# DEVELOPMENT, INEQUALITY AND POVERTY IN CHINA

Dissertation

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Schriftliche Arbeit zur Erlangung des akademischen Grades
doctor rerum politicarum (dr. rer. pol.)
im Fach Wirtschaftswissenschaften

eingereicht an der
Fakultät für Wirtschaftswissenschaften der
Universität Paderborn
Paderborn, im Juni 2012

Gutachter:

1. Prof. Dr. Thomas Gries
2. Prof. Dr. Manfred Kraft

## Acknowledgments

First and foremost I would like to express my deepest gratitude to my advisor, Prof. Dr. Thomas Gries, for his excellent guidance, caring, patience, and providing me with an excellent atmosphere and stimulating academic environment for doing research. His constant support and encouragement contributed significantly to the success of this work. This monograph grows from several joint works with him, and it's the result of countless exciting talks and discussions - though all remaining errors are my own.

I am thankful to Prof. Dr. Manfred Kraft who made many insightful comments on the early drafts and kindly agreed to serve as my second supervisor.

I thank my colleagues Stefan Gravemeyer, Natasa Bilkic, Rainer Grundmann, and Daniel Meierrieks for fruitful discussions about my dissertation study and for creating such a nice work atmosphere. I thank our student research assistants, in particular Martin Kokoschka for the laborious data entry and Ben Carreras Painter and Burkhard Wilmes for proofreading of my dissertation.

Special thanks for my current and former colleagues at the PhD colloquium and the department seminar Management and Economics for all the helpful comments and discussions.

I would also like to thank my parents, my grandma and especially my grandpa who had passed away last year. They have always loved me and encouraged me with their best wishes.

Finally, I want to thank my husband Pawel Redlin and our wonderful children Olivia and Louis. Thank you so much for your constant support, love and for always giving me strength and hope.

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# List of Abbreviations

| | | |
|---|---|---|
| ADL | .................... | Autoregressive Distributed Lag |
| CCP | .................... | Chinese Communist Party |
| CSY | .................... | China Statistical Yearbook |
| ECM | .................... | Error Correction Model |
| FDI | .................... | Foreign Direct Investment |
| FE | .................... | Fixed Effects |
| IV | .................... | Instrumental Variable |
| GDP | .................... | Gross Domestic Product |
| GLS | .................... | Generalised Least Squares |
| GMM | .................... | Generalised Method of Moments |
| MAR | .................... | Marshall-Arrow-Romer |
| NBS | .................... | National Bureau of Statistics |
| NEG | .................... | New Economic Geography |
| NERI | .................... | National Economic Research Institut |
| OLS | .................... | Ordinary Least Squares |
| PPP | .................... | Purchasing Power Parity |
| RE | .................... | Random Effects |
| SEZ | .................... | Special Economic Zone |
| SOE | .................... | State-Owned Enterprise |
| TFP | .................... | Total Factor Productivity |
| 2SLS | .................... | Two-Stage Least Squares |
| VIF | .................... | Variance Inflation Factor |

*So eine Arbeit wird eigentlich nie fertig,*
*man muss sie für fertig erklären,*
*wenn man nach der Zeit und den Umständen*
*das Möglichste getan hat.*

Johann Wolfgang von Goethe

# Chapter 1

# Introduction

The world economy has experienced persistent growth in the last decades. In this regard the driving factors for success are technological progress, economies of scale, increased productivity and efficiency and improvements in allocation of resources amongst others. However, the growth pattern differs significantly over time among countries and even within countries at regional level.

In this context, the People's Republic of China shows an outstanding example and reveals an unprecedented development. It is widely considered to be one of the most successful developing countries in modern times. China's sustained growth fuelled historically unprecedented poverty reduction. For this reason China's economic success is an interesting object of analysis to economists. Particularly, with regard to the experimental programs in major domains of China's economic reform the country provides an excellent example for the analysis and understanding of development, development policies and their effects. Since the economic reform in 1978 China gradually undertook the open door policy.[1] First, the government established Special Economic Zones (SEZ) in selected coastal cities for the purpose of stimulating exports and attracting foreign investment. In a second step an implementation of a series of reforms in the foreign trade system and a promotion of foreign direct investment (FDI) inflow followed.[2] But even though the country features enormous

[1] For a better understanding Appendices A1.1 and A1.2 and Table A1.1 and Figure A1.1 give a descriptive overview of the divisions of administrative areas, the characteristics of the provinces and of historical economic development of the People's Republic of China.

[2] Amongst others Chen and Feng (2000), Yao and Zhang (2001a, 2002), Chen and Fleisher (1996), Zhang and Song (2000), Madariaga and Poncet (2005), Cheung and Lin (2004) and Yao (2006) analyse the effect of the open door policy on economic development and point out that exports and inward FDI have a beneficial

economic growth, the growth rates are not distributed uniformly over the country. The preferential open door policy and lower transportation costs promoted the coastal provinces to develop superior, while the interior provinces showed only moderate growth rates and still a large part of the population is living in poverty. This uneven development involved an increase in inequality within the country.[3]

In this regard, China provides a particularly suitable example for the analysis of its successful economic development but also its rising inequality. The major questions to analyse are: What explains the differences in growth across Chinese province? What are the determinants that drive high economic growth in the coastal region, and what causes the inland province to lag behind? In other words, what factors are responsible for the unequal development of China's provinces? Are the provinces on a converging path with the option of decreasing inequality or is there a divergence process with the result of rising inequality? What are the reasons for the rising inequality of the last decades? And finally, how do growth, inequality and poverty affect each other? This comprehends the questions to which extend income growth translates into poverty reduction and how the degree of inequality impacts economic growth. The following three chapters intend to find answers for these questions. All three chapters capture different kinds of problems and can be read independently of each other, although the questions analysed are highly related with each other. Each chapter has its own introduction and reviews the relevant theoretical and empirical literature to the issue.

In chapter two we start with the analysis of the determinants of China's success story and investigate if there is a catch up process across the provinces. The subsequent chapter investigates the role of factor inequality on income inequality on the provincial level. We pick up the determinants of growth identified in chapter two and analyse to what extent the unequal distribution in this growth factors across provinces has an effect on the in-

effect on GDP growth in China.

[3] In this context Madariaga and Poncet (2005) and Bao et al. (2002) suggest that the unequal development is also driven by the advantageous geographic location of the coastal region which translates into lower international transaction costs.

come inequality in the country. Finally, chapter four extends the development debate by analysing the pairwise causal interactions of growth, inequality and poverty. In this context we investigate the issue to which extent the poor participate in the overall income growth and in turn, if the decline in poverty shows a beneficial effect on growth. How does the income distribution effect growth and poverty reduction and vice versa?

Chapter two of the thesis is based on the paper "International integration and the determinants of regional development in China" by Gries, T. and Redlin, M. published in Economic Change and Restructuring in 2011. It provides empirical evidence on the determinants of growth. Concerns about the duration of China's growth and hence the question of a permanent significant contribution of China to world economic growth relate, amongst other things, to the problem of reducing regional disparity in China. While China's high average growth is driven by a small number of rapidly developing provinces, the majority of provinces have experienced a more moderate development. To obtain broad continuous growth, it is important to identify the enhancing factors of provincial growth.

Therefore, we introduce a stylized model of regional development for a single backward region which is characterized by two pillars. First, international integration indicated by FDI and/or trade lead to imitation of international technologies, technology spill-overs and temporary dynamic scale economies.[4] The imitation process is affected by the technology gap between the backward region and the industrialised world. If the domestic stock of technology is low, it is relatively easy to increase the technology position by adopting foreign designs. However, the process becomes increasingly difficult as the technology gap narrows. In this respect, technological progress in a backward economy is modelled as a process of endogenous catching up relative to an exogenous growth path of a technology leader.[5] Second, in addition to international capital the final output sector uses human

[4]International knowledge spill-over and positive technological externalities from the influx of FDI were modelled by Markusen and Venables (1999).

[5]This idea is based on the Veblen-Gerschenkron effect (Veblen, 1915 and Gerschenkron, 1962) of catching up to foreign technologies.

capital and domestic real capital to produce a homogeneous final good.[6] These factors are available through interregional factor mobility. In summary the essential determinants of the speed of convergence and the final relative convergence position are modelled as the endowment of capital and human capital, technology relevant government expenditure and international (and domestic) transaction costs connected to exports and FDI and hence the share of FDI.

In the next step we test the model empirically. The literature in the context of China's growth determinants and convergence is large and still growing. Yet, empirical evidence is mixed and existing studies draw an inconsistent picture.[7] The results depend to a large extend on the choice of estimation methods. In this regard we use two General Method of Moments (GMM) estimators, namely the difference GMM estimator developed by Arrelano and Bond (1991) and the system GMM estimator developed by Blundell and Bond (1998), and in addition to various sources of Chinese official statistics corrected income and investment data on provincial level for the period 1991-2004 to test the predictions from our theoretical model of regional development. The results of the growth regression provide a negative and significant lagged GDP per capita that indicates a catching up, non-steady state process across China's provinces. Some sort of catching up or adjustment process seems to be characteristic for China's provinces. In other words, on the conditioning set of all other explanatory variables initially poorer provinces tend to have higher growth rates. This finding is predicted by the theoretical model. In the model this process is driven by technological imitation and spill-overs originally entering China through international integration. The catching up process is driven by the relative technology position of the region compared to the technological leader. During this period of rapid catching up scale

[6]Based on growth regressions empirical studies of Yao (2006), Fleisher, Li and Zhao (2005), Yao and Zhang (2001a and 2002), Wang and Yao (2003), Madariaga and Poncet (2005), Chen and Feng (2000), Chen and Fleisher (1996) and Démurger (2001) confirm the importance of these factors on economic growth in China.

[7]In this regard studies by Chen and Fleisher (1996), Cai, Wang and Du (2002), Choi and Li (2000), Wu (1999), Chen and Feng (2000), Jian, Sachs and Warner (1996), Yudong and Weeks (2003), Raiser (1998) and Gundlach (1997) support the convergence hypothesis while studies by Pedroni and Yao (2006), Yudong and Weeks (2003) and Yao and Zhang (2001a, 2001b, 2002) find divergence.

economies are additional driving forces of development. Positive and significant coefficients for FDI and trade confirm the underlying theory and support the importance of international integration and technology imitation. Highly significant human and real capital intensifies the importance of these growth restricting factors. This result indicates that the growth process in China is not only a phenomenon caused by foreign firms investing in a poor country; rather it has strong and important domestic components. However, other potentially important factors like labour or government expenditures are insignificant or even negative. With regard to labour this result is not surprising, as long as pure labour is not a growth restricting factor.[8] With respect to the theoretical model the negative result of government expenditures suggests that we have an inefficient investment in this kind of government activities.

After analysing the question of convergence and detecting the determinants of China's growth in chapter two, chapter three investigates the role of factor inequality on income inequality on the provincial level. This chapter results from the paper "China's provincial disparities and the determinants of provincial inequality" by Gries, T. and Redlin, M. published in the Journal of Chinese Economic and Business Studies in 2009. It explains the growth-inequality nexus for China's provinces and the major question is how the uneven distribution of growth determining factors affects income inequality.[9]

We introduce a theoretical model of provincial development that consists of two regions and studies the interactions of a mutually dependent development process. International spill-over and externalities through FDI and trade and infrastructure are relevant determinants of growth and development.[10] Incoming trade and FDI induce imitation and hence

[8] The theoretical model follows the ideas of Lewis (1954) where a country has a surplus of labour in the rural sector that can be added to the growth restricting factors as needed. Pure labour can be added to or withdrawn without affecting output.

[9] Analysing the economic development of the People's Republic of China Kanbur and Zhang (2005), Huang, Kuo and Kao (2003), Li and Zhao (1999) and Wan (1998) find statistical evidence of increasing provincial disparities between the coast and the interior and rural and urban. Chen and Fleisher (1996), Jian, Sachs and Warner (1996), Zhang, Liu and Yao (2001), Wang (2003) and Yao and Zhang (2001b) use the concept of sigma convergence. The results show that inequality has increased in past decades.

[10] See e.g. Fujita and Thisse (2002) or Kelly and Hageman (1999).

productivity growth. As in chapter two the dynamics of the model are not driven by accumulation but by technological catching up. The developing province acquires technologies by imitating foreign designs from international technology leaders. The regional government can influence the economy by changing international transaction costs and providing a public infrastructure. Mobile domestic capital reinforces disparity effects. As domestic capital can move between the two provinces, it migrates to the high-productivity and high-interest province. Inflowing capital and the resulting additional technological growth will drive a process of both acceleration and agglomeration. In this process, the success of one province is driven at the expense of the other with the consequence of rising disparities.

The implications of the theoretical model are tested. As the central intention of the paper is to explain provincial disparity, we directly relate income disparity (indicated by the contribution to the per capita income Theil index) to the disparity of selected income determining factors (indicated by the contribution to every other Theil index of the determinants). According to Tsui (2007) and Wan, Lu and Chen (2007) we use decomposition techniques to quantify the provincial contribution to the overall income inequality and the inequality of the growth determinants. In a first step we compute the Theil index for GDP growth and for each growth determinant over all provinces. Furthermore, the overall Theil index is broken down by the provinces' contributions to the overall inequality and we calculate the decomposed Theil index for the eastern, central and western regions. The results reveal that not all provinces contribute to the country's inequality to the same degree. The decomposition by provinces shows that especially the coastal provinces strongly inflate the Theil index to a high degree, while the central and western provinces have only a minor impact. This indicates that inter-provincial inequality in China is driven mainly by a few prosperous provinces. The decomposition by regions confirms this result and shows that the inequality within the western region and the central region has only a slight impact. In particular, the inequality within the eastern region and between the three regions is what drives the Theil index. To identify the sources of this inequality in a second step we regress the provincial contribution to income inequality on the contributions to the inequality of all growth determining factors. We use fixed effect panel estimation for 28 Chinese provinces over the period 1991–2004.

The results confirm the theoretical framework and suggest a direct link between the factors that determine regional income and regional disparity. More specifically, it is apparent that disparities in trade, domestic capital and infrastructure have a positive impact on the provincial income Theil disparity. Like income disparity these determinants show also an increasing trend in inequality which is mainly driven by a few coastal provinces. In comparison to this the Theil index of FDI is more evenly distributed and shows a decreasing trend. This results in a negative effect of FDI inequality on income inequality. This is also the case with the provincial disparity in human capital and government expenditure. The disparity of human capital continuously decreased over the period of investigation while the disparity in government activities is driven by completely different provinces compared with income inequality. Therefore, three decades of government reforms led to an extraordinary success of some provinces and also contrarily to increasing inequality. However, government expenditures and public human capital investments seemed to have a stabilizing effect on provincial disparity.

Finally, chapter four is based on the paper "Short-run and long-run dynamics of growth, inequality and poverty in the developing world" by Gries, T. and Redlin, M. of the Center for International Economics Working Paper Series. This chapter focuses on the interdependent relationships between growth, inequality and poverty.[11] These phenomena are central elements of the process of growth and development. However, the mutual effects and directions of causality have been, and remain, one of the most controversial issues.

In the first step of our analysis we review some fundamental theoretical relations between income growth, inequality and poverty. In the illustrated model the variables are connected through two engines of income growth, namely increasing capital intensity and

[11] Bourguignon (2004) refers to this relationship as the poverty-growth-inequality triangle and suggests that there is a two-way relationship between growth and distribution which can be divided into the effects of growth on distribution and the effects of inequality on growth. Furthermore, the combination of both variables has an effect on absolute poverty and poverty reduction.

technical progress. Although the model provides some theoretical linkages between the variables it is not able to identify possible causalities between the variables. So in the next step we analyse the causal relations empirically.

