each period in the sample. To follow the results throughout time, a series of graphs will be used in an effort to keep the information succinct. The regression tables still apply to every period, although the time trend increases linearly and appropriate time dummies are included in the calculation of the steady states. The time trend allows for estimation of g while time dummies help control for cross-sectional interdependency such as global macroeconomic shocks.

6.3.1. OECD Base Results: 1980 - 2010

To see if results vary, we'll compare convergence regressions which do not include institutions to ones that do by presenting the standard (without institutions) convergence regression first and then comparing it to one including institutions next. When the steady states are calculated using the former results, all the OECD countries except for Spain, Turkey, and France remain under their 1980 steady state, indicating that the long run growth rates should be above average for most countries in the following years. The sample begins in 1975 and has full observations in 1980 (since 1975 is needed as the first lag). Table 6.2 presents the detailed convergence results.

There are a couple of notable distinctions. First, when compared to the worldwide sample, the speed of convergence is much faster in the OECD group, corresponding to 6.8 years and 7.6 years for the restricted and unrestricted half-lives. This is a common result. Also, at 0.25, the OECD group has a lower physical capital share and a higher share of human capital at 0.35. Interestingly, the physical capital share is lower than 1/3 but closer to the estimates produced by the OECD itself through national accounts (Abu-Qarn and Abu-Bader, 2009). These shares are also fairly consistent with what others find in the OECD sample (Canarella and Pollard, 2011). The deterministic growth rate corresponds to a period of five years and is only significant under fixed effects estimation. In the next section, when institutions are included, the deterministic growth rate becomes significant in the system-GMM estimation. The coefficient on time, t, corresponds to slightly less than 1% per year which is lower than might be expected. It would seem that the impacts of the other variables make a strong

TABLE 6.2. Convergence Regressions using an OECD Sample: 1980 - 2010

	Pooled	Fixed Effects	GMM Unrestricted	GMM Restricted
	y_t	y_t	y_t	y_t
y_{t-1}	0.913***	0.601***	0.602***	0.634***
	(0.030)	(0.089)	(0.093)	(0.092)
$(n+g+\delta)$	-0.0826	0.0860	-0.301**	–
	(0.077)	(0.118)	(0.147)	–
s_k	0.115***	0.176**	0.257**	–
	(0.036)	(0.082)	(0.118)	–
s_h	0.0783*	0.118*	0.357***	–
	(0.043)	(0.063)	(0.118)	–
$s_k-(n+g+\delta)$	–	–	–	0.161**
	–	–	–	(0.082)
$s_h-(n+g+\delta)$	–	–	–	0.300***
	–	–	–	(0.083)
λ	0.018***	0.102***	0.102***	0.091***
	(0.000)	(0.001)	(0.005)	(0.000)
time t	-0.00101	0.0367***	0.0178	0.0202
	(0.005)	(0.011)	(0.016)	(0.018)
constant	0.727**	4.176***	2.735***	1.921***
	(0.300)	(0.903)	(0.891)	(0.537)
N	168	168	168	168
R^2	0.9655	0.9438	–	–
Hansen J	–	–	0.272†	0.242†
$AR(1)$	–	–	0.001†	0.001†
$AR(2)$	–	–	0.970†	0.788†

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

† p-values

enough contribution to growth that there isn't much left over for the time trend to pick up.

The focus is on the restricted results in column 5 of Table 6.2. Steady states are calculated as was described in Chapter 3 using Equation 20 and the results are illustrated in Figure 6.1. In Figure 6.1, the labels are at the 3 o'clock position, so some may appear to the right of the 45° line, but they may actually be closer. The full set of results are presented in the appendix with Table A.9 and, as is seen, all but one of the countries, Turkey, is significantly above its steady state in 1980. In this restricted version of the model, Spain and France are above, but very close to, their steady states.

There are some notable country-specific occurrences in the OECD panel. Ireland and Luxembourg had the best growth prospects starting in 1980. Interestingly, Greece was in a position to catch up to a much improved steady state, although it should be noted that the data end in 2010, missing the second half of the debt crisis. That said, the debt crisis often obscures the fact that the Greek economy nearly doubled in size, growing by 89.3% over

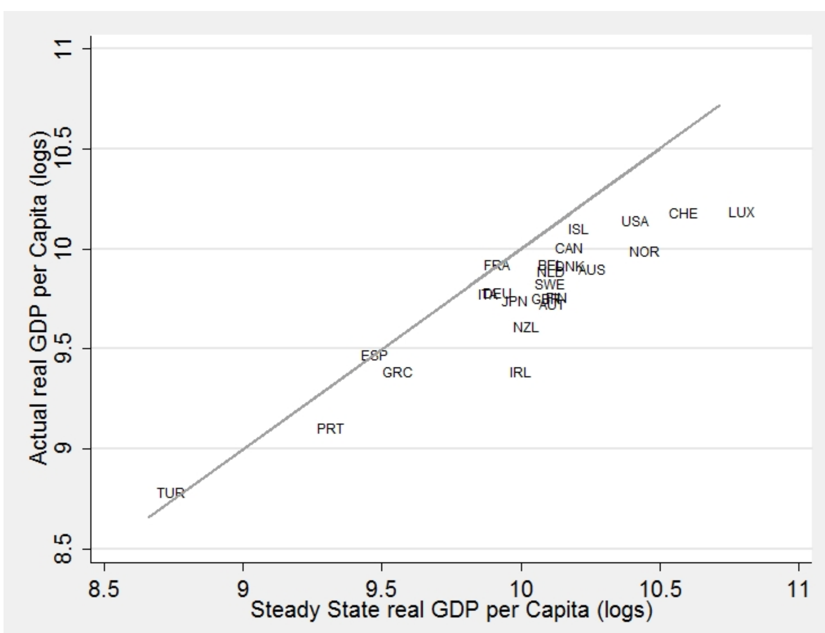

Figure 6.1. Per Capita GDP Relative to the Steady State, OECD 1980

those decades. Japan is still well below the steady state but its economy lost some luster entering into the 1980-2010 period of development as it came closer to a level of balanced growth and then become overcapitalized by the mid-90s.

6.4. The OECD Panel with Institutions: 1980 - 2010

As is mentioned earlier, the institutional measures in PolityIV have little variability among the OECD countries. All are fairly well-developed democracies. So, a measure of economic institutions, the Economic Freedom Index, is used. This section presents those results and then illustrates the resulting series of steady states. The distribution of OECD countries around their steady state is the most important part of this analysis, but the convergence results are also worthwhile so those are presented first. Table 6.3 presents those results.

OLS and fixed effects estimation are again used to make comparisons to the system-GMM estimation. As in the other samples, we find significant convergence as indicated by the positive coefficient on y_{t-1}. In every case, the speed of convergence is much faster for the OECD countries when compared to either the worldwide or transition economies. In column 5, the speed of adjustment parameter, λ, indicates that in only 6.61 years the average OECD country will be half-way to its steady state. As far as long-run growth is concerned, this is an extremely short period of time but makes sense considering that the OECD countries are quick to innovate and take on new technology while quickly adapting economic activity to the new potential levels of output. The coefficient on $(n + g + \delta)$ is insignificant irrespective of the estimation, but the capital investment s_k and human capital investment s_h coefficients take on fairly plausible values for developed economies. Those coefficients imply that $\alpha = 0.23$ and $\beta = 0.25$. The figures are again lower than the 1/3 standard for the level of physical capital that the literature has accepted, but are very close to the actual accounting estimates of the OECD's Productivity Database (Abu-Qarn and Abu-Bader, 2009).