The purpose is to first examine a general relationship between income growth, inequality and poverty for the developing world using a broad panel of developing countries. In the following we focus on China and examine the relations for the country separately.

The general analysis starts with panel unit root tests[12] which indicate that the variables are integrated of order one, so in the next step we test for cointegration.[13] The test results indicate that all three pairs of variables exhibit a cointegration relationship. In this case an error correction framework is the appropriate choice for testing for causalities.[14] Following Yasar, Nelson and Rejesus (2006) we apply Generalized Method of Moments (GMM) techniques on a generalised one-step panel error correction models (ECM) to estimate the pairwise short-run and long-run dynamics for income growth and changes in inequality and poverty in a panel of 114 developing countries as well as four income-related and six regional subpanels for 1981 to 2005. The results suggest that in nearly all cases the variables exhibit a short-run and long-run relationship. The findings reveal positive bidirectional causality between growth and inequality. In other words, higher changes in inequality, measured by changes in the Gini coefficient, generate higher economic growth and higher economic growth causes an increase in the changes of inequality. By contrast, the short-run effect is negative and highly significantly for both income and inequality. This means that in the short run rising inequality is harmful for growth and likewise an increase in income growth causes a reduction in inequality. Concerning the dynamics between income growth and changes in poverty the results show clear negative short-run and long-run relationships between these variables. In other words, higher economic growth reduces the extent of poverty measured by changes in the headcount, and in turn falling poverty gen-

[12] We use the IPS test by Im, Pesaran and Shin (2003) and the Fisher-type test by Maddala and Wu (1999) and Choi (2001).

[13] The pairwise cointegration is tested using the panel cointegration test developed by Pedroni (1999, 2004).

[14] See Engle and Granger (1987).

erates higher income growth. Consequently, it becomes apparent that the growth process raises not only the mean income of the country but also the income of the poor and lifts a fraction of the poor population out of poverty. Yet, the results of the subpanels show that the level of development affects the poverty-reducing effect of growth. Income growth has benefited the poor regions far less. Finally, with respect to the relationship between changes in inequality and changes in poverty the long-run effect is positive and significant in both directions indicating that higher inequality generates higher poverty and reversed a rise in the headcount causes a rise in the Gini coefficient. However, the short-run effect is only significant and positive when poverty is the dependent variable.

After analysing general relations in a panel of developing countries, in the next step we focus on China and examine the causal relationships between growth, inequality and poverty using more differentiated data for the country on rural and urban level. Since the variables are integrated of order one but not cointegrated in this case the concept of Granger causality is the appropriate choice (Granger 1969). Concerning the relations between growth and inequality, the results show a negative Granger causality running from growth to inequality. This means that higher income growth Granger causes a decline in inequality measured by changes in the Gini coefficient. As in the general panel the results for China confirm a negative relationship between growth and poverty in both directions, indicating that higher income growth Granger causes a reduction in poverty and vice versa. Finally, the results concerning the causal relationships between inequality and poverty indicate only a negative causality running from poverty to inequality, so decreasing poverty generates an increase in inequality.

In summary, we show that growth, income distribution and poverty reduction are strongly inter-related, so a development strategy would require effective, country-specific combinations of growth and distribution policies.

This monograph contributes to the existing research for the following three aspects:

- By combining a theoretical model based on international integration, imitation and interregional factor mobility with an empirical examination of the model this thesis seeks to close up the gap between theoretical analysis and empirical research. The empirical growth analysis is mainly motivated with the dissatisfaction with previous empirical studies. The literature in the context of China's growth determinants and convergence is large and still growing. Yet, empirical evidence is mixed and existing studies draw an inconsistent picture. The results depend to a large extend on the choice of the period. Furthermore, estimation methods and the selection of control variables show also a significant impact on the quality and the quantity of the results. This thesis extends the existing literature by using advanced estimation methods in a combination with revised provincial data and a selection of appropriate control variables. We apply two estimation techniques for dynamic panels: the difference GMM estimator developed by Arrelano and Bond (1991) and the system GMM estimator developed by Blundell and Bond (1998). Using these econometric techniques we account for province-specific effects, we can include dependent variables as regressors and control for endogeneity of all explanatory variables, and hence can provide unbiased and efficient estimates.

- With regard to the inequality analysis in chapter three we pick up the idea of directly addressing the phenomenon of disparity. We suggest a direct explanation of provincial disparity measured by the per capita income Theil index. Therefore, in our estimation we directly relate income disparity to the disparity of selected income determining factors. The decomposition of the Theil index by regions and provinces allows to identify to which degree the regions and provinces contribute to the overall inequality and how the growth determining factors are distributed across China. In addition to this we can estimate if the disparity of an income determining provincial variable positively or negatively contributes to the disparity of per capita income.

- The causality analysis in chapter four expands the existing literature by considering short-run and long-run dynamics between growth, inequality and poverty. It accounts for all possible relationships between these three variables by pairs, so we can clearly identify the causal directions of the triangle. Furthermore, panel-based error correction models are applied to explore the pairwise relationship between growth, inequality and poverty for a large panel of developing countries. We can identify if the causal effects are stationary long-term relations or more short-term transitory observations. Contrary to the most often applied regression approach, where the effect of a variable and a set of conditional variables is analysed on the variable of interest, our focus is to identify a possible causal relationship. In addition to this the methodology allows to analyse the overall picture of economic growth, inequality and poverty as well as their interdependencies in connection. Beyond that, a segmentation of the data by income and geographic location allows us to capture possible income-related and regional differences. And finally, we use a panel data set for rural and urban China to analyse China as one of the developing countries in more detail.

# Chapter 2

# International integration and the determinants of regional development in China

*This chapter is based on the paper "International integration and the determinants of regional development in China" by Gries, T. and Redlin, M. published in Economic Change and Restructuring in 2011.*

## 2.1 Introduction

For more than a decade the People's Republic of China has experienced very successful development. An outstanding average growth in real GDP per capita,[1] the unprecedented boom in foreign direct investment (FDI), and the sustained increase in trade are of impressive dimensions. This positive economic development caused an enormous improvement in China's standard of living and had an important impact on the global economy. However, the development of China is somehow deceptive considering that measured in GDP per capita, China is still a poor developing country.[2] Furthermore, China seems to be afflicted by growing regional disparities. The regional Gini coefficient increased from 0.35 in 1995 to 0.43 in 2004. Accelerated growth and increasing provincial inequality provoked great public interest and became a focus of numerous studies. Analysing the economic development of the coast and the interior and the rural and urban regions Kanbur and Zhang (2005), Huang, Kuo and Kao (2003), Li and Zhao (1999) and Wan (1998) find statistical evidence

[1] Average growth of the last ten years (1998-2007) is 9.79 per cent (Source: Penn World Table 6.3).

[2] With a GDP per capita (PPP) of $8,400 the People's Republic of China was ranked $117^{th}$ of 225 countries in 2011 (Source: The World Factbook 2012).

of increasing provincial disparities. Numerous studies try to analyse this rising inequality using the concept of $\sigma$- and $\beta$-convergence. The dominant finding in the literature is that inequality measured by $\sigma$-convergence has increased during the past decades (Chen and Fleisher 1996, Jian, Sachs and Warner 1996, Zhang, Liu and Yao 2001, Wang 2003 and Yao and Zhang 2001b). The question of regional disparity is not just a Chinese problem. Regional convergence can be regarded as an indicator of the continuity of the rapid growth process. A scenario of convergence indicates that China's average growth is not driven solely by a small number of rapidly developing regions and so it may be somewhat sustainable. Therefore, the question of the duration of Chinese growth and in turn of China's permanent and significant contribution to the world economy is central for the convergence of the Chinese regional growth process.

Chen and Fleisher (1996) find evidence of conditional convergence of per capita production from 1978 to 1993 when controlling for employment, physical capital, human capital, and coastal location. Further, Cai, Wang and Du (2002) support this finding for the period 1978 to 1998. Using panel data Choi and Li (2000) report convergence within China's provinces from 1978 to 1994. They argue that the poorer regions have higher convergence rates and hence catch up with the wealthier ones. This finding is also supported by Wu (1999). Results by Chen and Feng (2000), Jian, Sachs and Warner (1996), Yudong and Weeks (2003) also support the conditional convergence hypothesis, and Raiser (1998) and Gundlach (1997) report evidence even for absolute convergence.

However, using non-stationary panel techniques Pedroni and Yao (2006) argue that since 1978 per capita incomes in the majority of the provinces has appeared to be diverging. They show that this divergence process cannot be attributed to either the presence of geographically-oriented convergence clubs, or to the fact that some provinces run open-door policies while others do not. Yudong and Weeks (2003) indicate a system-wide divergence during the reform period, which in their opinion is a consequence of the technology gap between the coastal and the interior provinces. Yao and Zhang (2001a, 2001b, 2002) also have found evidence of regional income divergence in the last decades, which is explained by an increase in the average income gap between the coast and the inland, rather than by an increase in the variance within either the coastal or the inland regions. In summary, the convergence literature draws an inconsistent picture.

With respect to the determinants of the provincial growth process many studies focus on capital in form of physical and human capital, factors influencing openness, the government, and geographical location.

Physical capital stock persistently shows a significant impact on GDP growth in China (Yao 2006, Fleisher, Li and Zhao 2005, Yao and Zhang 2001a and 2002, Wang and Yao 2003 and Madariaga and Poncet 2005).

With respect to human capital it can be observed that besides the rapid economic development and high economic growth in the last years, endowment of human capital is also improving steadily, especially in the eastern provinces of China. Using the number of students enrolled in higher education as a proxy for human capital in a growth regression Yao (2006) and Chen and Feng (2000) estimate positive and significant coefficients. While Chen and Fleisher (1996) use university graduates/population, other studies by Fleisher, Li and Zhao (2005), Démurger (2001), Yao and Zhang (2001a) use secondary school enrolment as a proxy. All arrive at the conclusion that human capital contributes significantly to growth and welfare. Wang and Yao (2003) construct a new measure of human capital stock using average years of schooling and also find a positive effect.[3] Arayama and Miyoshi (2004) argue that the contribution of human capital is rather substantial in the central and western regions.

Apart from capital and human capital, there is a general view that economic integration has a strong impact on regional development in China. Since the start of the open door policy and the implementation of Special Economic Zones (SEZs) in the early 1980s China has made significant steps towards international integration and attracted many foreign direct investors. The importance of economic integration and openness for China's

[3] However, Soto (2002) and Portela, Alessie and Teulings (2006) argue that average years of schooling seem to have been estimated with considerable errors. Furthermore, it has to be noted that most of the human capital proxies do not account for differences in education quality between countries or regions.

provinces is broadly acknowledged. Particularly the effects of FDI and trade on China's regional growth have been studied in a number of papers. While Chen and Feng (2000) and Yao and Zhang (2001a, 2002) identify positive effects for exports in the last decades, Chen and Fleisher (1996), Zhang and Song (2000) and recently Yao (2006) have pointed out that both exports and FDI have a strong and positive effect on economic growth. Based on an analysis of 196 Chinese cities from 1990 to 2002, Madariaga and Poncet (2005) demonstrate that cities take advantages not only of their own financial openness but also of FDI flows received by neighbouring provinces. Cheung and Lin (2004) argue that inward FDI can have beneficial effects on innovation activity and growth via various spill-over channels such as reverse engineering, labour mobility, demonstration effects, supplier–customer relationships, and so on. They find evidence of positive spill-over effects of FDI on the number of domestic patent applications for the period 1995-2000.

Another set of studies focuses on the impact of geographic factors on growth and disparities. The advantageous location of the coastal provinces is discussed in the context of lower transportation costs and a more successful open door policy. For example, Bao et al. (2002) argue that spatial and topographic advantages promote higher returns on capital investment in the coastal provinces, thus attracting more FDI and migrant labour to a region and causing growth. Madariaga and Poncet (2005) and Bao et al. (2002) point out that geography, captured by international transaction costs, is responsible for a significant part of successful growth of the coastal belt. Furthermore, Chen and Fleisher found that convergence is conditional on coastal location, amongst others, while Yao and Zhang (2001b and 2002) use an augmented Solow's growth model and construct diverging clubs to identify that remote regions cannot catch-up with their eastern counterparts due to the long distance to economic centres.

In this paper the economy is a small region integrated into the world economy. The region is located in a developing country and characterised by a technological gap compared to leading industrialised countries. In this stylized economy an internationally traded final good is produced with human capital and real capital and internationally mobile real foreign capital. All trading transactions are directed at world markets. Due to positive externalities, incoming FDI induces imitation and hence productivity growth. The regional government can influence the economy by changing international transaction costs (transport costs as well as barriers to international trade and investments), and providing the public infrastructure required for imitation.

The empirical part examines the determinants of per capita income growth for 28 Chinese provinces over the period 1991-2004. We apply two estimation techniques for dynamic panels: the difference GMM estimator developed by Arrelano and Bond (1991) and the system GMM estimator developed by Blundell and Bond (1998). Using these econometric techniques we account for province-specific effects, we can include dependent variables as regressors and control for endogeneity of all explanatory variables, and hence can provide unbiased and efficient estimates. Our analysis is based on revised GDP and investment data from Hsueh and Li (1999).

## 2.2 A model of regional development

For a developing country access to relevant production factors, international spill-over and externalities through technologies and infrastructure are relevant determinants of growth and development.[4] While the idea of New Economic Geography (NEG) (Krugman 1991) basically works through increasing returns to scale, monopolistic competition, market size and pecuniary externalities, the idea in this paper is slightly different. Within a neoclassical model, we introduce technical and information externalities in the imitation process. The main reason for firms locating in a certain region hinges upon easy access and proximity to international technologies and a pool of human capital. In the discussion of this process Glaeser et al. (1992) point to the distinction between Jacobs (1969) and MAR (Marshall-Arrow-Romer) externalities. MAR externalities focus on knowledge spill-over processes between firms in the same industries. MAR externalities were discussed first by Marshall

[4] See e.g. Fujita and Thisse (2002, ch.11), or Kelly and Hageman (1999).

(1890 [1920]) and Arrow (1962). Starting with Romer (1986) this kind of spill-over process plays a crucial role in many models of the new growth theory. Jacobs externalities are not industry specific but general. They occur between firms that do not need to be in the same industry cluster. From an empirical point of view both externalities seem to matter. Glaeser et al. (1992) found evidence of Jacobs externalities while Black and Henderson (1999) and Kelly and Hagemann (1999) identified MAR externalities.

Taking these ideas of externalities and international spill-over as the point of departure, we develop a basic neoclassical model of growth for a single backward region. Externalities will lead to temporary dynamic scale economies and drive the technical imitation process. The dynamics of the model are not driven by accumulation but by technological catching up and imitation. The model will be stylized and simplified in such way that a region can be modelled with three equations.