Table 6.3. Sample of OECD Countries with Economic Institutions 1980 - 2010

	Pooled	Fixed Effects	GMM Unrestricted	GMM Restricted
	y_t	y_t	y_t	y_t
y_{t-1}	0.894^{***}	0.603^{***}	0.551^{***}	0.592^{***}
	(0.033)	(0.087)	(0.101)	(0.087)
$(n+g+\delta)$	-0.0820	0.0857	-0.198	–
	(0.077)	(0.120)	(0.150)	–
s_k	0.120^{***}	0.176^{**}	0.259^{**}	–
	(0.036)	(0.081)	(0.113)	–
s_h	0.0523	0.110^{*}	0.269^{**}	–
	(0.044)	(0.058)	(0.105)	–
$s_k-(n+g+\delta)$	–	–	–	0.184^{**}
	–	–	–	(0.080)
$s_h-(n+g+\delta)$	–	–	–	0.197^{***}
	–	–	–	(0.073)
$Econ\ Freedom$	0.0194	0.0118	0.0609^{**}	0.0630^{**}
	(0.012)	(0.023)	(0.026)	(0.028)
$time\ t$	-0.00139	0.0343^{***}	0.0308^{*}	0.0319^{*}
	(0.004)	(0.012)	(0.018)	(0.019)
$constant$	0.866^{**}	4.354^{***}	3.252^{***}	2.337^{***}
	(0.347)	(0.883)	(0.965)	(0.547)
λ	0.022^{***}	0.101^{***}	0.119^{***}	0.104^{***}
	(0.007)	(0.029)	(0.037)	(0.029)
N	168	168	168	168
R^2	0.9662	0.9441	–	–
$Hansen\ J$	–	–	$0.293^{\dagger}$	$0.268^{\dagger}$
$AR(1)$	–	–	$0.003^{\dagger}$	$0.003^{\dagger}$
$AR(2)$	–	–	$0.916^{\dagger}$	$0.830^{\dagger}$

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

† p-values

The Economic Freedom Index is significant and positive in the system-GMM estimation. The index is on a scale from 1–10 so that 0.063 indicates that the level of real GDP would increase by 6.3% for every 1-point increase in the index. For perspective, a 1-point difference in the index is found between the economic institutions of United States and Mexico, with the US having an index value of 7.73 and Mexico one of 6.64. At the highest end of the scale, Singapore has an index value 1-point higher than the United States. The reasons for the significant relationship to growth may vary. There may be a direct link to productivity, or an indirect link through beggar-thy-neighbor policies involving tax shelters and other incentives and trade policy to attract industry rather than grow it. These factors are not examined here, but may also explain the positive relationship to growth.

The variable labeled as *time* t is the time trend and among the OECD sample it is found to be significant even after time dummies are also included. Time dummies help control for shocks common to each cross-section, such as recessions and expansions affecting most OECD members. The coefficient is our estimate of g, and as with the previous example, it is lower than is typically assumed. Over a period of 5 years, the 3.19% deterministic growth rate implies that there is an average of 0.64% increase in real GDP per year due to growth in TFP. Common assumptions and rough estimates have assumed that the 2% – 3% average growth rates in real GDP among the OECD economies is due entirely to g. The estimate here and the fact that OECD economies move above their steady states in the later observations of the sample implies that much of the growth in real GDP isn't due to technical change, but investments in physical and human capital per worker.

As before, the methods of Chapter 3 are employed to derive the values of each steady state. This time institutions are used in the manner shown by Equation 30 from the chapter. The restricted estimates from the fifth column of Table 6.3 will be used, although there isn't very much difference between the two system-GMM estimates. Figure 6.2 begins the illustration of the country's positions relative to their steady states and the full results for 1980 can be found in Table A.10 of the appendix. OECD countries are much closer to the steady state and only a few are slightly above it, which paints quite a different picture to the worldwide sample. Every country except for Spain, France, and Turkey is below their steady state which gives a strong indication that OECD countries are able to increase their total factor productivity and thus are generally catching up to a continually improving steady state level of per capita real GDP. The estimates are all really tight fits. For example, Spain is \$933.90 above its steady state while France and Turkey are \$1590.85 and \$738.78 above their respective steady states.

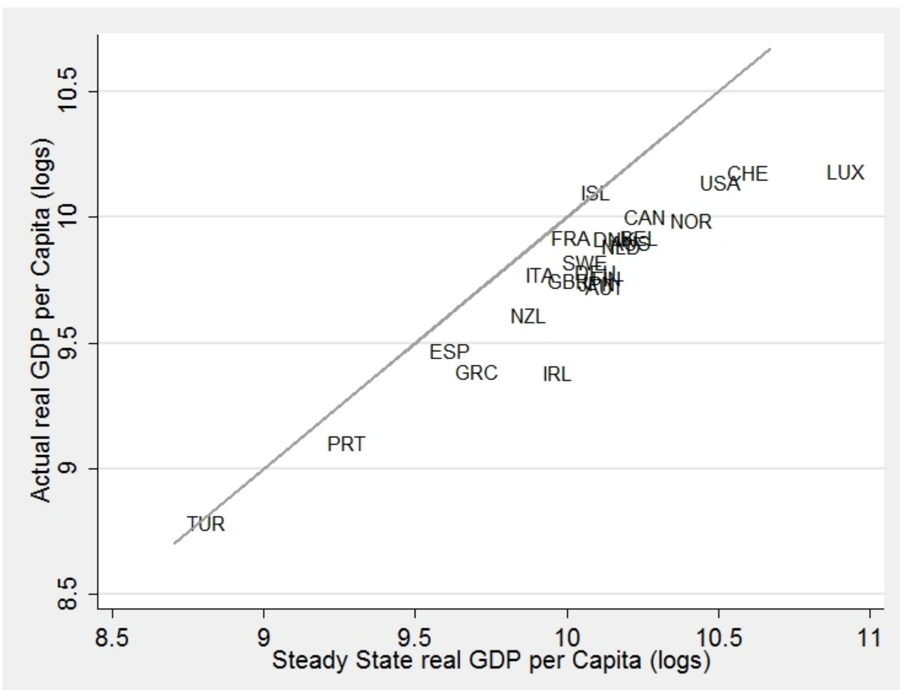

FIGURE 6.2. 1980 Per Capita GDP Relative to the Steady State

The following graphs illustrate the progression of estimates emerging from the base year. The *log* of the steady state now increases 0.0319 every 5-years due to g and will also increase in response to higher saving and education rates along with changes in economic institutions and any shock common to the countries.

By 1985, a shock has occurred which pushes a majority of the countries above their steady states. New Zealand, Canada, the United States, Sweden, and Italy all join the original 3 countries above the steady state. By 1985, the United States had just experienced a large recovery and expansion following the recessions of 1980 and 1982. In fact, the recessions and expansions were fairly global among the OECD economies, with the main differences being that the growth in real GDP and improvements in unemployment following the recovery were more tepid in Europe than in the US (Coe, Durand, and Stiehler, 1988). These impacts and subsequent slower growth is reflected here with the movement above steady states following an impressive recovery and prior to a period of slower growth.

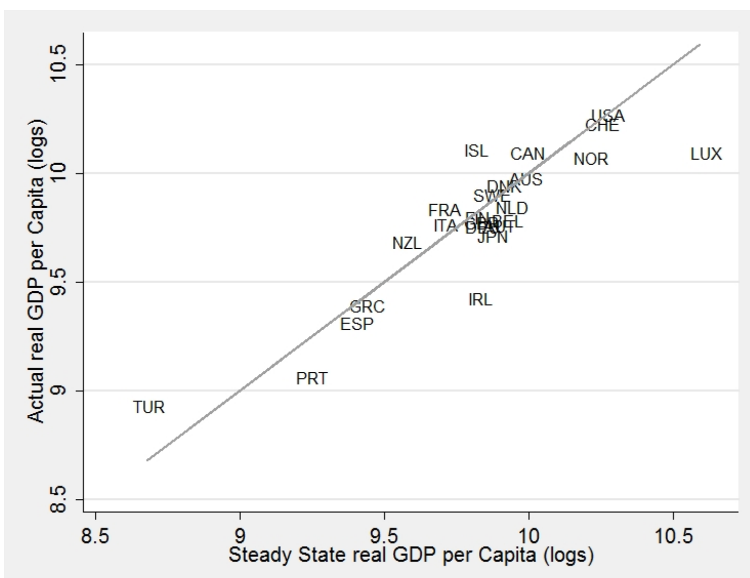

Figure 6.3. 1985 Per Capita GDP Relative to the Steady State

The rest of the pattern can be seen from the following graphs of output vs. steady states. The potential level of output has risen above actual levels of output as TFP has had time to evolve and enhance real productivity. The period following the 1980–1985 period is also one of moderation, that is until the 2007-2010 recession. Over the late 80s and early 90s, the majority of economies stayed at or well below their potential levels of output, indicating that they would incur higher levels of growth in later periods as capital was accumulated during the convergence to their own steady state. Interestingly, the US stays close to the steady state frontier which is consistent with its role as the source of TFP evolution.