### 2.2.1 Final output

The final output sector of region $i$ uses human capital $H_i$ and international capital flowing into the region as FDI $\mathcal{F}_i$ and domestic real capital $K_i$ to produce a homogeneous final good. Hence, in this model the most important factors of production that might eventually drive the growth process are three different types of capital. We particularly assume that domestic capital and international capital are different. The fundamental difference and the continued high degree of capital control segregate the market for domestic and international capital. Workers are assumed to be allocated to any production process at a subsistence level of income from a pool of surplus labour. As in a *Lewis Economy,* labour is not a growth restricting factor. The Lewis turning point has not yet been reached. Hence, $H_i$, $K_i$ and $\mathcal{F}_i$ can be regarded as the respective capital per unit labour. Based on the small economy assumption and the integration of regional goods markets into world markets, the per capita production of the final good $y_i$ can be regarded as Findlay's *foreign exchange production function.*[5] Hence, $y_i$ is a production value function measured in international

[5] See Findlay (1973, 1984).

prices. With the concept of the *foreign exchange production function* the aggregate production value function stands for a continuum of industries characterized by different factor intensities valuated in given international prices. Each level of output value indicates a full specialisation in the industry characterised by the corresponding factor intensity. A change in output value and hence factor intensity indicates a switch in specialisation pattern towards another industry. Inflowing international capital $F_i$ is fully depreciated during the period of influx. Production of the final good takes place under perfect competition and constant economies of scale. It is described by

$$\begin{aligned} y_i &= A_i H_i^{\alpha} \mathcal{F}_i^{\beta} K_i^{1-\alpha-\beta}, \qquad (2.1) \\ \textit{with} \quad A_i &= \omega_i A \end{aligned}$$

where $A_i$ indicates the regional level of technology and $\omega_i$ is the region's relative technological position compared to the technology leader $A$ which increases at a given rate $n$. As we will see later, domestic technology will be driven by $\omega_i$. The domestic product is used for government expenditures which is the fraction $\gamma_i$ of output, domestic consumption and exports.

### 2.2.2 FDI inflow and exports

Optimal capital inflow is derived from the firms' optimal factor demand. Due to the small country assumption, capital costs in a region for international capital $\mathcal{F}_i$ are determined by the exogenous world market interest factor $r$[6] and an ad valorem factor for region specific international transaction costs $\tau_i$. $\tau_i$ may include a risk premium related to the specific region. Since we are also looking at trade policies we introduce $\tau_i^{ex}$ as a transaction cost parameter for exports. $\tau_i^{ex}$ may be an export tariff or the equivalent of bureaucratic transaction costs. $\tau_i$ and $\tau_i^{ex}$ are modelled as iceberg costs on exports. As we assume that returns on international capital investments in a region $\mathcal{F}_i$ will be fully repatriated, exports

[6] The interest factor is one plus interest rate.

$Ex$ must earn international interest rates and all international transaction costs. On the firm level $Ex_i(1-\tau_i^{ex}) = \tau_i r \mathcal{F}_i$. Solving the firms' optimisation problem[7] we obtain the optimal influx of foreign capital

$$\mathcal{F}_i = \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} y_i \qquad (2.2)$$

and as a fraction $\varphi_i$ of GDP

$$\varphi_i = \frac{\mathcal{F}_i}{y_i} = \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}.$$

To keep things simple, international borrowing or lending beyond FDI is excluded. Since international capital costs have to be paid by exports, we can determine the export value necessary to cover international capital costs including all transaction costs

$$Ex_i = \frac{\tau_i r}{(1-\tau_i^{ex})} \mathcal{F}_i, \qquad \frac{Ex_i}{y_i} = (1-\gamma_i)\beta. \qquad (2.3)$$

Whereas the export share of GDP is simply determined by the elasticity of production of foreign capital $\beta$ and the tax rate $\gamma_i$ (2.2).

### 2.2.3 Determining the production level

Including optimal capital inflows in the production function leads to the production level[8]

$$Y_i = \omega_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)_i^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}. \qquad (2.4)$$

Production is now normalised for the international technology level. Hence, production is determined by regional factor endowments and the relative technology position of the region compared to the technological leader $\omega_i$.

[7] The firm has to determine optimal factor inputs by maximising profits. Since all capital services have to be paid in terms of exports, the full capital costs include several components such as government taxes on output $\gamma_i$ or transaction costs for exports.

[8] $Y = yA^{-\frac{1}{1-\beta}}$, see also Appendix A2.1.

### 2.2.4 Technology and imitation

The developing region does not create new knowledge but acquires technologies by decoding and imitating foreign designs from international technology leaders. In the present model growth through technological imitation and agglomeration is driven by three components:[9]

1) International knowledge spill-over and positive technological externalities from the influx of FDI were modelled by Markusen and Venables (1999). Here the effects of these externalities are included at a macro level of modelling.

2) In order to make spill-over from FDI effective for the host region, technology and firm-relevant public infrastructure must exist.[10]

3) As the focus lies on underdeveloped regions, the case of innovations in this backward region is excluded. The imitation process is affected by the technology gap $(1-\omega)$ between the backward region and the industrialised world. If the domestic stock of technology is low ($\omega$ is small), it is relatively easy to increase the technology position by adopting foreign designs. However, the process becomes increasingly difficult as the technology gap narrows.[11] Therefore, in this approach technological progress in a backward economy is modelled as a process of endogenous catching up relative to an exogenous growth path of a technology leader.

While the exogenous process is driven by international innovation growth, the endogenous process of imitation and participation in worldwide technical progress is determined by pure externalities from FDI $\mathcal{F}(t)$ and from domestic government investments in the

[9] There is a broad literature on international technology diffusion that has suggested various channels. Eaton and Kortum (2001) discuss trade as a channel of diffusion in a multi-country setting. See also Coe and Helpman (1995) who link the direction of technology diffusion to exports. Keller (1998) however has some doubts about the link between trade and diffusion.

[10] E.g. Martin (1999) has analysed the effects of public policies and infrastructure on the growth performance of a regional economy.

[11] This idea draws back to the well-known Veblen-Gerschenkron hypothesis (Veblen (1915) and Gerschenkron (1962)). Later Nelson and Phelps (1966), Gries and Wigger (1993), Gries and Jungblut (1997) and Gries (2002) further developed these ideas in the context of catching up economies. The catching up hypothesis has been tested successfully and robustly by Benhabib and Spiegel (1994), de la Fuente (2002), and Engelbrecht (2003).

ability to imitate and improve productivity.[12]

In this aggregate model $G(t)$ stands for the supply of various public goods, and government and administrative functions in the economy. In traditional modelling this spending indicates service necessary to run the institutional arrangements and to make institutions effective. Therefore, the implicit assumption of such aggregate modelling is that the design of government institutions and the quality of public governance serves (as a public good) for the economic efficiency of the private sector. However, recent discussions challenge this assumption and put emphasis on institutional quality.[13] If the design of government institutions is not meant to serve for the efficiency of markets and the private sector, or even more, if government institutions are instructed to control and direct micro decisions, increasing government spending may have negative effects on private economic activities. In this case the government would provide a negative public good for the private sector via a poor or even destructive institutional design. This problem may be even more likely if government institutions in a transformation economy do not have the self-conception of serving for the efficiency of the economy, and if the government sector acts more in the tradition of controlling and restricting decentralised private activities. However, even if we consider this issue in the empirical section, in the theoretical model we assume that spending on government services generates a positive externality.

Therefore, FDI-driven and government externalities and the resulting relative increase in domestic technologies by imitation are the elements that allow us to depart from neoclassics. Externalities in the imitation process generate temporary dynamic scale economies. As scale economies are the driving element in the models introduced by the New Economic Geography (NEG*)*, there is a link to NEG even if the market structure is not monopolistic competition. While pure size and pecuniary externalities are permanently positive in NEG

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[12] Note that $\mathcal{F}(t)$ and $G(t)$ are normalised values transformed by an international technology index factor $A(t)^{\frac{1}{1-\beta}}$, and $A$ is growing at a given constant rate $n$. See also Appendix A2.1.

[13] Finally, examining the determinants of growth several studies present empirical evidence that there is also an effect of institutions and the quality of governance on growth (Basu 2006, Barro 1997, Knack and Keefer 1997a, 1997b, Mauro 1995, Svensson 1998, Chong and Calderon 2000, Hall and Jones 1999, Gradstein 2004 and the series of papers "Governance Matters" (Kaufmann, Kraay and Zoido-Lobatón 1999, 2002 and Kaufmann, Kraay and Mastruzzi 2004, 2005, 2006, 2007).

models, in this approach we focus on the underlying factors of technical externalities from factors of production and the resulting transitory dynamic scale economies,[14]

$$\dot{\omega}_i(t) = G(t)_i^{\delta_G} F(t)_i^{\delta_F} - \omega(t). \tag{2.5}$$

The externalities from FDI and government infrastructure are assumed to have a rather limited effect on imitation such that $\delta_G + \delta_F = \delta < 1$ and $\delta$ is small.

As described above, government expenditures are restricted by government tax income. We abstract from government borrowing or lending and interregional transfers. Hence, the government budget constraint is

$$G_i = \gamma_i y_i. \tag{2.6}$$

The three equations (2.1), (2.2), and (2.5) capture the model of regional development for one region. The solution to (2.1), (2.2), and (2.5) is a differential equation determining the growth of the relative stock of technology available to the region (catching up in technology) during the period of transition to the steady state.[15] In this period we observe additional technological catching up with the steady state productivity growth. As this acceleration process is driven by additional factors flowing into the region, the economy can realise temporary dynamic scale economies during this catching up and adjustment period. While $\dot{\omega}_i(t)$ is positive during transition, it converges to zero when approaching the steady state path. Equation (2.7) suggests a decreasing speed of growth with a rising income level as a result of increasing difficulties in the imitation process.[16]

$$\dot{\omega}_i(t) = \gamma_i^{\delta_G} \varphi_i^{\left(\delta_F + \frac{\beta}{1-\beta}\right)} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t), \qquad \text{with} \quad \frac{d\dot{\omega}_i(t)}{d\omega(t)} < 0. \tag{2.7}$$

[14] For the dynamic catching up spill-over equation we assume that $G$ and $\mathcal{F}$ are sufficiently large for positive upgrading.

[15] See Appendix A2.1.

[16] The dynamic catching up spill-over equation contains a scaling problem if $H$ and $K$ are taken as absolute values. As the region is assumed to remain backward, the values of $\gamma$, $\varphi$, $H$ and $K$ are assumed to be sufficiently small. See Appendix A2.2 for the derivatives.

Not only the speed of technological catching up $\dot{\omega}_i(t)$ is determined by the factor endowments $K_i$, $H_i$ and the fractions $\gamma_i$ and $\varphi_i$. For each endowment we can determine the steady state position $\omega_i^*$ of the region. For $\dot{\omega}_i(t) = 0$[17] we obtain

$$\omega^* = \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} \varphi_i^{\frac{\delta_F (1-\beta)+\delta\beta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}, \tag{2.8}$$

$$\frac{\partial \omega_i^*}{\partial K_i} = \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega^* K_i^{-1} > 0, \quad \frac{\partial \omega_i^*}{\partial H_i} = \frac{\delta\alpha}{1-\beta-\delta} \omega^* H_i^{-1} > 0, \tag{2.9}$$

$$\frac{\partial \omega_i^*}{\partial \tau_i} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[ \delta_F + \frac{\beta}{1-\beta}\delta \right] \tau_i^{-1} < 0, \tag{2.10}$$

$$\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[ \delta_F + \frac{\beta}{1-\beta}\delta \right] (1-\tau_i^{ex})^{-1} < 0, \tag{2.11}$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[ \delta_G \gamma_i^{-1} - \left( \delta_F + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right] \gtreqless 0. \tag{2.12}$$

The essential determinants of the speed of convergence and the final relative convergence position are the endowment of capital $K_i$ and human capital $H_i$, technology relevant government expenditure indicated by $\gamma_i$ and international (and domestic) transaction costs connected to exports $\tau_i^{ex}$ and FDI $\tau_i$ and hence the share of FDI $\varphi_i$.

The economic story is rather simple. Reducing $\tau_i$ will reduce the costs of international capital and increase the input of international capital. As more FDI or government investments enter the region, spill-over and positive externalities will accelerate imitation and technology convergence and in turn improve the final relative technology position of the region. Similarly, with a larger endowment of capital or human capital, capital productivity will increase such that additional FDI speeds up imitation and the final position of the region improves.

*Optimal level of government activity:* The steady state reaction of $\omega_i^*$ resulting from a change in government expenditures is ambiguous and depends on the present state of government policy. With respect to the potential goal of maximising the region's steady

[17] We assume that the contribution of FDI to production $\beta$ as well as the externality effect of FDI on technology $\delta$ are sufficiently small. This also reflects the already mentioned assumption of a rather limited spill-over effect of FDI on the relative catching up process.

state position we can determine an optimum tax rate[18] and hence an optimum value of government expenditures for technology related infrastructure

$$\max_{\gamma_i} \quad \omega^* \qquad \Rightarrow \gamma_i^* = \frac{\delta_G}{\left(\delta_F + \frac{\beta}{1-\beta}\delta + \delta_G\right)}. \tag{2.13}$$

Therefore, there is a range $\gamma_i < \gamma_i^*$ where an increase in $\gamma$ positively affects $\omega_i^*$. Beyond the optimal value $\gamma_i^*$ (for $\gamma_i > \gamma_i^*$) increasing taxes and increasing government expenditures reduce $\omega_i^*$.

$$\frac{\partial \omega^*}{\partial \gamma_i} \begin{cases} > 0 & \gamma_i < \gamma_i^* \quad \text{underinvestment} \\ = 0 \quad \text{for} & \gamma_i = \gamma_i^* \quad \text{GDP maximising spending} \\ < 0 & \gamma_i > \gamma_i^* \quad \text{overinvestment} \end{cases} \tag{2.14}$$

From the discussion of the adjustment and the steady state we can turn to the general dynamic behaviour of the region's income path over time. At any point in time $t_0$ the income path can be described by a Taylor approximation

$$\ln Y(t_0) = \ln Y(t_0) + \frac{Y'(t_0)}{Y(t_0)}(t - t_0) + \frac{1}{2}\frac{Y''(t_0)y(t_0) - Y'(t_0)^2}{Y(t_0)^2}(t - t_0). \tag{2.15}$$

From this path we can derive the general rule of motion which describes the speed of the process defined by the growth rate.[19]

$$\begin{aligned} \frac{\Delta \ln Y(t_0)}{\Delta t} &= \frac{Y'(t_0)}{Y(t_0)} + \frac{Y''(t_0)y(t_0) - Y'(t_0)^2}{Y(t_0)^2}(t - t_0) + \frac{1}{2}... \\ &= \frac{Y'}{Y} + \frac{Y''}{Y} - \left(\frac{Y'}{Y}\right)^2 = \frac{Y'}{Y} + \frac{Y''}{Y}. \end{aligned} \tag{2.16}$$

[18] In Appendix A2.3 we show that the government can maximise the final development position of the economy and the speed of growth by choosing an optimal level of government expenditure for public infrastructure.

[19] Since $\left(\frac{y'}{y}\right)^2$ is rather small we can approximate the process.

Using the model specification we obtain equation (2.17) for the development of each region.[20] Equation (2.17) will be transformed into the estimation equation later on.

$$\frac{d\ln Y(t_0)}{dt} = \frac{\dot{\omega}}{\omega}(G,F,\omega) + \alpha\frac{\dot{H}}{H} + \left(\beta + \frac{\partial^2 y}{\partial\omega^2}\frac{\partial\dot{\omega}}{\partial F}\right)\frac{\dot{F}}{F} + (1-\alpha-\beta)\frac{\dot{K}}{K} + \frac{\partial^2 y}{\partial\omega^2}\frac{\partial\dot{\omega}}{\partial G}\frac{\dot{G}}{G} \quad (2.17)$$

## 2.3 GMM and dynamic panel data estimation

For the empirical analysis we suggest applying a panel data analysis and generalised method of moments (GMM) estimation. We prefer dynamic panel estimators mainly for two reasons.