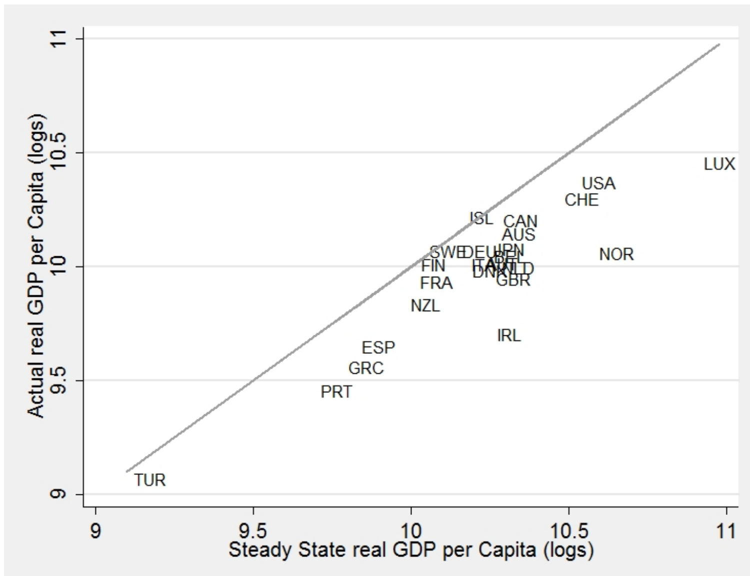

Figure 6.4. 1990 Per Capita GDP Relative to the Steady State

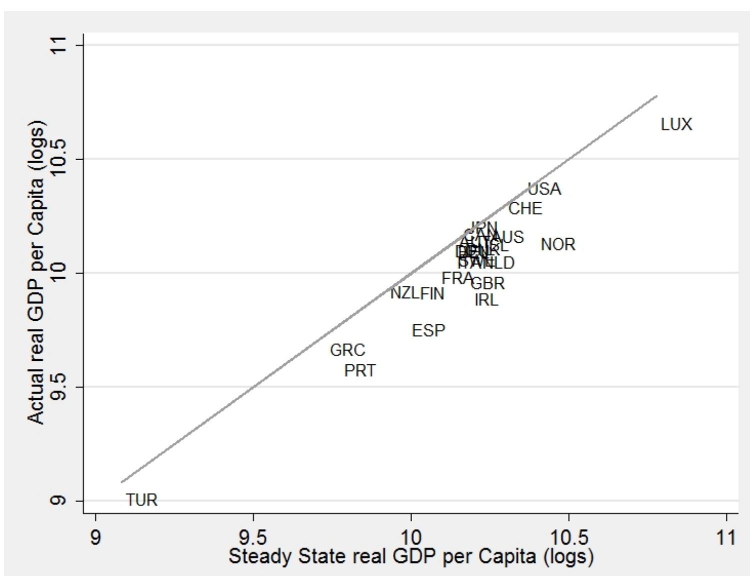

Figure 6.5. 1995 Per Capita GDP Relative to the Steady State

By 2000, the economies are in great positions to grow, however, beginning in 2005 the OECD economies begin to move above their steady states and by 2010, with the exception of Turkey, Iceland, and France, every OECD economy is above its potential level of output. The most dramatic change is in the position of Luxemburg. Partly due to the presence of high-income foreign workers, the per capita GDP of Luxemburg is much larger than that of the other economies, however the analysis here does well in describing the dynamics. Luxemburg grew rapidly leading into the 2007-2009 recession, but has since seen slower growth in real GDP per capita. The results here would predict such slow growth to occur for some time given the unusually high levels of growth left unexplained by any particular country-specific characteristic that Luxemburg possesses.

The actual data for Luxemburg reflect this slow growth since 2010, even though this is when the sample ends. In fact, the out-of-sample predictions thus far seem to be a fair description of reality. There has been no return to recession for the US, despite strong potential for one to occur (Berge and Jordà, 2010), but growth has been slower than

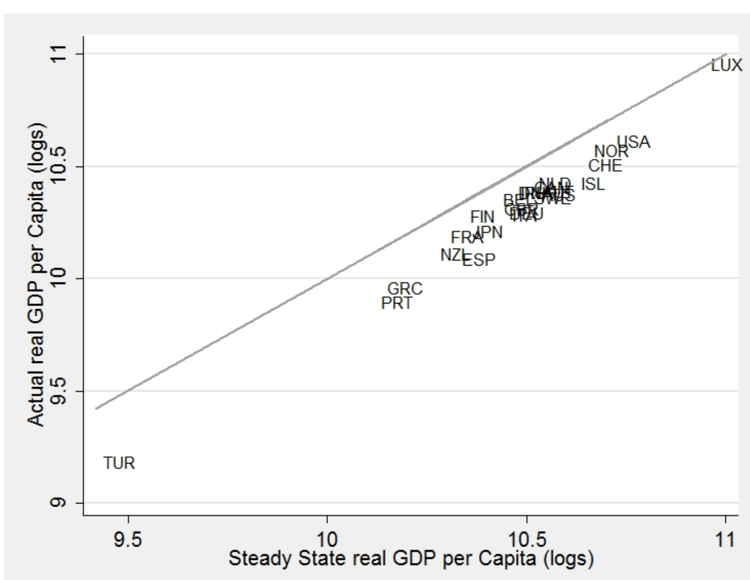

FIGURE 6.6. 2000 Per Capita GDP Relative to the Steady State

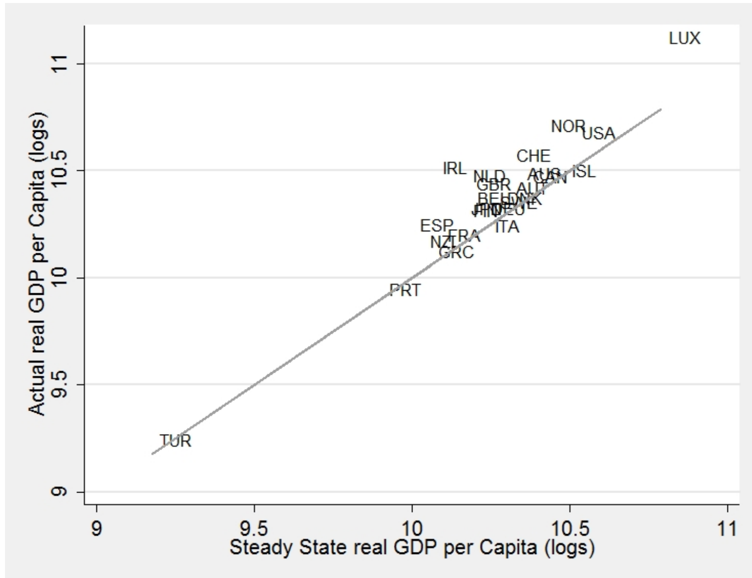

FIGURE 6.7. 2005 Per Capita GDP Relative to the Steady State

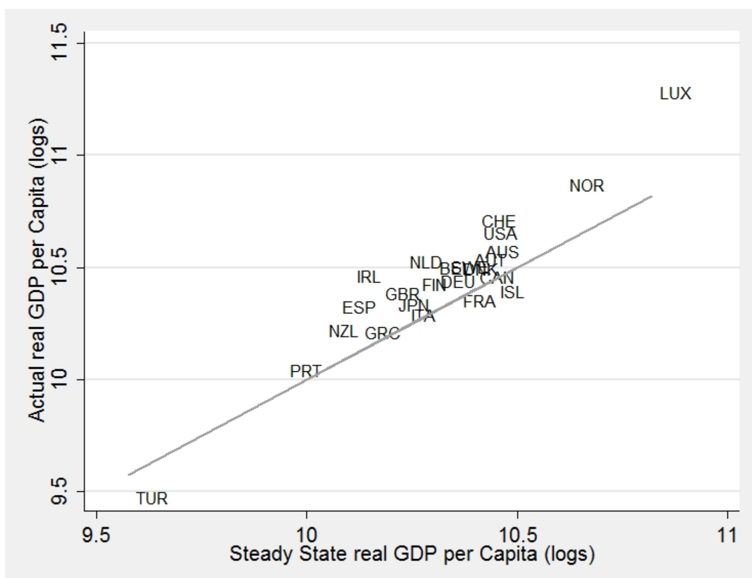

FIGURE 6.8. 2010 Per Capita GDP Relative to the Steady State

in the average rates of prior decades. This is likely to continue. And, of course, the European debt crisis is only presently subsiding, roughly seven years following the onset of the 2007-2009 recession. The positions of the economies in 2010 are in line with institutional long-term forecasts emerging after the recession (Johansson et al., 2012; OECD, 2012; Energy

Information Administration, 2013). All of these outlooks anticipate slower than average growth in the upcoming decades. In looking at the past periods of slower growth, the present may be comparable to the 1985–1995 period, but with even slower rates of growth and over a more extended period.

As mentioned in Chapter 3, it might be suspected that issues arise due to the assumption of a common g among all the countries in the sample to the point that the model may be described as driving the results. In order to maintain such a criticism, it is important to be specific as to how this description would be realized. The empirical issues which come from a common g would tend to reduce the variance of each year's distribution. Essentially, the assumption would lead to estimates of the steady states which have the economies closer to the 45° line in the preceding graphs.

6.5. Brief Analysis of the Results

In order to gain insights into what is driving the movements in the OECD sample, we'd like to take the estimates and explain them with movements in capital. In this section, we compute an output gap which is equivalent to the actual per capita real GDP less the estimated per capita steady state values. A positive value of the output gap, $(y_t - y_t^*)$, tells us that the economy is above its steady state while a negative value indicates that it is below. A basic fixed effects regression is run using lagged values of measure of types of capital investments and capital services. Lagged values are used to avoid contemporaneous endogeneity and to interpret the results as the outcome of past investments or capital intensities. For instance, past investments should reduce a negative value of $(y_t - y_t^*)$, shrinking the output gap, while if economies are above their steady states, $(y_t - y_t^*)$ is positive and increases in investment should further increase the output gap.

TABLE 6.4. Dependent Variable: Output Gap, Actual GDP Less Steady State GDP; Independent Variables in Lags

	(1)	(2)
	$(y_t - y_t^*)$	$(y_t - y_t^*)$
Nonresidential $GFCF_A$	2.647**	7.208***
	(1.192)	(1.303)
Nonresidential $GFCF_B$	2.042**	7.169***
	(0.997)	(1.501)
Residential $GFCF_A$	-2.527	0.972
	(1.751)	(2.257)
Residential $GFCF_B$	-1.525	2.194
	(1.467)	(2.392)
Ag and Manufacturing Cap $Services_A$		-0.114***
		(0.034)
Ag and Manufacturing Cap $Services_B$		-0.0447
		(0.039)
ICT Cap $Services_A$		0.177***
		(0.048)
ICT Cap $Services_B$		0.0704**
		(0.029)
constant	-0.135	-0.939***
	(0.134)	(0.165)
N	107	68
R^2	0.0873	0.6227

Standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Capital services and measures of gross fixed capital formation come from the OECD (OECD, 2013). Capital services give the flows of contributions that existing capital contributes to production. They are a measure of value added per unit of capital. More information on the methods used to estimate capital services can be found in Schreyer, Bignon, and Dupont (2003). Table 6.4 presents the results where subscripts indicate positions above or below the steady state.

Dummy variables are used to split the sample into positions above and below in case the behavior changes. Gross fixed investment has the most direct interpretation while capital services are also affected by the intensity of the utilization of the investments and may be affected by other variables. Given this, regressions with and without the capital service variables are included. There may have been an omitted variable bias when excluding the service variables in the initial regression, so the focus will be on the inclusive one.

In comparing states above and below, there doesn't seem to be much difference in direction or significance of the coefficients of nonresidential gross fixed capital formation and the capital services of information and communication technologies. Although, the size of the ICT coefficient significantly increases above the steady state, indicating that overinvestment in ICT above the steady state will move us away from the steady state faster than it moves us towards it when below. Here we may also find an explanation of why the OECD economies move above their steady states. Below their steady states, pro-investment policies and behavior are appropriate: the increase in nonresidential investment and the increase in ICT services moves economies toward their steady state. If these polices are continued above the steady state, they lead to higher levels of output output while technology and potential output is unaffected. It appears that the movements above the steady state, and their continued position even after the 2007–2009 recession is likely due to overinvestment into business-related fixed capital and investment into and increased utilization of information and communication capital. This is somewhat surprising, but gives a relatively unique insight into the present slow-growth environment.

The unexpected result occurs with agricultural and manufacturing services are increased. Below the steady state, there is no significant relationship, but above the steady state, the negative coefficient tells us that increases in capital investment (when we are already overcapitalized) will serve to decrease the steady state. The only way this could occur were if there is feedback between the capital services of agriculture and manufacturing and that of TFP. As such, investment into agriculture and manufacturing may be part of an industrialization process which encourages overall productivity increases, thus increasing TFP so that potential output grows to a level appropriate for the high levels of capital stock per person. Simply investing and increasing the intensity of nonresidential structures and increasing the use of computing and networking may not themselves have any spillovers.

Additionally, if we are to explain the overcapitalization of the 2007–2009 recession and the subsequent slowdown, the notion of residential investments or the overconstruction of housing seems to not offer too much of an explanation here. There simply may be too much inconsistent variation in the sample and other methods may need to be employed. The effect of a bubble is such that housing investment is increasing before the crash (and output is increasing). After the crash, housing investment is still very repressed yet economic growth has begun to recover, giving a negative relationship which could be offsetting the positive one prior to the crash. In fact, the drop in housing investment seems to have happened starting in 2005 as investors began to anticipate falling home values.

6.6. Concluding Statements

There are several main results which were presented in this chapter; some of them are in line with the standard growth forecasts and theories while others may offer a slightly new perspective on things. The first result shows the evolution of the OECD economies, with the US as a likely TFP innovator being close to its steady state and with the other OECD economies growing in part to the adoption of the innovation. This may be consistent with the US as source of TFP evolution, that is, until the 2007–2009 recession. A regression of this output gap on different forms of investment and capital utilization informs our understanding of what may be causing the movements above the steady state.

In much of the research on growth, the United States is treated as the main innovator of anything affecting TFP. In fact, a common convention is to have countries' TFP expressed as a fraction of that of the US (Hall and Jones, 1999; Feenstra, Inklaar, and Timmer, 2013). We find some support of this practice as the US stays close to its steady state and others move around it, but for the OECD economies, most are below until 2005. The movements prior to 2005 are in line with the presence of a recession with a strong and quick recovery by 1985, along with the steady growth of the 1990–2000 period. After 2005, there is support for a bearish outlook toward future long-run growth. It's possible this most recent period may mimic that of 1985–1995 but with even slower growth and over a longer time period. The recessions of 1987 and 1991 were not nearly as severe as the 2 largest ones in the sample, and were part of a fairly stable period of lackluster growth for the OECD economies. Of course the period after 1995 was quite different and this is also reflected in the economies remaining below their steady states through the year 2000.