First, from a theoretical point of view we should assume that a number of individual factors exist that cannot be captured in the conditioning set $X_i$, as different cross-sections exhibit different technological or geographical endowments. The dynamic panel procedure allows controlling for these specific effects whereas a standard OLS estimator assumes that the intercept capturing the effect of all omitted and not observable variables is the same for all provinces. This individual effect must be considered to correlate with the included explanatory variables, hence omission of the individual effect would become part of the error term, which would lead to a bias in the estimates.

Second, some of the variables in conditioning set $X_i$ must be considered not strictly exogenous and determined simultaneously with growth. Accounting for these problems, panel procedures enable a calculation of consistent and efficient estimates.

With regard to the first point, panel data estimations can take a cross-section's heterogeneity explicitly into account by allowing for individual steady state positions (individual specific effects) using fixed effects. In comparison to the standard fixed effect estimator,

[20] To simplify we consider only linear and log linear processes.

GMM estimation additionally circumvents the bias associated with the inclusion of a lagged dependent variable as a regressor. Additionally, by combining the time series dimension with the cross-sectional dimension, the panel data gives a richer set of information to analyse the relationship between the dependent and independent variables. It reduces the collinearity among the explanatory variables, increases the degrees of freedom and gives more variability and efficiency.[21]

### 2.3.1 Instrumentation

In the following we point to the problem of bias caused by a correlation between the regressor $X$ and the error term $\varepsilon$ and introduce the idea of instrumentation. When $X$ and $\varepsilon$ are correlated the basic idea of instrumentation is to find a variable $Z$, that highly correlates with $X$, but does not correlate with $\varepsilon$ and therefore with $Y$.[22]

More specifically, the starting point is a linear regression

$$y = X\beta + \varepsilon \text{ with } \mathrm{var}(\varepsilon) = \sigma^2 I \tag{2.18}$$

with a correlation between the observable and the error term

$$p\mathrm{lim}\left(\frac{1}{n}X'\varepsilon\right) \neq 0. \tag{2.19}$$

To circumvent the bias an instrument $Z$ is used that highly correlates with $X$

$$p\mathrm{lim}\left(\frac{1}{n}Z'X\right) \neq 0 \tag{2.20}$$

but is orthogonal to $\varepsilon$

$$p\mathrm{lim}\left(\frac{1}{n}Z'\varepsilon\right) = 0. \tag{2.21}$$

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[21] See Gujarati (2003, p.637).
[22] See Behr (2003).

The instrumentation is a two-stage procedure, where in a first step the explanatory variable $X$ is regressed on the instrument $Z$

$$X = Z\gamma + \nu, \tag{2.22}$$

$$\widehat{X} = Z\widehat{\gamma} = Z(Z'Z)^{-1}Z'X. \tag{2.23}$$

In a second step the regressed values $\widehat{X}$ are used as explanatory variables.

$$y = \widehat{X}\beta + \varepsilon, \tag{2.24}$$

$$\beta_{IV} = (\widehat{X}'\widehat{X})^{-1}\widehat{X'}y. \tag{2.25}$$

Inserting the regressed values $Z(Z'Z)^{-1}Z'X$ for $\widehat{X}$ results in the instrumental variable (IV) or two-stage least squares (2SLS) estimator of $\beta$ with the projection matrix $P = Z(Z'Z)^{-1}Z'$

$$\beta_{IV} = \left((Z(Z'Z)^{-1}Z'X)'Z(Z'Z)^{-1}Z'X\right)^{-1}(Z(Z'Z)^{-1}Z'X)'y \tag{2.26}$$

$$= (X'Z(ZZ')^{-1}Z'Z(Z'Z)^{-1}Z'X)^{-1}X'Z(ZZ')^{-1}Z'y$$

$$= (X'Z(ZZ')^{-1}Z'X)^{-1}X'Z(ZZ')^{-1}Z'y = (X'PX)^{-1}X'Py.$$

### 2.3.2 GMM

In recent years generalised method of moments (GMM) has become very popular, particularly in growth regressions and other macroeconomic studies where the inclusion of a lagged dependent variable leads to an endogeneity problem. Before we discuss some selected dynamic panel estimators based on this method, we introduce the basic concept of GMM.

Starting with a linear regression of $y$ on $X$, an important assumption of the least squares estimator is the orthogonality of the explanatory variables and the error term

$$E(X'\varepsilon) = 0. \tag{2.27}$$

Applying this assumption to the sample leads to

$$\frac{1}{n}X'(y - X\widehat{\beta}) = 0. \tag{2.28}$$

The estimator for $\beta$ has to satisfy the moment equation, which just represents the basic equation for the OLS estimator. Thus, it appears that the OLS method can be represented as an application of the method of moments. So solving the equation results in the OLS estimator

$$\widehat{\beta} = (X'X)^{-1}X'y. \tag{2.29}$$

With respect to this procedure the instrumentation can be expressed as an application of GMM. Starting with the assumption of orthogonality of the instrumental variable and the error term

$$E(Z'\varepsilon) = 0, \tag{2.30}$$

and applying it to the sample leads to

$$\frac{1}{n}Z'(y - X\widehat{\beta}) = 0. \tag{2.31}$$

Solving this equation results in the IV estimator

$$\widehat{\beta}_{IV} = (X'PX)^{-1}X'Py \tag{2.32}$$

with $P = Z(Z'Z)^{-1}Z'$.

If the number of instrumental variables equals the number of explanatory variables then generalised least squares (GLS) leads to the familiar instrumental variables estimator[23]

$$\widehat{\beta}_{IV} = (Z'X)^{-1}Z'y. \tag{2.33}$$

### 2.3.3 Dynamic panel data estimation

Our point of departure is a simple fixed effects growth model of the form

$$y_{i,t} - y_{i,t-1} = \widetilde{\theta} y_{i,t-1} + \beta X'_{i,t} + u_{i,t} \tag{2.34}$$

for $i = 1, ..., N$ and $t = 2, ..., T$, where the lagged endogenous variable $y_{i,t-1}$ is included as a regressor and $X'_{i,t}$ is a row vector of explanatory variables. This method allows for the inclusion of individual effects for each cross-section. Hence $u_{it} = \eta_i + \varepsilon_{it}$ denotes the disturbance term that is composed of the individual effect $\eta_i$ and stochastic white noise disturbance $\varepsilon_{it}$, where

$$E(\eta_i) = 0,\ E(\varepsilon_{i,t}) = 0,\ E(\varepsilon_{i,t};\eta_i) = 0 \text{ for } i = 1,\ ...,\ N \text{ and } t = 2,\ ...,\ T. \tag{2.35}$$

We can now rewrite equation (2.34) and obtain

$$y_{i,t} = \theta y_{i,t-1} + \beta X'_{i,t} + \eta_i + \varepsilon_{i,t} \tag{2.36}$$

[23] See Behr (2003).

whereas $\theta = \widetilde{\theta} + 1$. The errors are assumed to be serially uncorrelated

$$E(\varepsilon_{i,t}; \varepsilon_{i,s}) = 0 \text{ for } s \neq t, \tag{2.37}$$

the individual effect captures the cross-section specific characteristics and might correlate with the explanatory variables

$$E(X'_{i,t}; \eta_i) \neq 0. \tag{2.38}$$

To receive consistent results one has to assume that the error term is orthogonal to all explanatory variables

$$E(X'_{i,t}; \varepsilon_{i,t}) = 0, \tag{2.39}$$

$$E(y_{i,t-1}; \varepsilon_{i,t}) = 0. \tag{2.40}$$

At this point a problem arises as the lagged endogenous variable used as a regressor correlates with the error term

$$E(y_{i,t-1}\varepsilon_{i,t}) \neq 0. \tag{2.41}$$

If this correlation structure is not taken into account and estimation of (2.36) is carried out by a common least squares estimator, our estimates will be biased and inefficient (Nickell 1981).

**Anderson and Hsiao difference estimator:**

Anderson and Hsiao (1982) suggest taking differences of the original equation to eliminate the individual fixed effect

$$y_{i,t} - y_{i,t-1} = \theta(y_{i,t-1} - y_{i,t-2}) + \beta(X'_{i,t} - X'_{i,t-1}) + \varepsilon_{i,t} - \varepsilon_{i,t-1}. \tag{2.42}$$

This can be simplified in

$$\triangle y_{i,t} = \theta \triangle y_{i,t-1} + \beta \triangle X'_{i,t} + \triangle\varepsilon_{i,t} \tag{2.43}$$

where $\triangle$ is the first difference operator.

However, using differences does not eliminate the problematic relationship between $\triangle y_{i,t-1}$ and $\triangle\varepsilon_{i,t}$, since $y_{i,t-1}$ and $\varepsilon_{i,t}$ are contained in these terms. So a new correlation problem arises that again leads to a coefficient bias as the difference of the lagged endogenous variable correlates with the new error term

$$E(\triangle y_{i,t-1}; \triangle\varepsilon_{i,t}) \neq 0. \tag{2.44}$$

Starting with the problem of correlation between the regressor and the error term in (2.44), a bias can be avoided using an instrumental variable $Z$ that strongly correlates with the explanatory variable $\triangle y_{i,t-1}$ in the equation but does not correlate with the error term $\triangle\varepsilon_{i,t}$. Hence, a valid instrument is characterised by the following assumptions

$$E(\triangle y_{i,t-1}; Z) \neq 0, \tag{2.45}$$

$$E(Z; \triangle\varepsilon_{i,t}) = 0. \tag{2.46}$$

The structure of the error term contains the periods $t$ and $t-1$ , so assuming no serial correlation in the errors, variables from the period $t-2$ do not correlate with $\triangle\varepsilon_{i,t}$. Anderson and Hsiao (1982) recommend using either the lagged level observation ($y_{i,t-2}$) or the lagged difference ($\triangle y_{i,t-2}$) as instruments for the differenced lagged explanatory variable. Both correlate with the explanatory variable but not with the error term

$$E(y_{i,t-2}; \triangle\varepsilon_{i,t}) = 0, \tag{2.47}$$

$$E(\triangle y_{i,t-2}; \triangle\varepsilon_{i,t}) = 0. \tag{2.48}$$

For the case of levels as instruments the following $(T-2)\times m$ matrix is used for estimation

$$Z_i^{AH1} = \begin{bmatrix} y_{i,1} & 0 & \cdots & 0 \\ 0 & y_{i,2} & \cdots & 0 \\ . & . & . & . \\ 0 & 0 & \cdots & y_{i,T-1} \end{bmatrix}. \qquad (2.49)$$

And the following matrix is used for the case of differences as instruments:

$$Z_i^{AH2} = \begin{bmatrix} y_{i,2}-y_{i,1} & 0 & \cdots & 0 \\ 0 & y_{i,3}-y_{i,2} & \cdots & 0 \\ . & . & . & . \\ 0 & 0 & \cdots & y_{i,T-2}-y_{i,T-3} \end{bmatrix}. \qquad (2.50)$$

The matrices result in the following two estimators

$$\begin{aligned} \widehat{\beta}^{AH} &= (XPX)^{-1}X'Py \qquad (2.51) \\ \text{where } P &= Z^{AH1}(Z^{AH1\prime}Z^{AH1})^{-1}Z^{AH1\prime} \text{ or } P = Z^{AH2}(Z^{AH2\prime}Z^{AH2})^{-1}Z^{AH2\prime}. \end{aligned}$$

Arellano (1989) shows that in models with an autoregressive exogenous variable instruments in levels are better suited. In contrast to the estimator that uses differenced instruments, the estimator with level instruments has no singularities and much smaller variances.[24]

**Arellano and Bond difference estimator:**

Though the method recommended by Anderson and Hsiao (1982) provides consistent results, Arellano and Bond (1991) show that the Anderson-Hsiao estimator is not necessarily efficient since it does not make use of all available moment restrictions. Following Arellano

[24] See Bond, Hoeffler and Temple (2001).

and Bond (1991) all lagged observations should be used as instruments

$$E(y_{i,t-s}; \triangle\varepsilon_{i,t}) = 0 \text{ for } s \geq 2 \text{ and } t = 3, ..., T. \tag{2.52}$$

The corresponding $1/2(T-1)(T-2)$ moment condition can be expressed as follows

$$Z_i^d = \begin{bmatrix} y_{i1} & 0 & 0 & \cdots & 0 & \cdots & 0 \\ 0 & y_{i1} & y_{i2} & \cdots & 0 & \cdots & 0 \\ . & . & . & \cdots & . & \cdots & . \\ 0 & 0 & 0 & \cdots & y_{i1} & \cdots & y_{iT-2} \end{bmatrix}. \tag{2.53}$$

Using the lagged levels dated $t-2$ and earlier as instruments for the equation in first differences, the estimator provides consistent and efficient parameter estimates. Simulations by Judson and Owen (1996) and Arellano and Bond (1991) suggest significant efficiency gains of the difference GMM estimator relative to that of the Anderson-Hsiao type in the form of smaller variances of the estimated coefficients.[25]

**Blundell and Bond system estimator:**

However, Blundell and Bond (1998) argue that this difference estimator has poor finite sample properties in terms of bias and imprecision when the lagged levels of the variables are weak instruments for the equations in first differences. This is the case when the time series are persistent or have near unit root properties. They propose using additional instruments in levels. In a system GMM estimator they combine the regression in differences with the regression in levels. The regression equation in differences is given by (2.43), the additional regression equation in levels is

$$y_{i,t} = \theta y_{i,t-1} + \beta X'_{i,t} + \eta_i + \varepsilon_{i,t}, \tag{2.54}$$

[25] See Bond, Hoeffler and Temple (2001).

where differences are used as instruments. Blundell and Bond (1998) consider an additional stationarity assumption

$$E(\triangle y_{i,2}\eta_i) = 0 \text{ for } i = 1, ..., N. \tag{2.55}$$

The moment restriction for the regression equation in differences is the same as above. Indicating that the differences do not correlate with the error term for the regression equation in levels, the following moment restrictions are used

$$E(\triangle y_{i,t-1}u_{i,t}) = 0 \text{ for } i = 1, ..., N \text{ and } t = 3, ..., T. \tag{2.56}$$

The following matrix defines the additional $1/2(T-1)(T-2)$ moment conditions

$$Z_i^l = \begin{bmatrix} \triangle y_{i2} & 0 & 0 & \cdots & 0 & \cdots & 0 \\ 0 & \triangle y_{i2} & \triangle y_{i3} & \cdots & 0 & \cdots & 0 \\ . & . & . & \cdots & . & \cdots & . \\ 0 & 0 & 0 & \cdots & \triangle y_{i2} & \cdots & \triangle y_{iT-1} \end{bmatrix}, \tag{2.57}$$

so that the system estimator uses the following instrument matrix

$$Z_i^s = \begin{bmatrix} Z_i^d & 0 \\ 0 & Z_i^l \end{bmatrix}. \tag{2.58}$$

Using the moment conditions in (2.52) and (2.56), we construct a GMM estimator that yields consistent and efficient values for the parameters. It combines the equations in differences with suitably lagged levels as instruments with the set of equations in levels with suitably lagged first-differences. Bond, Hoeffler and Temple (2001) compare the difference and the system GMM estimator and show that in an estimation of an empirical growth model, the system GMM estimator yields more reasonable results. Blundell, Bond and Windmeijer (2000) report similar improvements for a typical growth model with a lagged dependent variable and additional right-hand-side variables. Furthermore, Monte Carlo simulations[26] on the finite sample properties of the GMM estimator for dynamic panel data models demonstrate a significant improvement in performance of the system estimator to the regular difference GMM estimator.[27]

**Test for serial correlation and Sargan test of over-identifying restrictions:**

The consistency of the GMM estimators hinges heavily upon the assumption that

$$E(\triangle\varepsilon_{i,t};\triangle\varepsilon_{i,t-2}) = 0. \tag{2.59}$$

Arellano and Bond (1991) propose a test for the hypothesis that there is no second-order serial correlation. The test statistic based on residuals from the first-difference equation is

$$m2 = \frac{\widehat{\triangle\varepsilon}'_{-2}\widehat{\triangle\varepsilon}}{\widehat{\triangle\varepsilon}^{1/2}} \sim N(0,1), \tag{2.60}$$

the corresponding null hypothesis is that of no second order serial correlation.

To check the validity of the instruments Arellano and Bond (1991) suggest Sargan's test of over-identifying restrictions. The null hypothesis for this test is that the instruments are valid in the sense that they are not correlated with the errors in the first-differenced equation. The test statistic is computed as

$$s = \triangle\widehat{\varepsilon}' Z \left(\sum_{i=1}^{N} Z_i' \triangle \widehat{\varepsilon}_i \triangle \widehat{\varepsilon}_i' Z_i\right)^{-1} Z' \triangle \widehat{\varepsilon} \sim \chi^2_{p-K-1} \tag{2.61}$$

where $p$ is the number of columns in $Z$ and $\triangle\widehat{\varepsilon}$ denotes the residuals from the two-step estimation.

The Difference Sargan test can be used to test the additional assumptions and the validity of the additional instruments for the equation in levels.[28]

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[26] Monte Carlo results on the finite sample properties of the GMM estimator for dynamic panel data models have been reported, amongst others, by Arellano and Bond (1991), Kiviet (1995), Ziliak (1997), Blundell and Bond (1998) and Alonso-Borrego and Arellano (1999).

[27] See Bond, Hoeffler and Temple (2001) and Behr (2003).

[28] For a detailed presentation of the specification tests see Verbeek (2008, pp. 155-157).

## 2.4 Specification of the model and data

To analyse the determinants of growth and the convergence process within China, it is necessary to use regional data to take the regions' heterogeneity into account. Our data set covers the period 1991-2004 and contains annual data for 28 Chinese provinces, autonomous regions, and municipalities.[29] These are Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Shanxi, Jilin, Heilongjiang, Anhui, Jiagxi, Henan, Hubei, Hunan, Inner Mongolia, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. The provinces Tibet and Hainan are excluded because of missing values. In constructing our data set we use new income and investment data reported by Hsueh and Li (1999) and various sources of Chinese official statistics provided by the National Bureau of Statistics (NBS), namely the China Statistical Yearbook (CSY) from 1996-2004 and the China Compendium of Statistics 1949-2004. Regarding the reliability of China's statistics economists and general observers have different views. And although Chinese official data are widely used for economic research, there are still critics who claim that the data may be falsified for political purposes. Recent opinions show a tendency of an enormous improvement of the reliability of data. For example, Chow (2006) point out that Chinese official statistics are by large reliable and useful for drawing conclusions about the Chinese economy. Rawski (2001) argues that two decades of reform have produced impressive achievements in the realm of economic statistics. The range, depth, and quality of statistical documentation surrounding China's economic performance matched or exceeded comparable materials for many nations at similar or even higher levels of economic development. However, both authors suggest that Chinese statistical reporting during the last few years has not been accurate and there is an overestimation of the official GDP statistics. Yet, taking differences of the data, which

[29] The choice of the period makes sense for two reasons. First, the early 1990s saw the latest wave of international integration policy in China. Also in the early 1990s the Chinese government started to prepare for WTO accession and a further opening up of the economy. Second, with respect to some important indicators some provinces would have had to be excluded if the time period had been expanded to earlier years.

is the case in our empirical model, attenuates the possible measuring inaccuracy. In the following the variables are described in detail.

Our estimation equations are directly derived from the theoretical model presented above. The general equation of motion for the above model (2.17) translates into the estimation equations (2.62), (2.63) and (2.64) with the following specification

$$\begin{aligned} \triangle y_{i,t} &= \beta_1 y_{i,t-1} + \beta_2 \triangle K_{i,t} + \beta_2 \triangle POP_{i,t} + \beta_4 \triangle HC_{i,t} \\ &+ \beta_5 \triangle FDI_{i,t} + \beta_6 \triangle GOV1_{i,t} + \beta_7 \triangle GOV2_{i,t} \\ &+ \beta_8 POPKM2_{i,t} + \beta_9 URBAN_{i,t} + \triangle \varepsilon_{i,t} \end{aligned} \tag{2.62}$$

and an alternative version where trade is assumed to have positive technology spill-over

$$\begin{aligned} \triangle y_{i,t} &= \beta_1 y_{i,t-1} + \beta_2 \triangle K_{i,t} + \beta_2 \triangle POP_{i,t} + \beta_4 \triangle HC_{i,t} \\ &+ \beta_5 \triangle T_{i,t} + \beta_6 \triangle GOV1_{i,t} + \beta_7 \triangle GOV2_{i,t} \\ &+ \beta_8 POPKM2_{i,t} + \beta_9 URBAN_{i,t} + \triangle \varepsilon_{i,t} \quad . \end{aligned} \tag{2.63}$$

To capture the effect of governance and institutional quality on GDP growth in a further step we extend our specification by an additional explanatory variable. We also note, that the inclusion of the Marketisation index which is only available for the period 1997-2005, means that our results are based upon an unbalanced panel. Because VIF values denote a bigger problem of multicollinearity in the case where the index of Marketisation is included in specification (2.62), we use the extended version of model specification (2.63)

$$\begin{aligned}\triangle y_{i,t} &= \beta_1 y_{i,t-1} + \beta_2 \triangle K_{i,t} + \beta_2 \triangle POP_{i,t} + \beta_4 \triangle HC_{i,t} \\ &+\beta_5 \triangle T_{i,t} + \beta_6 \triangle GOV1_{i,t} + \beta_7 \triangle GOV2_{i,t} \\ &+\beta_8 POPKM2_{i,t} + \beta_9 URBAN_{i,t} + \beta_9 \triangle MARKET_{i,t} + \triangle\varepsilon_{i,t}\end{aligned} \tag{2.64}$$

where $y_{i,t}$ denotes GDP per capita, $K_{i,t}$ denotes provincial capital stock, $POP_{i,t}$ measures the population, $HC_{i,t}$ is the proxy for human capital, $FDI_{i,t}$ refers to FDI and $T_{i,t}$ to trade, $GOV1_{i,t}$ and $GOV2_{i,t}$ are the shares of government expenditure in GDP, $POPKM2_{i,t}$ is the proxy for aggregation, $URBAN_{i,t}$ the proxy for urbanization and $MARKET_{i,t}$ represents the NERI index of Marketisation. Table 2.1 presents the descriptive statistics of all variables. The notation of the estimation equation translates as follows:

**Real GDP per capita -** $y_{i,t}$ :

$y_{i,t}$ denotes the log of real GDP per labour unit and $\Delta y_{i,t}$ gives growth rate $y_t - y_{t-1}$ over time period $t-(t-1)$. We obtained provincial level output data from Hsueh and Li (1999) covering the period 1978-1995 and from various issues of the Statistical Yearbook of China for 1996-2004. GDP expressed in current prices (Yuan) has been deflated with 1995 as the base year. The number of employed persons is taken from the China Compendium of Statistics 1949-2004.

**Real capital stock -** $K_{i,t}$ :

$K_{i,t}$ denotes the log of real capital stock per unit labour in each province $i$. The real physical capital stock for all provinces is estimated using the standard perpetual inventory approach. It is accumulated according to

$$\mathcal{K}_{i,t+1} = I_{i,t} + (1-\delta)\mathcal{K}_{i,t} \tag{2.65}$$

where $\mathcal{K}_{i,t}$ and $\mathcal{K}_{i,t+1}$ is the capital stock of year $t$ and $t+1$, $I_{i,t}$ denotes investment, and $\delta$ the depreciation rate. The investment series used is gross fixed capital formation and is taken at current prices, it is obtained from Hsueh and Li (1999) and the Chinese Statistical Yearbooks. We assume that the depreciation rate $\delta$ is 5 per cent for all provinces as in Miyamoto and Liu (2005). For the initial capital stocks for each province we use the average ratio of provincial GDP to national GDP for each province over the period 1952-1977 as the weight. Following Wang and Yao (2003) we assume their estimate of 26,609.67 billion Yuan as the initial real capital stock for 1977 at the national level. By multiplying this initial capital stock with the provincial weights we derive the initial capital stock for each province. To calculate the real capital stock we use a new investment deflator provided by Hsueh and Li (1999) for the period 1978-1995 combined with the price index for fixed asset investment for the period 1996-2004. Again we use the number of employed persons to calculate the real capital stock per labour unit.

**Population -** $POP_{i,t}$ :

$POP_{i,t}$ denotes the population in a province. The population data is obtained from the China Compendium of Statistics 1949-2004.

**Human capital -** $H_{i,t}$ :

Enrolment in higher education as log of the share in the total employed population is the proxy for human capital $H_{i,t}$. According to the Ministry of Education of the People's Republic of China, higher education in China has played a significant part in economic growth, scientific progress and social development in the country "by bringing up large scale of advanced talents and experts for the construction of socialist modernisation." This is also confirmed by our results when we use enrolment in secondary school instead of higher education. In this case the coefficient of human capital is not significant. We obtained the data from the China Compendium of Statistics 1949-2004.[30]

[30] Barro and Lee (2001) argue that enrolment rates do not adequately measure the aggregate stock of human capital available contemporaneously as an input to production and alternatively average years of schooling should be used. However, a multiplicity of empirical studies uses enrolment rates with plausible results supporting the validity of this variable. Since data on average years of schooling is available only on country and not on provincial level we decide to use enrolment rates as a proxy for human capital.

**FDI -** $FDI_{i,t}$ :

We use the log of foreign direct investment per employee as a measure for economic integration. Because FDI data is available only in Yuan, we transform the data into US Dollars using the national exchange rate for each year reported by the National Bureau of Statistics.

**Trade -** $T_{i,t}$ :

The second variable measuring economic integration is trade. It is the log of the sum of imports and exports taken from the China Compendium of Statistics 1949-2004 divided by the number of employed persons.

**Government spending -** $GOV1_{i,t}$, $GOV2_{i,t}$ :

Two variables can indicate the effect of government expenditure on economic growth. The first is local government general expenditure on administration ($GOV1_{i,t}$) and the second is local government general expenditure in culture, education, science and public health ($GOV2_{i,t}$), both as a share of GDP. Again, the source of the data is the China Compendium of Statistics 1949-2004.

**Agglomeration -** $POPKM2_{i,t}$ :

Agglomeration is not formally modelled in the above theoretical model. However, models introduced by New Economic Geography (NEG) emphasise the relevance of agglomeration for growth.[31] Population density, measured as the provincial population per square kilometre is used as a proxy for the degree of agglomeration in a province. The data are obtained from the China Compendium of Statistics 1949-2004.

**Urbanisation -** $URBAN_{i,t}$ :

Urbanisation is the second variable addressing the hypothesis of positive agglomeration effects on growth from NEG. Urbanisation is measured by the ratio of the urban employed

[31] The empirical literature on the New Economic Geography suggests many variables which could function as a proxy for agglomeration. We concentrate on population density and the share of urbanisation. Those measures are widely used and valid proxies for agglomeration (see Büttner, Schwager and Stegarescu 2004, Sala-i-Martin, Doppelhofer and Miller 2004, Brüllhart and Sbergarmi 2009).

**Table 2.1:** Descriptive statistics

| Variable | Obs | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| $\triangle y_{i,t}$ | 364 | 0.0359 | 0.0622 | -0.1621 | 0.2181 |
| $y_{i,t-1}$ | 364 | 9.0246 | 0.5205 | 7.8907 | 10.4600 |
| $\triangle K_{i,t}$ | 364 | 0.1017 | 0.0375 | -0.0667 | 0.3012 |
| $\triangle POP_{i,t}$ | 364 | 0.0094 | 0.0086 | -0.0197 | 0.1062 |
| $\triangle HC_{i,t}$ | 364 | 0.1293 | 0.1033 | -0.2676 | 0.6027 |
| $\triangle FDI_{i,t}$ | 364 | 0.2641 | 0.5691 | -1.6910 | 3.0636 |
| $\triangle T_{i,t}$ | 364 | 0.1769 | 0.2068 | -0.5755 | 0.7759 |
| $\triangle GOV1_{i,t}$ | 364 | 0.0157 | 0.1015 | -0.4567 | 0.4963 |
| $\triangle GOV2_{i,t}$ | 361 | 0.0024 | 0.0505 | -0.2993 | 0.2805 |
| $POPKM2_{i,t}$ | 392 | 359.3168 | 416.1426 | 6.5136 | 2253.983 |
| $URBAN_{i,t}$ | 383 | 0.3358 | 0.1700 | 0.1190 | 0.7993 |
| $\triangle MARKET_{i,t}$ | 196 | 0.0650 | 0.0674 | -0.0975 | 0.2959 |

population to the total population. The data were sourced from the China Compendium of Statistics 1949-2004.

**Quality of governance and institutions -** $MARKET_{i,t}$ :

To capture the effect of good governance and institutions, we use the NERI index of Marketisation for China's Provinces, newly published by the National Economic Research Institute (NERI) (Fan, Wang and Zhu 2007). This index measures five levels of institutional development using 23 indicators of institutional environments. Each indicator is valued by a score between zero and ten, with 2001 as the base year. A larger score indicates a higher level of institutional development. The five fields of the index are: 1. government-market relations, 2. the development of the non-state enterprise sectors, 3. the development of commodity markets, 4. the development of factor markets and 5. the development of market intermediaries and the legal framework (Wang, Fan and Zhu 2008).

## 2.5 Estimation results

The results of the estimates are summarised in Table 2.2, Table 2.3 and Table 2.4. Table 2.2 shows the results for the Arellano and Bond difference estimator reported as GMM-

**Table 2.2:** GMM growth regressions with FDI (1991-2004)

Dependent variable: $\triangle y_{i,t}$

| | GMM-DIFF | | GMM-SYS | |
|---|---|---|---|---|
| | coeff. | Std. Err. | coeff. | Std. Err. |
| $y_{i,t-1}$ | -0.186*** | (0.099) | -0.117*** | (0.000) |
| $\triangle K_{i,t}$ | 1.066*** | (0.359) | 0.744** | (0.302) |
| $\triangle POP_{i,t}$ | 0.832 | (1.443) | -0.019 | (1.375) |
| $\triangle HC_{i,t}$ | 0.377*** | (0.100) | 0.376*** | (0.120) |
| $\triangle FDI_{i,t}$ | 0.029** | (0.012) | 0.030** | (0.014) |
| $\triangle GOV1_{i,t}$ | -0.029 | (0.072) | -0.148 | (0.147) |
| $\triangle GOV2_{i,t}$ | -0.311*** | (0.100) | -0.244** | (0.123) |
| $POPKM2$ | -0.001 | (0.001) | 0.000 | (0.000) |
| $URBAN$ | -0.438 | (0.294) | -0.146 | (0.411) |
| m1 | 0.005 | | 0.001 | |
| m2 | 0.982 | | 0.853 | |
| Sargan | 0.524 | | 0.275 | |
| Obs | 299 | | 327 | |

Note: *, ** and *** denote significance at the 10%, 5% and 1% level.