To explain these movements, it seems that investments into nonresidential fixed capital and ICT capital are likely to move output either toward its steady state (if below) or away from it (if above). Interestingly, we don't find any significant relationship between that of residential investment and movements above or below the steady state. Investments into manufacturing and agriculture when above the steady state may have spillover effects into an economy's entire level of productivity.

These are somewhat qualitative results in that the implication is for either slower than average or faster than average growth in per capita real GDP. However, with a longer sample of economies, there may be enough time observations so that that current positions above and below the steady state can be compared to similar positions in the past. In this way, the results could be more precise by forecasting similar output falls and similar length of slow-growth periods in the future. This analysis is an extension as methods would need to be developed to determine the statistical significance of these types of forecasts.

CHAPTER 7

General Conclusion and Possible Extensions

7.1. Conclusion

Using the classic augmented Solow model, this dissertation develops a method which allows us to find estimates of countries' long-run steady states after conducting an analysis of convergence. The uniqueness of the method comes from its use of panel data. Having both cross-sectional and time series observations permits the estimation of country-specific total factor productivities. Country-specific TFPs are essential to the interpretation of the results. If countries have the same TFP, then the Solow growth model appears to be invalid since the estimates show that many developing countries are converging from above and are therefore overcapitalized. It just wouldn't make sense for them to have too much capital relative to the developed nations. However, in the panel data setting it's clear that the issue isn't that they have too much capital relative to a common level of TFP, but rather they are overcapitalized relative to their own low productivities.

The various applications in this presentation may seem to be unrelated, but they have been chosen in order to illustrate key circumstances in which countries' positions relative to steady states show particular understandings of macroeconomies. In the first case, a wide variety of economies are included in a worldwide sample. This makes estimation more challenging as the coefficient estimates could be biased if the assumption of a common growth trend is too far off. In order to address this, we have included institutional variables and instruments in order to include these country-specific growth rates in the estimation. The benefit of using this sample is that it permits estimation and explanation of the global patterns of development which have occurred over the last several decades. Other methods of estimation exist (Pesaran, 2006) which are not dependent on the assumption of a common deterministic growth trend and could be applied to this same sample as a future extension and comparison. As for patterns of development, these results tend to confirm what Danny Quah described as"twin peaked" global income distributions (Quah, 1997). The countries above their steady states are predicted to fall in terms of per capita output. These countries also tend to be the ones who are starting with some of the lowest incomes. The development patterns at the higher levels of income also describe why there is twin peaked development: Those countries starting below their steady state in 1965 were prepared to catch up to their higher level of total factor productivity while the lower incomes were about to fall to theirs.

In a second application, a sample of the transition economies is used to see if the method can accurately describe a state of the economy which we knew was likely to be true. The method here was originally designed to test overcapitalization in the transition economies after observing strong anecdotal evidence. Even though these economies seem to have much in common, after-all they are all transitioning, the economic change is so radical that it complicates estimation. The problem in finding significant estimates of TFP lies in the insignificant constant. The economies are at very different starting points in 1995. However, the steady state results are highly significant and indicate that the economies began in a state of overcapitalization. In hindsight, this result is fortunate given the behaviors of these macroeconomies over the period of transition.

In a final application, the OECD sample is chosen because we would expect most economies to begin the 1980–2010 period below their steady states and the common deterministic growth rate is likely to be significant. The countries in this sample are treated as a "'growth club" and the assumptions of the model are much less restrictive. There is significant and rapid convergence among the economies and a deterministic growth rate is smaller than expected, but significant. This growth rate is used to project steady states outside of the $gt = 0$ initial position. Perhaps it shouldn't be surprising that the OECD economies are almost all above their steady states in 2010. This is consistent with many other forecasts. A supplemental regression can help explain which capital movements might be responsible for this. Interestingly, the movements in housing capital are insignificant, perhaps due to there being a stronger relationship to investment speculation than real GDP during the housing bubble. Nonresidential investments and information and communication capital investments do seem to move output toward and then above the steady state.

Several extensions follow from what is presented here. An immediate extension could be to employ a clustering algorithm as in Phillips and Sul (2009) in order to derive growth clubs on which to run this analysis. Probably the most contentious assumption made in this paper was that of a common deterministic growth trend. This assumption is particularly problematic for the worldwide sample. In fact, the deterministic time trend is insignificant in those estimates. There are real consequences to this strict assumption, but it's likely such consequences are less severe in country groups which have been clustered based on common characteristics. A significant time trend allows for forecasting methods based on past distances from the steady state and the average time it took to converge following such a period and while controlling for movements in the steady state.

In the end, convergence theory may still have much to say, just not in the same way that it always has. The method developed here could open the door once again for structural models of standard convergence to be relevant in the field of economic development, although this may depend on the researcher's opinion of the Solow growth model. The model still relies on some restrictive assumptions, however there are recent developments which address most of the serious concerns. The common correlated effects estimator of Pesaran (2006) can estimate country-specific growth rates and parameters. The time series methods that Bai, Kao, and Ng (2009) have coined the "continuous-updated fully modified estimator" can estimate the augmented Solow model without any restrictive assumptions. This present research takes a much simpler and direct approach by using measures of institutions to include the variation in the model itself.

The main contribution herein comes from the fact that without calculating a country's position relative to its steady state, you have little country-specific knowledge in the standard convergence analysis. As with any economic research, the outcomes here are likely to contain a level of imprecision, but there is little demanded of the results. One only needs to know whether a country is above or below its steady state to gain insight into development policy. Below the steady state, financial investment and capital accumulation will be worthwhile; above the steady state, resources will be better used to strengthen institutions and ensure stability. If nothing else, this present work elaborates on this insight and finds supporting evidence.

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APPENDIX A

Tabular Results

Table A.1. Worldwide Country-Specific Initial Steady States: Table 1

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Japan	JPN	8.472829	13.48237	1.066896	4.123812	0.865975	-5.00954
South Korea	KOR	7.142813	12.02429	1.072209	5.446478	0.926558	-4.88147
Greece	GRC	8.706996	13.03063	0.948299	3.604782	0.883751	-4.32363
Singapore	SGP	8.744803	12.88358	1.091011	4.758174	0.876541	-4.13878
Botswana	BWA	6.542078	10.58713	1.014058	5.766559	0.961946	-4.04506
Israel	ISR	8.763598	12.41891	0.942467	4.153919	0.86567	-3.65531
Ireland	IRL	8.823548	12.3957	0.946166	4.194328	0.865386	-3.57215
Thailand	THA	7.084164	10.54916	0.878944	4.938237	0.885923	-3.465
Portugal	PRT	8.423261	11.47528	0.911303	4.343345	0.865599	-3.05201
Hong Kong	HKG	8.909737	11.89339	0.950001	4.655633	0.872435	-2.98365
Panama	PAN	7.995051	10.9695	0.786779	4.158754	0.865628	-2.97445
Germany	DEU	9.275387	12.24268	0.822103	3.144215	0.918373	-2.96729
Italy	ITA	8.893101	11.81493	0.792439	3.385231	0.898152	-2.92183
Argentina	ARG	7.880062	10.66804	0.711834	3.793286	0.874594	-2.78798
Finland	FIN	9.226933	11.9805	0.798485	3.018027	0.930706	-2.75357
Brazil	BRA	7.747119	10.21966	0.72731	4.213902	0.865301	-2.47254
Belgium	BEL	9.375829	11.67043	0.690004	2.660677	0.971658	-2.2946
Sweden	SWE	9.543871	11.7805	0.718924	2.837421	0.950329	-2.23663
United States	USA	9.828521	12.01922	0.814566	3.263261	0.907825	-2.1907
Netherlands	NLD	9.522995	11.66157	0.711053	2.885951	0.944835	-2.13858
Denmark	DNK	9.560939	11.61475	0.713032	2.959894	0.936774	-2.05381
New Zealand	NZL	9.52365	11.52875	0.703938	2.694619	0.967405	-2.0051
U.K.	GBR	9.470875	11.43097	0.701294	3.002109	0.932343	-1.9601
Tunisia	TUN	7.561902	9.493548	0.680852	3.931241	0.86983	-1.93165
Turkey	TUR	8.415745	10.30239	0.756426	4.217939	0.865288	-1.88664
Zimbabwe	ZWE	7.4306	9.298877	0.663657	4.303905	0.86535	-1.86828
Australia	AUS	9.656332	11.52021	0.665954	2.506073	0.991931	-1.86388
Pakistan	PAK	6.963017	8.804588	0.4979	3.105044	0.922076	-1.84157
Austria	AUT	9.259677	11.0921	0.660516	2.937366	0.939189	-1.83243
Spain	ESP	8.875869	10.61386	0.854884	4.398307	0.866177	-1.73799
Egypt	EGY	6.854135	8.523556	0.804904	5.564309	0.938762	-1.66942
Mauritania	MRT	7.120744	8.789836	0.913305	3.464227	0.892518	-1.6690

Table A.2. Worldwide Country-Specific Initial Steady States: Table 2

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Canada	CAN	9.714241	11.29852	0.675304	2.72632	0.963499	-1.58428
France	FRA	9.338856	10.91945	0.713359	3.407655	0.896502	-1.5806
Switzerland	CHE	9.92191	11.44714	0.646417	2.407262	1.005635	-1.52523
Norway	NOR	10.22457	11.63747	0.719201	2.839153	0.95013	-1.4129
Chile	CHL	8.533376	9.817999	0.623813	3.066846	0.925796	-1.28462
Philippines	PHL	7.414521	8.632562	0.438545	1.935333	1.078338	-1.21804
Malaysia	MYS	8.148812	9.341635	0.515356	2.975131	0.93516	-1.19282
Colombia	COL	8.195703	9.384128	0.490574	2.633502	0.975115	-1.18843
India	IND	6.993005	8.178699	0.477228	2.671787	0.970258	-1.18569
Mauritius	MUS	8.154783	9.135348	0.608753	3.727737	0.877435	-0.98057
Peru	PER	8.056111	8.977972	0.533672	3.137629	0.918988	-0.92186
South Africa	ZAF	8.578183	9.441067	0.468816	1.486877	1.156988	-0.86288
Ecuador	ECU	8.055964	8.889461	0.461222	2.535885	0.987909	-0.8335
Bolivia	BOL	7.815931	8.617425	0.458267	1.96502	1.073438	-0.80149
Guatemala	GTM	7.764289	8.382382	0.606143	4.305295	0.865356	-0.61809
Mexico	MEX	8.768744	9.224843	0.552958	3.281325	0.906319	-0.4561
Paraguay	PRY	7.464075	7.883798	0.549873	3.088899	0.923636	-0.41972
Dominican Rep	DOM	7.815662	8.128248	0.559402	3.647467	0.881413	-0.31259
Mozambique	MOZ	5.874566	6.072383	0.569487	3.646091	0.881486	-0.19782
Costa Rica	CRI	8.500722	8.690825	0.612058	4.01766	0.867695	-0.1901
Uganda	UGA	6.652877	6.728026	0.477081	2.683175	0.968831	-0.07515
Morocco	MAR	7.432045	7.428314	0.562635	3.92393	0.870041	0.003731
Uruguay	URY	8.714332	8.600107	0.470744	2.087128	1.053723	0.114224
Ivory Coast	CIV	7.326859	6.98131	0.492986	3.330354	0.90236	0.345549
Honduras	HND	7.600611	7.198283	0.470061	2.889615	0.944426	0.402328
Cameroon	CMR	7.264589	6.732702	0.483073	2.473544	0.99638	0.531887
Sri Lanka	LKA	7.684044	7.08003	0.706325	1.227426	1.206025	0.604013
Syria	SYR	8.197214	7.398436	0.458207	2.435967	1.001596	0.798778
Ghana	GHA	7.612188	6.809407	0.643158	-0.00405	1.464954	0.802782
Benin	BEN	7.058228	6.117886	0.552085	3.347642	0.901008	0.940342
Trin. and Tob.	TTO	9.931529	8.89192	0.562013	3.169538	0.916039	1.039609
Venezuela	VEN	9.602985	8.500276	0.449697	1.734966	1.112443	1.10271

Table A.3. Worldwide Country-Specific Initial Steady States: Table 3

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Rwanda	RWA	6.623828	5.398211	0.722564	5.059721	0.893779	1.225617
Mali	MLI	6.173426	4.837312	0.654874	4.204379	0.865338	1.336113
Tanzania	TZA	6.951486	5.565319	0.602873	3.111238	0.921483	1.386167
Jamaica	JAM	8.461774	7.013874	0.536576	0.870491	1.277058	1.4479
Liberia	LBR	6.863859	5.398535	0.905482	-0.92612	1.67841	1.465324
Burundi	BDI	6.114016	4.581931	0.642114	2.805568	0.954022	1.532084
Kenya	KEN	7.183502	5.572913	0.577765	2.473181	0.99643	1.610589
Jordan	JOR	8.325767	6.679572	0.58882	2.130934	1.046827	1.646194
Malawi	MWI	6.450041	4.782954	0.722742	2.244857	1.029352	1.667087
Sierra Leone	SLE	6.713822	4.925921	0.822343	3.969502	0.868804	1.787901
Cent. Afr. Rep.	CAF	6.928868	5.060091	0.925274	0.541849	1.345605	1.868777
El Salvador	SLV	6.240699	4.364111	0.966364	-0.19159	1.507294	1.876588
Togo	TGO	6.924266	5.017327	0.753567	1.227975	1.205919	1.90694
Nepal	NPL	6.592993	4.35745	0.715848	2.932176	0.939751	2.235543
Niger	NER	7.053513	4.510646	0.938744	1.751504	1.109562	2.542866
Congo Brazz.	COG	8.363701	5.715114	0.590256	1.564871	1.142723	2.648587
Senegal	SEN	7.392613	4.683955	0.687249	3.592848	0.884432	2.708658
Bangladesh	BGD	7.153975	4.309885	0.98759	1.801055	1.101	2.84409
Zambia	ZMB	7.84347	3.623432	0.811223	2.199495	1.03623	4.220038
Congo Kinshasa	COD	6.807577	2.505917	1.351276	-1.88088	1.910498	4.30166

Table A.4. Worldwide Country-Specific Initial Steady States With Institutional Variables: Part 1

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Japan	JPN	8.472829	13.16681	1.199465	5.911076	1.364778	-4.69398
South Korea	KOR	7.142813	11.61965	1.320215	6.512898	1.219597	-4.47684
Israel	ISR	8.763598	12.75323	1.185645	6.343426	1.37676	-3.98964
Singapore	SGP	8.744803	12.48383	1.295567	6.184101	1.237163	-3.73903
Panama	PAN	7.995051	11.56077	1.212509	6.275014	1.23001	-3.56572
Ireland	IRL	8.823548	12.23937	0.97582	5.875679	1.345235	-3.41582
Greece	GRC	8.706996	12.05023	0.965208	4.742286	1.280998	-3.34323
Thailand	THA	7.084164	10.00672	1.105103	5.654413	1.013722	-2.92256
Italy	ITA	8.893101	11.75195	0.898152	5.216651	1.366979	-2.85885
Germany	DEU	9.275387	11.91595	0.898755	4.863836	1.294668	-2.64056
Finland	FIN	9.226933	11.86746	0.901218	4.922064	1.378605	-2.64053
Argentina	ARG	7.880062	10.48188	0.79251	5.146879	1.258987	-2.60182
Brazil	BRA	7.747119	10.05325	0.890565	5.393279	1.183545	-2.30613
Belgium	BEL	9.375829	11.67573	0.787572	4.689542	1.393775	-2.2999
Pakistan	PAK	6.963017	9.249234	0.699296	4.825509	1.071074	-2.28622
Sweden	SWE	9.543871	11.69576	0.753994	4.761197	1.384486	-2.15189
Netherlands	NLD	9.522995	11.61813	0.799319	4.813279	1.385895	-2.09513
United States	USA	9.828521	11.92276	0.8051	5.128312	1.412782	-2.09424
Denmark	DNK	9.560939	11.569	0.79489	4.857277	1.383147	-2.00807
Portugal	PRT	8.423261	10.40117	0.844387	4.873032	1.065205	-1.97791
Austria	AUT	9.259677	11.18688	0.733932	4.860924	1.382925	-1.9272
U.K.	GBR	9.470875	11.38077	0.674365	4.842484	1.38499	-1.90989
Colombia	COL	8.195703	10.06654	0.946854	4.830272	1.182855	-1.87084
New Zealand	NZL	9.52365	11.39176	0.652343	4.537619	1.415228	-1.86811
Australia	AUS	9.656332	11.48703	0.666886	4.495632	1.410302	-1.83069
Egypt	EGY	6.854135	8.611726	0.717919	6.304762	1.105307	-1.75759
Turkey	TUR	8.415745	10.16168	1.025049	5.442958	1.290062	-1.74594
Tunisia	TUN	7.561902	9.244748	0.747384	4.932	1.070759	-1.68285
Mauritania	MRT	7.120744	8.765087	0.948558	4.645423	1.086254	-1.64434
Canada	CAN	9.714241	11.31134	0.652491	4.660673	1.398207	-1.5971
Switzerland	CHE	9.92191	11.46633	0.642358	4.457849	1.443772	-1.54442
France	FRA	9.338856	10.83345	0.789113	5.009861	1.356605	-1.49459