DIFF and the Blundell and Bond system estimator denoted as GMM-SYS for the period 1991-2004. The estimates are based on the specified model in (2.62).[32]

Table 2.3 accordingly presents the results of the alternative specification in (2.63). We avoid including both FDI and trade in one model because of multicollinearity problems.[33] Finally, Table 2.4 shows the results of the model specification in (2.64). To verify GMM consistency, we have to make sure that the instruments are valid. We use the Sargan test of over-identifying restrictions to test the validity of the instrumental variables which is a general specification test. The null hypothesis assumes that the orthogonality conditions

[32] We calculate also the OLS and the FE estimates of the three models with FDI and trade. These are presented in Table A2.3. The results are largely consistent with the GMM results concerning the signs and the significance levels. In contrast to the dynamic estimation technique in the first and second model only the human capital coefficients shows a negative significant effect. Possible explanations for these differences are the omitted province specific effects, so we concentrate our interpretation on the GMM results. Additionally, we use the Hausman test to check for unobserved heterogeneity between the provinces. If the null hypothesis is significant, a simple OLS estimator is consistent and efficient, whereas the GMM estimator is consistent in all cases. For our model the null hypothesis is rejected so that the GMM estimation should be favoured.

[33] We also checked for multicollinearity of all other variables. Table A2.1 presents the correlation matrix of the variables and Table A2.2 shows the VIFs for all three models.

**Table 2.3:** GMM growth regressions with trade (1991-2004)

Dependent variable: $\triangle y_{i,t}$

| | GMM-DIFF | | GMM-SYS | |
|---|---|---|---|---|
| | coeff. | Std. Err. | coeff. | Std. Err. |
| $y_{i,t-1}$ | -0.221*** | (0.099) | -0.181*** | (0.000) |
| $\triangle K_{i,t}$ | 0.958*** | (0.172) | 0.746*** | (0.143) |
| $\triangle POP_{i,t}$ | 0.754 | (1.110) | 0.781 | (1.148) |
| $\triangle HC_{i,t}$ | 0.239** | (0.105) | 0.300*** | (0.095) |
| $\triangle T_{i,t}$ | 0.066*** | (0.023) | 0.048** | (0.019) |
| $\triangle GOV1_{i,t}$ | -0.045 | (0.095) | -0.172** | (0.078) |
| $\triangle GOV2_{i,t}$ | -0.185 | (0.117) | -0.141 | (0.130) |
| $POPKM2$ | -0.000 | (0.001) | 0.000 | (0.000) |
| $URBAN$ | 0.268 | (0.375) | 0.409 | (0.312) |
| m1 | 0.005 | | 0.002 | |
| m2 | 0.982 | | 0.896 | |
| Sargan | 0.524 | | 0.440 | |
| Obs | 299 | | 327 | |

Note: *, ** and *** denote significance at the 10%, 5% and 1% level.

of the instrumental variables are satisfied. In the case of the difference estimator the test indicates that the instruments appropriately do not correlate with the error term. The validity of lagged levels combined with lagged first differences is lower in both models while the p-values remain satisfactory.

Looking at Tables 2.2 and 2.3, most explanatory variables enter with the sign predicted from the model, except government expenditures and the proxies for agglomerations and urbanisation. Hence, the major findings of the estimates suggest that there are two sources for the Chinese growth process: external sources available due to international integration, and domestic sources:

1. *Development and international integration*

   - Controlling for other explanatory variables the coefficient for *lagged GDP per capita* is negative and significant. This result indicates a non-stationary process. Some sort of non-linear catching up or adjustment process seems to be char-

**Table 2.4:** GMM growth regressions with Marketisation (1991-2004)

Dependent variable: $\triangle y_{i,t}$

| | GMM-DIFF | | GMM-SYS | |
|---|---|---|---|---|
| | coeff. | Std. Err. | coeff. | Std. Err. |
| $y_{i,t-1}$ | -0.273** | (0.124) | -0.040** | (0.021) |
| $\triangle K_{i,t}$ | 0.921*** | (0.143) | 0.689*** | (0.167) |
| $\triangle POP_{i,t}$ | 0.462 | (0.345) | -0.090 | (0.559) |
| $\triangle HC_{i,t}$ | 0.055* | (0.035) | 0.137** | (0.055) |
| $\triangle T_{i,t}$ | 0.039* | (0.020) | 0.042* | (0.024) |
| $\triangle GOV1_{i,t}$ | -0.005 | (0.033) | -0.038 | (0.050) |
| $\triangle GOV2_{i,t}$ | -0.078 | (0.048) | -0.130* | (0.071) |
| $POPKM2$ | 0.000 | (0.000) | 0.000 | (0.000) |
| $URBAN$ | 0.149** | (0.071) | 0.094** | (0.043) |
| $\triangle MARKET$ | 0.088** | (0.040) | 0.141*** | (0.043) |
| m1 | 0.041 | | 0.015 | |
| m2 | 0.010 | | 0.085 | |
| Sargan | 0.997 | | 1.000 | |
| Obs | 166 | | 194 | |

Note: *, ** and *** denote significance at the 10%, 5% and 1% level.

acteristic for China's provinces. In other words, on the conditioning set of all other explanatory variables initially poorer provinces tend to have higher growth rates.[34] This finding is predicted by the model above. During the period of rapid catching up and non-stationary growth and non-linear temporary dynamic scale economies are additional driving forces of development. In the model this process is driven by technological imitation and spill-overs originally entering China through international integration.

- *Trade* is highly significant and shows a positive effect on growth. Learning to produce for the international market seems to be an important growth driving mechanism through international integration.

[34] To get a better impression of the relationship between growth and the lagged GDP per capita, we plot these variables for the whole panel as well as for each province. All scatter plots suggest a negative linear relationship between these variables which is consistent with our results. Additionally, we run a simple regression in logs to investigate a non-linear relationship however the results fell off in quality with regard to the significance level of the linear regression which is again an indication for a linear relationship. The results are available upon request.

- In the alternative model where *Foreign Direct Investment* is included instead of trade, we likewise see a positive significant effect at the 5% level. This result supports the underlying theory that FDI may create technology spill-over through imitation. At least part of the technological catching up process may be driven by international integration via FDI. In the theoretical model above FDI and exports are two sides of the same coin. However, introducing marketisation as a proxy for market oriented institutional arrangements and governance the picture becomes more complex. As FDI and marketisation are highly collinear, the sole technology spill-over from FDI does not seem to be the full story (see the discussion of marketisation below).

2. *Domestic sources of development*

- The coefficient for *physical capital* is significant and shows the strongest positive impact on output growth in absolute terms for both the GMM-DIFF and the GMM-SYS independent of whether FDI or trade are included in the model. This result indicates that the growth process in China is not only a phenomenon caused by foreign firms investing in a poor country. The growth process has strong and important domestic components. However, while the theoretical model does not address the origin of domestic capital in each province, this question seems crucial. If provincial real capital is accumulated via savings in each province there is no inter-provincial growth conflict. If the source of capital in successful provinces is an inter-provincial capital flow, these provinces may grow at the expense of other provinces. In this case, inter-provincial capital flows may be a source of growth but also of divergence.
- *Human capital* (measured in higher education enrolment) contributes positively and is highly significant. As expected this result suggests that better education at the higher level improves the process of industrialisation. Qualified workers with intermediate skill level have the ability to work in production plants with

high productivity. Hence, increasing human capital per capita affects economic output in the sense that it leads to higher productivity.

- In both models (GMM-DIFF and the GMM-SYS ) in Table 2.4 the coefficients of the *marketisation* proxy show positive significant effects on growth supporting the literature. The results suggest that good governance in a province is inextricably linked to its competitiveness and that the quality of institutions has a positive effect on economic growth. High collinearity of marketisation with FDI suggests that FDI are attracted by marketisation and a bundle of components consisting of good institutional conditions, FDI and the expansion of the domestic private sector drives growth.

3. *No significant sources of development*

    - In all cases *population* shows an insignificant effect.[35] Following the ideas of surplus labour introduced by Lewis (1954) this result is not surprising as long as China has not reached the Lewis turning point. In other words, as long as pure labour is not a growth restricting factor, China still seems to have a surplus of labour in the rural sector that can be added to the growth restricting factors as needed. Pure labour can be added to or withdrawn from a region without affecting output.

    - The coefficient for *government administration expenditure* and the *expenditures in culture, education, science and public health* shows, if anything, a significant negative impact on growth. With respect to the theoretical model this result suggests that we have an inefficient investment in this kind of government activities. From the theory and discussion above we know there are two potential explanations for this result: 1. Bad quality of governance and institutions may lead to a government spending as negative public good. That is, government

[35] Using employees instead of population leads to insignificant results as well.

arrangements and institutions do not promote the private sector, but deteriorate productivity growth. 2. Even if provincial governments may cause positive effects (government activities really decrease international transaction costs or help to improve technology spill-over from international technologies), if at the same time taxes become too high, potential positive effects are over-compensated and the financed government activities must be regarded as over-investment. Our findings suggest that there is an over-investment in certain fields of government spending. Government expenditure needs to be adjusted and optimised to drive the growth process more efficiently.

- Agglomeration can be measured by the degree of *urbanisation*. However, as for density, urbanisation measured as the ratio of the employed urban population to total population has no significant effect on growth in the estimations in Tables 2.2 and 2.3. These results suggest that agglomerations do not seem to generate the growth driving positive externalities sometimes proposed.[36] The result is also supported by the coefficient for population density. However, when marketisation is included, urbanisation becomes highly significant suggesting that agglomerations are an own ingredient for growth. We believe that this change may be due to the very broad construction of the marketisation index having many interactions with other variables.

To sum up the empirical findings: We show that based on the theoretical model all three kinds of capital, namely domestic physical capital, human capital and foreign capital, enter positively and significantly. To a large extent, these factors are responsible for the development of China's provinces and hence of China as a whole. With regard to the tremendous success story of the coastal belt during the sample period the hypothesis that international integration has had an enormous effect is supported by the positive effect of

[36] To account for a possible non-linear effect of urbanisation on growth we run additional regressions with an additional quadratic term of urbanisation. However, the results for the original and the quadratic variable are not significant.

FDI and trade. However, we also identify a group of variables that has no or even a negative effect on growth - these include population, government expenditure and the proxies for agglomeration and urbanisation. These two surprising results contradict the NEG. They propose that pure agglomeration and urbanisation do not favour economic growth, and they emphasise the importance of fundamental production factors such as domestic, foreign and human capital. Since we included these factors in our analysis, there is no additional effect that could come from pure agglomeration or urbanisation. Finally, we identify a positive significant coefficient of marketisation indicating that good governance exhibit a beneficial effect on the development process.

## 2.6 Summary and conclusion

In the last decade the People's Republic of China experienced a very impressive development. However, the country is characterised by increasing inequality. To ensure that China's successful development can be maintained, it seems important to identify the determinants of provincial success.

To address this question we introduce a stylised model of regional development. Growth and development is driven by two sources. 1. International integration indicated by FDI and trade promotes imitation from international technologies and leads to a technological upgrading of a region. 2. The domestic capital endowment in terms of real and human capital and government investments into growth relevant infrastructure represent domestic sources of growth.

Using panel data analysis and GMM estimation, our empirical analysis supports the predictions of our theoretical model of growth. International integration indicated by foreign direct investment and trade is significant and shows the predicted positive effects on growth. This result supports the underlying theory that these factors create technology spill-over effects and promote productivity growth. Controlling for other explanatory variables we find a non-stationary and non-linear adjustment process across China's provinces, which suggests that poorer provinces are catching up. The domestic capital endowment in terms of real and human capital enters with the expected positive signs, verifying the importance of these production factors and suggesting that a better educated population affects economic output through higher productivity.

However, other factors also expected to contribute positively to development such as government expenditure and labour, do not promote growth. According to the theory the negative effect of government expenditure can be regarded as bad quality of institutions or an over-investment in certain fields of government activities. The insignificant labour effect supports Lewis' idea of surplus labour, and suggests that China has not yet reached the Lewis turning point.

According to NEG, agglomerations and urbanisation are factors driving growth. Although not included in the theoretical model, we approximate these factors to examine their importance. However, the results of these two variables are not stable in the different models. Finally, when extending the model by a proxy for the quality of governance and institutions using an unbalanced panel we identify a positive effect of good governance and institutions on the development process.

# Chapter 3

# China's provincial disparities and the determinants of provincial inequality

*This chapter results from the paper "China's provincial disparities and the determinants of provincial inequality" by Gries, T. and Redlin, M. published in the Journal of Chinese Economic and Business Studies in 2009.*

## 3.1 Introduction

Regional disparity[1] is a clearly identified problem in China's development. In the current period of increasing regional disparity, which began in the late 1970s,[2] various determinants of increasing provincial inequality[3] have been discussed. With the economic reforms and the "Open Door Policy" introduced about three decades ago, preferential policy[4] and geographic advantages of the coastal region[5] reduced international transaction costs for exports and international investors.[6] For the period 1978 to 1993 Chen and Fleisher (1996) found evidence of regional convergence conditional e.g. on coastal location and FDI. How-

[1] Milanovic (2005) distinguishes two different concepts of regional inequality. The first considers the disparity of regional income averages, while the second refers to the issue of overall income inequality among citizens within a nation.

[2] Kanbur and Zhang (2005) identified a structural break in their time series data in 1979.

[3] Analysing the economic development of the coast, the interior and the rural and urban provinces Kanbur and Zhang (2005), Huang, Kuo and Kao (2003), Li and Zhao (1999) and Wan (1998) find statistical evidence of increasing provincial disparities. A major finding in the literature is that inequality measured e.g. by sigma convergence has increased in past decades (Chen and Fleisher 1996, Jian, Sachs and Warner 1996, Zhang, Liu and Yao 2001, Wang 2003 and Yao and Zhang 2001b).

[4] See Démurger et al. (2002).

[5] Bao et al. (2002) point out that geography, translating into international transaction costs, is responsible for a significant part of the success story.

[6] See Wei (2000).

ever, disparities between coastal areas and the hinterland seemed to increase.[7] Since 1992 the experiment of trade and FDI facilitating deregulation has been extended to other locations. Again, the most important of the now privileged regions are located along the coast. International integration seems to be a major determinant of successful development and a driving force of regional disparity.[8] "Export and FDI have been causing the Chinese economy to grow faster, while at the same time the highly uneven distribution of trade and FDI has caused regional disparity to increase greatly" (Fujita and Hu, 2001, p. 31).

While this view is widespread, few papers directly address the determinants of disparity. Tsui (2007) examines five decades of provincial development, ending 1999. Using a decomposition method the provincial GDP per capita growth differential is decomposed into contributions by total factor productivity (TFP) and other factor inputs. The increase in inequality from the mid 1960s to the mid 1970s is due to the contribution of TFP which dominates that of physical capital. The opposite is true for the 1980s. The increase in the 1990s is mainly driven by the distribution of investments in favour of the coastal provinces and is reinforced by the contribution of TFP. The other study that methodologically and explicitly addresses disparity is Wan, Lu and Chen (2007). It discusses China's process of international integration. Among other things, the income generating estimation incorporates trade and FDI variables. Using these estimation results the authors apply the Shapley value decomposition technique to quantify the contributions of globalisation to regional disparity. They find that internationalisation, domestic capital and reforms contribute substantially to regional inequality. Other, much smaller contributions come from education, location and urbanisation.

In this paper we pick up the idea of directly addressing the phenomenon of disparity. We suggest a direct explanation of provincial disparity measured by the per capita income Theil index. Therefore, in our estimation we directly relate income disparity (indicated by

[7] See also Wen (2003) who found industrial clustering and a high geographic concentration of industries in several coastal regions. Cumulative causation in this process of industrial concentration is emphasised by Golley (2002).

[8] Wang and Ge (2004) discover that the regional disparities between the eastern region and the rest of China are widening, while regional disparity between central and western China is shrinking.

the contribution to the per capita income Theil index) to the disparity of selected income determining factors (indicated by the contribution to every other Theil index of the determinants). In other words, we estimate whether the disparity (Theil index contribution) of an income determining provincial variable positively or negatively contributes to the disparity of per capita income measured by the Theil index.

To obtain a general impression of disparity in China and the provincial contribution to this inequality, we calculate the Theil index and focus on the composition of this index. As a first step we show the development of the total Theil index and the contributions of the most important provinces to disparity.

The Theil index is defined as

$$T = \frac{1}{n}\sum_{i=1}^{n}(\frac{x_i}{\overline{x}} \ln \frac{x_i}{\overline{x}}), \tag{3.1}$$

where $x_i$ is the GDP per capita of province $i$, $\overline{x}$ is the mean income, and $n$ is the number of provinces. Figure 3·1 presents the results for the post-reform period from 1978 to 2004. Starting with a value of 0.19 in 1978 the Theil index fell below 0.15 in 1990. At this point the picture changed, inequality increased consistently and reached 0.17 in 2004. Hence, the post-reform period can be divided into two sub-periods: 1) the period from 1978 to 1990 where inequality decreased, and 2) the period since 1990 where inequality has increased. Furthermore, the overall Theil index is broken down by the provinces' contributions which are defined as

$$T_i = \frac{1}{n}(\frac{x_i}{\overline{x}} \ln \frac{x_i}{\overline{x}}). \tag{3.2}$$

The composition reveals that not all provinces contribute to the country's inequality to the same degree. In Figure 3·1 we present only the seven provinces with the highest contribution to the Theil index, as all other provinces have a contribution that is lower than 0.02 or even negative.

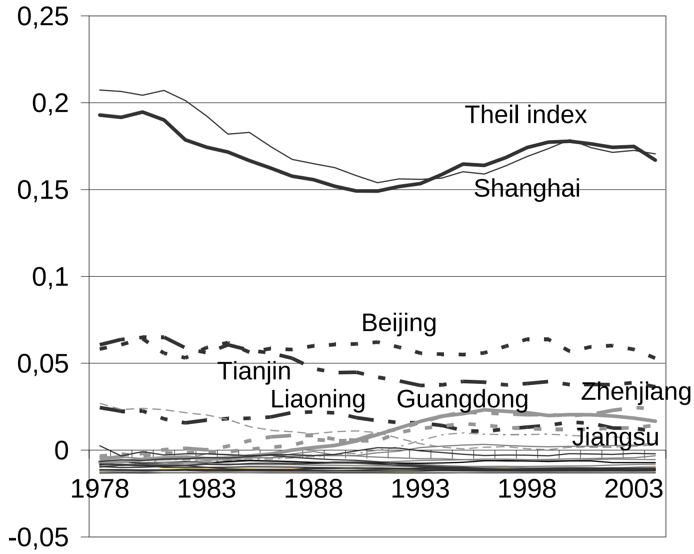


**Figure 3·1:** China's Theil index and its provincial contributions

Figure 3·2 presents a map with the provincial contribution to the Theil index for 2004. Especially the eastern provinces, and here in particular Shanghai, strongly inflate the Theil index to a high degree, while the central and western provinces have only a minor impact. This indicates that inter-provincial inequality in China is driven mainly by a few prosperous provinces.

This picture is confirmed if we analyse the inequality contribution of China's eastern, central and western regions.[9] We decompose the Theil index accounting for the weighted average of inequality within the three regions, plus inequality between these regions. The decomposed Theil index is defined as

$$T = \sum_{k=1}^{m} s_k T_k + \sum_{k=1}^{m} s_k \ln \frac{\overline{x_k}}{\overline{x}}, \tag{3.3}$$

[9] The provinces Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Guangxi are referred as eastern provinces. Shanxi, Jilin, Heilongjiang, Anhui, Jiagxi, Henan, Hubei, Hunan and Inner Mongolia belong to the central region. Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang are the western provinces. See also Figure A1.1.

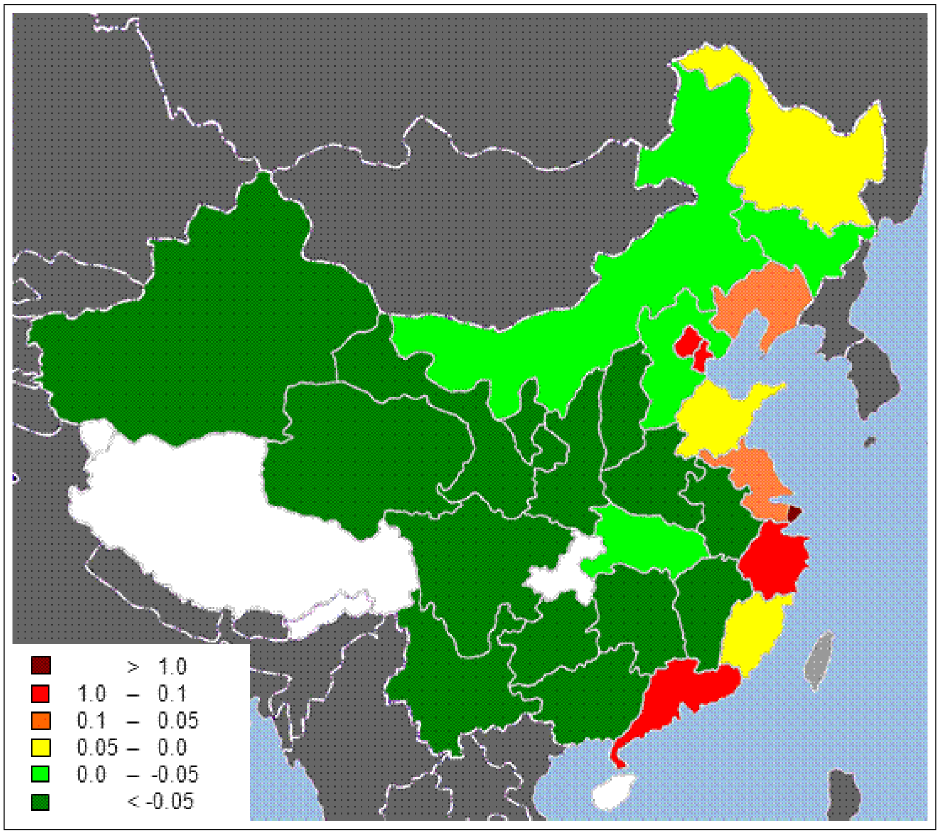


**Figure 3·2:** Provincial Theil index contribution (2004) where the country is divided in $m$ regions and $s_k$ is the income share of region $k$, $T_k$ is the Theil index for that region, and $\overline{x_k}$ is the average income in region $k$.

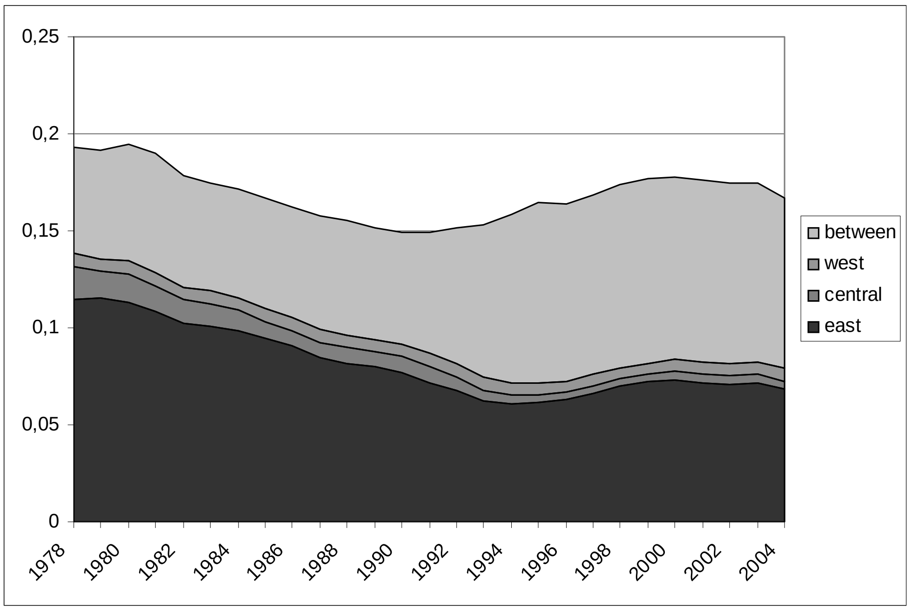


**Figure 3·3:** Decomposition of China's Theil index

Figure 3·3 presents the decomposition of the regional Theil index. The three regions do not contribute to the country's inequality to the same degree. The inequality within the western region and the central region has only a slight impact. In particular, the inequality within the eastern region and between the three regions is what drives the Theil index.[10] In other words, the disparity between east, central and west, and also to a large extent the disparity between the eastern provinces (within east) is most important. Again, provincial disparity measured by the Theil index is a phenomenon caused by a handful of rich provinces. Inequality is mainly caused by the rich eastern provinces, in particular by the within effect of the eastern provinces.

[10]Figures A3·1, A3·2 and A3·3 in the Appendix show the regional Theil indices for the eastern, central and western provinces with the provincial contribution. The Theil index of the eastern region reveals much higher inequality than in the central and western region.

Therefore, the main goal of this paper is to explain provincial disparity in China. The focus is not on the income and growth process itself; rather, the process leading to disparity is the phenomenon the paper seeks to understand. As a theoretical approach we introduce a two-region model of development where a change in international transaction costs will trigger disparity accelerating growth with two mutually dependent processes. First, additional trade or FDI and positive externalities in one province will accelerate relative technological growth in that province. Second, there is arbitrage of domestic capital towards the faster growing province. As an inflow of domestic capital and faster imitation and growth of technologies are mutually favourable, an agglomerating process is initiated. International and inter-regional factor mobility reinforces disparity. They are positive in one province and negative in the other. Local policies not only affect the province itself. Factor mobility, both international and interprovincial, will clearly have additional effects on all provinces and on provincial disparity. Generally, disparities in provincial income are caused by disparities in income determining factors.

While in the standard income and growth regression only the existence of a slope between the dependent and independent variable is important, explaining disparity requires additional information. As disparity measured in distances is the aim, the distance from the mean must be included in the measurement concept. The Theil concept fulfils this requirement. The decomposition of the overall Theil index which identifies the share attributable to the between-region component becomes a helpful tool for the analysis of regional inequality as it suggests the relative importance of spatial dimension of inequality (Novotny 2007). Therefore, we suggest a direct explanation of provincial disparity measured by the per capita income Theil index. In our estimation we directly relate income disparity (indicated by the contribution to the per capita income Theil index) to the disparity of selected income determining factors (indicated by the contribution to every other Theil index of the determinants). In other words, we estimate whether the disparity (Theil index contribution) of an income determining provincial variable positively or negatively contributes to the disparity of per capita income measured by the Theil index. We apply a fixed effects panel estimation to identify the determinants of inequality for 28 Chinese provinces over the period 1991-2004.

## 3.2 A model of provincial development and disparity

In a developing region, international spill-over and externalities through FDI and trade and infrastructure are relevant determinants of growth and development.[11] Taking these externalities and international spill-over as the starting point, we develop, in effect, a neoclassical model of growth for a single backward province. Externalities will lead to temporary dynamic scale economies and drive the technical imitation process. The dynamics of the model are not driven by accumulation but by technological catching up and imitation. The model is taken from Gries and Redlin (2011)[12] and is stylised and simplified in such a way that a province can be modelled with three equations.

### 3.2.1 Final output

Final output of a province $i$ uses human capital $H_i$, international capital flowing into the province as FDI $\mathcal{F}_i$ and domestic real capital $K_i$ to produce a homogeneous final good. Domestic capital and international capital are supposed to be different. As in a *Lewis Economy,* labour is not a growth restricting factor, and the Lewis turning point has not yet been reached. Hence, $H_i$, $K_i$ and $\mathcal{F}_i$ can be regarded as the respective capital per unit of labour. Based on the small economy assumption and the integration of provincial final product markets into world markets, the per capita production of the final good $y_i$ can be defined as Findlay's *foreign exchange production function.*[13] $y_i$ is a production value function measured in international prices. Each value of output indicates a full specialisation in the industry characterised by the corresponding factor intensity. Inflowing international capital $\mathcal{F}_i$ is fully depreciated during the period of influx. Production of the

[11] See e.g. Fujita and Thisse (2002, ch. 11), or Kelly and Hageman (1999).
[12] See Chapter 2.2.
[13] See Findlay (1973, 1984).

final product takes place under constant economies of scale and perfect competition and is described by

$$\begin{aligned} y_i &= A_i H_i^{\alpha} \mathcal{F}_i^{\beta} K_i^{1-\alpha-\beta}, \qquad (3.4) \\ with \quad A_i &= \omega_i A. \end{aligned}$$

In (3.4) $A_i$ measures the level of technology in province $i$, and $\omega_i$ is the province's relative technological position compared to the technology leader $A$ which increases at a given rate $n$. The domestic output is used for domestic consumption, exports, and government expenditures which is the fraction $\gamma_i$ of GDP.

### 3.2.2 FDI inflow and exports

Optimal capital inflows are determined by the firm's optimal factor demand. Due to the small economy assumption, capital costs of international capital are determined by an exogenous world market interest factor $r$ and an ad valorem factor for international transaction costs $\tau_i$ which is specific to each province. $\tau_i^{ex}$ is a transaction cost parameter for exports. $\tau_i$ and $\tau_i^{ex}$ are modelled as iceberg costs on exports. Returns on international capital investments in a province will be fully repatriated, while exports $Ex_i$ must earn international interest rates and all international transaction costs. On the firm or provincial level each province needs to export a corresponding value to cover international capital costs connected to the province's FDI $Ex_i^{\mathcal{F}}(1-\tau_i^{ex}) = \tau_i r \mathcal{F}_i$. Solving the firms' optimisation problem[14] we obtain the required influx of foreign capital

$$\mathcal{F}_i = \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} y_i \qquad (3.5)$$

and as a fraction $\varphi_i$ of GDP

$$\varphi_i = \frac{\mathcal{F}_i}{y_i} = \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}.$$

[14] The firm has to determine optimal factor inputs by maximising profits.

To simplify, international borrowing or lending beyond FDI is excluded. We also assume that foreign exchange reserves are not transferred between provinces. Therefore, international capital costs have to be covered by provincial exports. Additional exports are required to finance imports of the province. Imports for consumption purposes are determined by a standard household decision problem.[15]

$$\frac{Ex_i}{y_i} = \varepsilon_i = (1-\lambda)\left[1-(1-\tau_i^{ex})\beta\right](1-\gamma_i) \tag{3.6}$$

whereas the export share of GDP is simply determined by the elasticity of production of foreign capital $\beta$ and the tax rate $\gamma_i$ (3.5). Including optimal capital inflows in the production function leads to the production level

$$Y_i = \omega_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)_i^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}, \qquad Y_i = \frac{y_i}{A^{\frac{1}{1-\beta}}}. \tag{3.7}$$

As we do not intend to consider scale effects from technological leaders, production is now normalised for the international technology level.[16] Therefore, production is determined by provincial factor endowments and the relative technology position of the province compared with the technological leader $\omega_i$.

### 3.2.3 Technology and imitation

The developing province acquires technologies by imitating foreign designs from international technology leaders. International knowledge spill-over and positive technological externalities from the influx of FDI are included at a macro level of modelling. In order to make spill-over from FDI effective for the host province, a technology and firm-relevant public infrastructure must exist. As the focus lies on underdeveloped provinces the case

[15] The households decision problem is described as:

$$\begin{aligned} \max \quad &: \quad U = C^{\lambda}\,\mathrm{Im}^{1-\lambda}, \\ s.t. \quad &: \quad 0 = y(1-\gamma_i) - \tau_i r \mathcal{F}_i - C_i - p_i(1-\tau_i^{ex})\,\mathrm{Im}_i \end{aligned}$$

For the solution see Appendix A3.2.