Table A.5. Worldwide Country-Specific Initial Steady States With Institutional Variables: Part 2

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Malaysia	MYS	8.148812	9.631389	0.622391	4.692148	1.398203	-1.48258
Philippines	PHL	7.414521	8.851409	0.531151	3.655127	1.361262	-1.43689
Norway	NOR	10.22457	11.65032	0.833284	4.830329	1.384465	-1.42575
India	IND	6.993005	8.334685	0.716688	4.064185	1.308411	-1.34168
Chile	CHL	8.533376	9.873787	0.827034	4.630645	1.281105	-1.34041
Peru	PER	8.056111	9.340884	0.659955	4.805406	1.196966	-1.28477
Ecuador	ECU	8.055964	9.202087	1.008334	4.273681	1.109154	-1.14612
Spain	ESP	8.875869	9.953069	1.045488	5.13546	0.972456	-1.0772
Bolivia	BOL	7.815931	8.882817	0.619899	3.719775	1.064068	-1.06689
South Africa	ZAF	8.578183	9.436787	0.475085	3.266337	1.459778	-0.8586
Guatemala	GTM	7.764289	8.365429	0.742383	5.197572	0.985358	-0.60114
Dominican Rep	DOM	7.815662	8.41256	0.640677	4.928719	1.17688	-0.5969
Mexico	MEX	8.768744	9.303502	0.576262	4.693677	1.083495	-0.53476
Morocco	MAR	7.432045	7.921878	0.91594	5.194448	1.270034	-0.48983
Costa Rica	CRI	8.500722	8.95907	0.619672	5.326361	1.352528	-0.45835
Uruguay	URY	8.714332	9.08465	0.483338	4.028895	1.457867	-0.37032
Paraguay	PRY	7.464075	7.659819	0.545542	3.931653	1.151851	-0.19574
Uganda	UGA	6.652877	6.817311	0.737301	3.676108	1.318036	-0.16443
Cameroon	CMR	7.264589	7.281719	0.479711	3.976242	1.152449	-0.01713
Honduras	HND	7.600611	7.39921	0.831995	4.051988	1.12763	0.2014
Sri Lanka	LKA	7.684044	7.442882	0.65885	2.89338	1.440208	0.241162
Syria	SYR	8.197214	7.879649	0.505759	4.029768	1.093374	0.317565
Mali	MLI	6.173426	5.742635	0.777009	5.245217	1.064656	0.430791
Rwanda	RWA	6.623828	6.135897	0.675341	5.857208	1.073411	0.487931
Ivory Coast	CIV	7.326859	6.759607	0.55833	3.923552	1.153103	0.567252
Togo	TGO	6.924266	6.2449	0.708199	3.308933	1.246412	0.679367
Benin	BEN	7.058228	6.347244	0.541669	4.188953	1.110459	0.710983
Jamaica	JAM	8.461774	7.744378	0.564975	2.978611	1.608304	0.717396
Ghana	GHA	7.612188	6.832542	0.727346	1.550795	1.606846	0.779646
Trin. and Tob.	TTO	9.931529	9.028192	0.738412	4.582472	1.283628	0.903338
Tanzania	TZA	6.951486	5.951229	0.696932	4.046082	1.144649	1.000257

Table A.6. Worldwide Country-Specific Initial Steady States With Institutional Variables: Part 3

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Venezuela	VEN	9.602985	8.391151	0.555138	3.146475	1.426897	1.211834
El Salvador	SLV	6.240699	5.00748	0.849086	1.467306	1.57986	1.233219
Kenya	KEN	7.183502	5.930271	0.744825	3.518248	1.404431	1.253231
Liberia	LBR	6.863859	5.59586	0.997624	0.695468	1.902691	1.268
Jordan	JOR	8.325767	7.020305	0.871153	3.482876	1.412635	1.305462
Sierra Leone	SLE	6.713822	5.307364	0.893714	4.546091	1.28455	1.406458
Malawi	MWI	6.450041	4.905459	0.916023	2.937912	1.307123	1.544581
Cent. Afr. Rep.	CAF	6.928868	5.148922	0.846581	1.653697	1.337356	1.779945
Congo Brazz.	COG	8.363701	6.546967	0.554395	3.325659	1.285254	1.816734
Niger	NER	7.053513	5.037053	1.050179	2.904502	1.31113	2.016459
Burundi	BDI	6.114016	4.075839	0.973041	2.691312	1.346889	2.038177
Senegal	SEN	7.392613	5.133701	0.745411	4.273582	1.164367	2.258912
Nepal	NPL	6.592993	4.146932	1.17084	3.028807	1.47847	2.446061
Zambia	ZMB	7.84347	4.391402	0.97117	3.275616	1.392259	3.452068
Congo Kinshasa	COD	6.807577	2.810975	1.539918	-0.58928	2.168549	3.996601

Table A.7. Panel Growth Accounting

	Pooled	Fixed Effects	System GMM
	y_t	y_t	y_t
$(n+g+\delta)$	-1.491***	-0.277	-1.345***
	(0.228)	(0.222)	(0.324)
s_k	0.349***	0.116*	0.464***
	(0.043)	(0.067)	(0.095)
s_h	0.458***	-0.181**	0.537***
	(0.027)	(0.081)	(0.066)
Autocracy	-0.0487***	-0.00348	-0.0553***
	(0.010)	(0.016)	(0.017)
Duration	0.00453***	0.00731***	0.00436***
	(0.001)	(0.002)	(0.001)
Exec Reg	0.129**	-0.0165	0.0710
	(0.061)	(0.068)	(0.116)
Exec Open	0.0761***	0.0467**	0.0944**
	(0.022)	(0.023)	(0.044)
Participation	0.239***	0.0546	0.269***
	(0.031)	(0.039)	(0.062)
time t	-0.0632***	0.0815***	-0.0666***
	(0.010)	(0.016)	(0.021)
_cons	2.700***	7.288***	3.076***
	(0.557)	(0.664)	(0.786)
N	832	832	647 †
R^2	0.7472	0.4172	
Hansen J	–	–	0.206‡
$AR(1)$	–	–	0.551‡
$AR(2)$	–	–	0.848‡

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

† $N = 647$ due to use of 3 lags as predetermined instruments

‡ p-values

Table A.8. Transition Economies 1995 Steady State and TFP Values

All			*Including Ed*			*Without Ed*		
Country	ISO Code	y_t	$y^*(0)$	*SE of* $y^*(0)$	*Output Gap*	$y^*(0)$	*SE of* $y^*(0)$	*Output Gap*
Turkmenistan	TKM	8.529903	9.000783	-0.47088	1.768743	9.752611	1.307137	-1.22271
Ukraine	UKR	8.451516	9.076936	-0.62542	1.952035	9.517054	1.682921	-1.06554
Armenia	ARM	7.830938	8.563177	-0.73224	1.096632	8.786906	1.0153	-0.95597
Serbia	SRB	8.123534	8.75806	-0.63453	0.547809	8.77449	0.437594	-0.65096
Tajikistan	TJK	7.519883	7.217274	0.302609	1.256776	7.914296	0.860914	-0.39441
Kazakhstan	KAZ	8.583786	8.367742	0.216044	0.986007	8.879159	0.784419	-0.29537
Albania	ALB	8.160993	7.822063	0.33893	0.836653	8.436807	0.731124	-0.27581
Poland	POL	9.140798	8.891968	0.24883	0.640682	9.070254	0.508815	0.070543
Mongolia	MNG	7.545415	6.795932	0.749484	1.450875	7.466433	1.189098	0.078983
Montenegro	MNE	8.468914	8.071082	0.397832	0.823126	8.346259	0.513532	0.122655
Russia	RUS	9.287383	8.712465	0.574918	1.006787	9.108479	0.840382	0.178904
Estonia	EST	9.117818	8.658057	0.459761	0.623668	8.901613	0.570703	0.216205
Romania	ROU	8.707734	7.877919	0.829815	1.177802	8.472293	0.963906	0.235441
Belarus	BLR	8.801151	7.652968	1.148183	1.615987	8.221274	1.371949	0.579877
Kyrgyzstan	KGZ	7.902579	6.871182	1.031397	0.903142	7.221712	0.630001	0.680868
Lithuania	LTU	8.872332	7.777193	1.095139	0.727455	8.154852	0.542449	0.71748
Czech Republic	CZE	9.764218	8.579601	1.184617	0.524534	8.928106	0.429543	0.836112
Slovakia	SVK	9.406616	8.062954	1.343662	0.678463	8.47106	0.559357	0.935556
Croatia	HRV	9.168647	7.924415	1.244232	0.578271	8.159762	0.42418	1.008884
Slovenia	SVN	9.757798	8.459229	1.29857	0.736393	8.702238	0.658385	1.05556
Macedonia	MKD	8.472664	6.654301	1.818363	0.974504	7.258905	0.73329	1.213758
Latvia	LVA	8.846411	7.078615	1.767796	0.830322	7.499949	0.717317	1.346462
Georgia	GEO	7.720325	5.297908	2.422417	1.13434	6.02105	0.952867	1.699275
Uzbekistan	UZB	8.053531	5.723946	2.329585	1.292057	6.247634	0.859654	1.805896
Moldova	MDA	7.758147	4.650255	3.107892	1.638246	5.487996	1.334854	2.270151
Hungary	HUN	9.416359	6.378755	3.037604	0.993945	6.938254	0.683743	2.478105
Bulgaria	BGR	8.879488	5.717027	3.162461	1.215708	6.258498	0.950382	2.62099
Azerbaijan	AZE	7.675982	3.952684	3.723297	1.502029	4.863918	0.925849	2.812063

Table A.9. OECD Country-Specific Initial Steady States

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Ireland	IRL	9.380075	9.929687	0.124937	5.161755	0.668431	-0.54961
Luxembourg	LUX	10.18192	10.71747	0.294945	5.957545	0.692833	-0.53555
Norway	NOR	9.986549	10.35656	0.153818	5.372159	0.669234	-0.37001
New Zealand	NZL	9.606219	9.939119	0.115871	4.910712	0.672881	-0.3329
Switzerland	CHE	10.17508	10.5013	0.153315	5.326584	0.668709	-0.32621
Austria	AUT	9.718603	10.03275	0.127309	5.289408	0.668424	-0.31415
Finland	FIN	9.753799	10.05972	0.110941	5.110016	0.668869	-0.30592
Australia	AUS	9.895083	10.17558	0.139879	5.157544	0.668458	-0.2805
United Kingdom	GBR	9.746694	10.00638	0.171531	5.509099	0.671975	-0.25969
Sweden	SWE	9.819626	10.01584	0.11446	5.203695	0.668261	-0.19622
United States	USA	10.13885	10.32874	0.195438	5.448217	0.670542	-0.18989
Denmark	DNK	9.910967	10.08903	0.117305	5.232757	0.668239	-0.17807
Japan	JPN	9.737726	9.899283	0.094301	4.984936	0.670957	-0.16156
Netherlands	NLD	9.8823	10.02553	0.135967	5.293478	0.668449	-0.14323
Portugal	PRT	9.098595	9.234029	0.105704	5.049526	0.669697	-0.13543
Belgium	BEL	9.916563	10.02891	0.106942	5.170045	0.668385	-0.11235
Canada	CAN	10.00054	10.08858	0.148307	5.288702	0.66842	-0.08804
Greece	GRC	9.382698	9.469603	0.09307	4.968965	0.671328	-0.0869
Germany	DEU	9.778031	9.832085	0.119869	5.267173	0.668316	-0.05405
Italy	ITA	9.767516	9.81568	0.126497	5.310772	0.668572	-0.04816
Iceland	ISL	10.09609	10.14087	0.160428	5.368726	0.669188	-0.04478
Spain	ESP	9.465978	9.390906	0.124478	5.17068	0.668381	0.075071
France	FRA	9.91651	9.834743	0.141718	5.401444	0.669674	0.081766
Turkey	TUR	8.779228	8.658591	0.173879	5.06657	0.669429	0.120637

Table A.10. OECD Country-Specific Steady States with Institutional Variables

Country	ISO Code	P.C. Real GDP	Steady State	Steady State SEs	TFP	TFP SEs	Output Gap
Luxembourg	LUX	10.18192	10.8245	0.183256	7.737871	0.77556	-0.64258
Ireland	IRL	9.380075	9.892089	0.092719	6.749399	0.727577	-0.51201
Norway	NOR	9.986549	10.31053	0.172209	6.995863	0.692726	-0.32398
Switzerland	CHE	10.17508	10.4981	0.090266	7.080151	0.777215	-0.32301
Austria	AUT	9.718603	10.02996	0.103432	6.929947	0.71971	-0.31136
Finland	FIN	9.753799	10.05013	0.093232	6.754152	0.729064	-0.29633
United States	USA	10.13885	10.40894	0.123434	7.247829	0.779488	-0.27009
Japan	JPN	9.737726	10.00316	0.064148	6.736267	0.766618	-0.26543
Belgium	BEL	9.916563	10.14424	0.068537	6.945624	0.760665	-0.22768
Greece	GRC	9.382698	9.600724	0.079229	6.608015	0.710686	-0.21803
Australia	AUS	9.895083	10.11207	0.11311	6.809887	0.736692	-0.21698
Germany	DEU	9.778031	9.991111	0.088725	6.972876	0.74892	-0.21308
Netherlands	NLD	9.8823	10.08045	0.089301	6.995283	0.747079	-0.19815
New Zealand	NZL	9.606219	9.782552	0.124047	6.501047	0.735171	-0.17633
Canada	CAN	10.00054	10.15622	0.081678	7.015695	0.769647	-0.15568
United Kingdom	GBR	9.746694	9.90166	0.11371	7.021758	0.722845	-0.15497
Denmark	DNK	9.910967	10.05535	0.112504	6.875874	0.716103	-0.14438
Sweden	SWE	9.819626	9.95092	0.143372	6.808125	0.693867	-0.13129
Portugal	PRT	9.098595	9.176582	0.083818	6.433609	0.683501	-0.07799
Italy	ITA	9.767516	9.832492	0.121489	6.880918	0.690684	-0.06498
Spain	ESP	9.465978	9.513092	0.088092	6.729359	0.720857	-0.04711
France	FRA	9.91651	9.91372	0.114595	7.001723	0.70617	0.00279
Turkey	TUR	8.779228	8.713037	0.147972	6.288241	0.646751	0.066191
Iceland	ISL	10.09609	10.01684	0.172603	6.829157	0.669951	0.079255