[16] $Y_i = y_i A^{-1/(1-\beta)}$, see also Appendix A3.1.

of innovations in this backward province is excluded. The imitation process is affected by the technology gap $(1-\omega)$ between the backward province and the industrialised world. If the domestic stock of technology is low ($\omega$ is small), it is relatively easy to improve the technology by imitating foreign designs. However, the process becomes increasingly difficult as the technology gap narrows.

The endogenous process of imitation and participation in worldwide technical progress is determined by pure externalities from FDI or trade indicated by exports and from domestic government investments in the ability to imitate and improve productivity.[17] Externalities in the imitation process generate temporary dynamic scale economies. We focus on the technical externalities from factors of production and the resulting transitory dynamic scale economies[18]

$$\dot{\omega}_i(t) = G(t)_i^{\delta_G} F(t)_i^{\delta_F} Ex(t)_i^{\delta_{Ex}} - \omega(t). \tag{3.8}$$

The externalities from FDI $F(t)$ or exports $Ex(t)$, and government infrastructure $G(t)$ are assumed to have a rather limited effect on imitation such that $\delta_G + \delta_F + \delta_{Ex} = \delta < 1$ and $\delta$ is small.

As we abstract from government borrowing or lending and interprovincial transfers, government expenditures are restricted by tax income. Therefore, the government budget constraint is

$$G_i = \gamma_i y_i, \qquad Ex_i = \varepsilon_i y_i. \tag{3.9}$$

Equations (3.4), (3.5), and (3.8) capture the model of provincial development for one province. The solution to equations (3.4), (3.5), and (3.8) is a differential equation determining the growth of the relative stock of technology available to the province (catching

[17] As we would like to exclude pure scale effects from technical progress of the technical leader $F(t)_i$ and $G(t)_i$ and $Ex_i$ are normalised values transformed by an international technology index factor $A(t)^{1/(1-\beta)}$, and $A$ is growing at a given constant rate $n$. See also Appendix A3.1.

[18] For the dynamic catching up spill-over equation we assume that $G$ and $\mathcal{F}$ and $Ex$ are sufficiently large for positive upgrading.

up in technology) during the period of transition to the steady state.[19] The economy can realise temporary dynamic scale economies during this catching up and adjustment period. While $\dot{\omega}_i(t)$ is positive during transition, it converges to zero when approaching the steady state path. Equation (3.10) suggests a decreasing speed of growth with a rising income level as a result of increasing difficulties in the imitation process[20]

$$\dot{\omega}_i(t) = \gamma_i^{\delta_G} \varphi_i^{\left(\delta_F + \frac{\beta}{1-\beta}\right)} \varepsilon_i^{\delta_G} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t), \quad \text{with} \quad \frac{d\dot{\omega}_i(t)}{d\omega(t)} < 0. \quad (3.10)$$

Not only the speed of technological catching up $\dot{\omega}_i(t)$ is determined by the factor endowments $K_i$, $H_i$ and the fractions $\gamma_i$ and $\varphi_i$. For each endowment we can determine the steady state position $\omega_i^*$ of the province. For $\dot{\omega}_i(t) = 0$[21] we obtain

$$\omega^* = \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} \varphi_i^{\frac{\delta_F(1-\beta)+\delta\beta}{(1-\beta-\delta)}} \varepsilon_i^{\delta_G} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \quad (3.11)$$

$$\text{with} \quad \Psi_i := \gamma_i^{\delta_G} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \varepsilon_i^{\delta_{Ex}}. \quad (3.12)$$

$$\frac{\partial \omega_i^*}{\partial K_i} = \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega^* K_i^{-1} > 0, \quad \frac{\partial \omega_i^*}{\partial H_i} = \frac{\delta\alpha}{1-\beta-\delta} \omega^* H_i^{-1} > 0, \quad (3.13)$$

$$\frac{\partial \omega_i^*}{\partial \tau_i} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[ \delta_F + \frac{\beta}{1-\beta}\delta \right] \tau_i^{-1} < 0, \quad \textit{FDI effect} \quad (3.14)$$

$$\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} = -\frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[ \delta_F + \frac{\beta}{1-\beta}\delta \right] (1-\tau_i^{ex})^{-1} < 0, \quad \textit{trade effect} \quad (3.15)$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[ \delta_G \gamma_i^{-1} - \left( \delta_F + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right] \gtreqless 0. \quad (3.16)$$

The essential determinants of the speed of convergence and the final relative convergence position are the endowment of capital $K_i$ and human capital $H_i$, technology relevant government expenditure indicated by $\gamma_i$, and international (and domestic) transaction costs

[19] See Appendix A3.3.

[20] The dynamic catching up spill-over equation contains a scaling problem if $H$ and $K$ are taken as absolute values. As the region is assumed to remain backward, the values of $\gamma$, $\varphi$, $H$ and $K$ are assumed to be sufficiently small. See Appendix A3.3 for the derivatives.

[21] We assume that the contribution of FDI to production $\beta$ as well as the externality effect of FDI on technology $\delta$ are sufficiently small. This also reflects the already mentioned assumption of a rather limited spill-over effect of FDI on the relative catching up process.

connected to exports $\tau_i^{ex}$ and FDI $\tau_i$ and hence the share of FDI $\varphi_i$.

## 3.3 Two provinces and provincial equilibrium

To analyse interprovincial factor mobility and the effects on provincial disparity, we need to look at two provinces $i = 1, 2$ in a country. Both provinces have a local immobile factor (human capital) and a mobile factor (domestic real capital).

$$K = K_1(t) + K_2(t), \qquad \frac{dK_2}{dK_1} = -1 < 0. \tag{3.17}$$

The mobility of domestic factors between provinces represents a shift of resources.

As there is an interaction between the development position of a province and the allocation of domestic capital, two conditions, the final development condition and the equilibrium condition for the domestic capital market (interest parity condition), have to be considered.

### 3.3.1 Relative regional development

From equation (3.11) we know that $\omega_i^*$ is the steady state position of each province. The relative steady state position for the two provinces for a given endowment is[22]

[22]See Appendix A3.4.

$$\begin{aligned} \lim_{K_1 \to 0} \Omega^D &= 0, \quad \lim_{K_1 \to o} \frac{d\Omega^D}{dK_1} = \infty, \lim_{K_1 \to K} \Omega^D = \infty, \quad \lim_{K_1 \to N} \frac{d\Omega^D}{dK_1} = \infty \\ \Omega^D_{|K_1 = K_2} &= 1, \quad \frac{d\Omega^D}{dK_1}_{|K_1=K_2} = 2\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} H_1^{-\frac{\alpha}{1-\beta}} K_1^{-1} > 0, \end{aligned}$$

for identical regions see Appendix A3.5.

$$\Omega^D = \frac{\omega_1^*}{\omega_2^*} = \left(\frac{A_1}{A_2}\right)^* = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \tag{3.18}$$

$$\frac{d\Omega^D}{dK_1} > 0, \quad \frac{d\Omega^D}{d\tau_1} < 0, \quad \frac{d\Omega^D}{d\tau_1^{ex}} < 0, \quad \text{and} \quad \frac{d\Omega^D}{d\gamma_1} < 0 \ \text{ for } \ \gamma_1 > \gamma_1^*.$$

This condition is referred to as the *final development condition.* The final development condition identifies the relative technological position of a province compared to the other province in steady state. In general, this relative final position depends on all parameters of $\varphi_i$ (see equation (3.12)) and in particular on the allocation of the mobile factor $K$ to the two provinces. Depending on $K$ the final development condition can be drawn as the *final development curve* $\Omega^D$ in the $K_1 - \Omega$ diagram (Figure 3·4).

Dynamic adjustment can be directly derived from the equation of motion for each single province. Denoting $a_i$ as the distance of the province's present position relative to the steady state position ($a_i = \omega_i(t)/\omega_i^*$), the dynamics are given by

$$\Omega(t) = \frac{A_1(t)}{A_2(t)} \implies \frac{\dot{\Omega}}{\Omega} = \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \tag{3.19}$$

$$\frac{\dot{\Omega}(t)}{\Omega(t)} = a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \ \text{ for } \Omega(t) > \Omega^D.$$

For $a_1 > a_2$ the present position of the two provinces $\Omega$ is above[23] the final development curve $\Omega^D$ in Figure 3·4. As we can see from equation (3.19) $\Omega$ decreases ($\frac{\dot{\Omega}}{\Omega} < 0$).[24]

[23] $\Omega = \frac{\omega_1(t)}{\omega_2(t)} = \frac{a_1\omega_1^*}{a_2\omega_2^*} = \frac{a_1}{a_2}\Omega^D$.

[24] See Appendix A3.6.

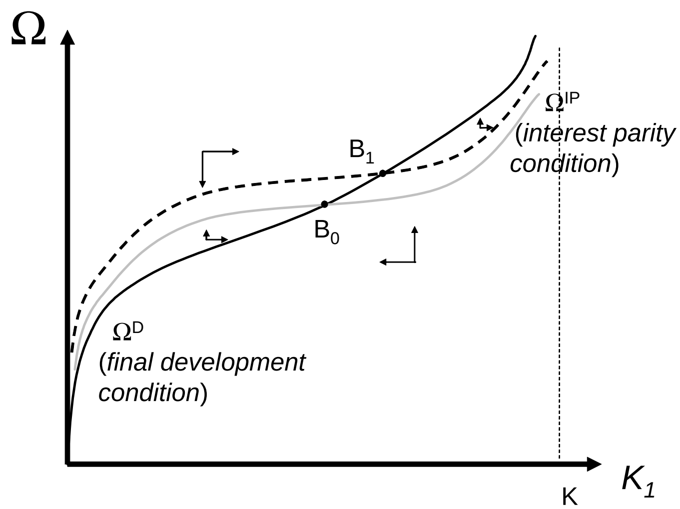


**Figure 3·4:** Steady state and dynamics

### 3.3.2 Regional factor mobility

In this model, domestic capital is the only mobile factor between provinces. As we assume perfect competition in the final goods market, domestic interest rates $i_i$ for domestic capital in each province $i$ are determined by marginal productivity[25]

$$i_i = \frac{1-\beta-\alpha}{1-\beta}\left(1-\gamma_i\right)A_i^{\frac{1}{1-\beta}}H_i^{\frac{\alpha}{1-\beta}}\left(\frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}}K_i^{\frac{-\alpha}{1-\beta}}. \tag{3.20}$$

The arbitrage process is not perfect; adjustment takes time. Gradual adjustment to interest parity translates into an imperfect arbitrage function

$$\dot{K}_1(t) = m(\frac{i_1}{i_2} - 1). \tag{3.21}$$

In a no-arbitrage equilibrium $\dot{K}_1(t) = 0$. For capital markets the assumption of a gradually adjusting capital allocation seems rather odd. In a fully developed market econ-

[25] See Appendix A3.8.

omy with a well-functioning financial system, capital allocation would enter the model by perfect and permanent interest arbitrage. However, China is a transition economy with less-developed financial institutions, where many financial activities take place directly between firms. Even more, capital allocation may also be to some extent under government control. Hence, given that capital allocation is not completely driven by non-economic considerations, differentials in return to capital should imperfectly and gradually direct the allocation of capital. Therefore, a gradual adjustment of capital allocation seems the appropriate way to capture the imperfectness of capital markets. Even in the long run we may think of non-perfect interest arbitrage such that certain conditions prevent identical returns on capital ($i_1/i_2 = \vartheta$). However, for the sake of simplicity we do not consider this potentially long-term differential and state that the potential interest parity equilibrium is characterised by the interest parity condition

$$\frac{i_1}{i_2} = 1. \tag{3.22}$$

Further, as a matter of fact, concentration of capital in some provinces may also reflect a high rate of capital accumulation in these provinces. However, as long as market forces dominate, accumulated capital will be allocated to the province with the highest return, no matter where the accumulation took place. The location of accumulation becomes less important for the eventual use of capital. In China, both driving forces behind a concentration of capital, accumulation (because of high income) and allocation (because of high productivity and high returns), seem to coincide. In this model we would like to focus on disparity driving forces. Hence, mutual dependencies and competition for resources are expected to be a major reason for disparity. An accumulated mobile resource at one location will only have a major impact on the respective regional development if the region is attractive enough to keep the resource at the location of original accumulation. Therefore, we do not model the accumulation process as the most important factor determining the relative concentration of resources. In a world with mobile resources we expect the highest return to dominate the provincial concentration of capital.

However, from condition (3.22) we can derive a curve describing all *interest parity* positions of relative technological upgrading $\Omega^{IP}$.[26]

$$\Omega^{IP} = \frac{\omega_1}{\omega_2} = \frac{A_1}{A_2} = \frac{(1-\gamma_2)^{1-\beta} H_2^{\alpha} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_2^{-\alpha}}{(1-\gamma_1)^{1-\beta} H_1^{\alpha} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_1^{-\alpha}} \tag{3.23}$$

$$\frac{d\Omega^{IP}}{dK_1} > 0 \quad \text{for identical provinces,} \quad \frac{d\Omega^{IP}}{dK_1} \lesseqgtr 0 \quad \text{in general,}$$

$$\frac{d\Omega^{IP}}{d\tau_1} > 0, \quad \frac{d\Omega^{IP}}{d\tau_1^{ex}} > 0, \quad \frac{d\Omega^{IP}}{d\gamma_1} > 0.$$

We refer to this condition as the *interest parity curve.* The *interest parity curve*[27] is also drawn in Figure 3·4. $\Omega^{IP}$ intersects the origin with an infinite positive slope. With increasing $K_1$ the slope starts positively, may become negative and eventually turns positive such that $\Omega^{IP}$ becomes infinite when $K_1$ approaches $K$ [$\lim_{K_1 \to K} \Omega^{IP} = \infty$].[28]

Dynamic adjustment is shown in Figure 3·4. If at a given endowment $K_1$ in province 1 relative productivity is presently smaller than required by the *interest parity* condition, domestic capital will move away from province 1 and $K_1$ will decrease. Therefore, at any point below the $\Omega^{IP}$ curve, domestic capital will flow out of province 1. This process is indicated by the horizontal arrows in Figure 3·4.

### 3.3.3 Steady state

When both provinces are identical,[29] there must be at least one equilibrium. Using the implicit function theorem we obtain an equilibrium for the steady state of the relative technology position $\Omega_{ij}^{*} = \omega_1^{*}/\omega_1^{*}$

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[26] For the derivative $\frac{d\Omega^M}{dK_1}$ see Appendix A3.8.

[27] For the reactions of the *interest parity curve* see Appendix A3.10.

[28] The properties of the *no-migration curve* are given by $\lim_{K_1 \to 0} \Omega^M = 0$, $\lim_{K_1 \to 0} \frac{d\Omega^M}{dK_1} = \infty$, $\lim_{K_1 \to K} \Omega^M = \infty$, $\lim_{K_1 \to N} \frac{d\Omega^M}{dK_1} = \infty$. See also Appendix A3.8.

[29] For identical regions all parameters and factor endowments (including $K_1 = K_2$) are identical.

$$\Omega_{ij}^* = \Omega_{ij}^* \left( \frac{H_i}{H_j}, \frac{K_i}{K_j}, ... \right). \tag{3.24}$$

At point B in Figure 3·4 the two provinces are identical since $K_1 = K_2$ and we consider a stable case. For stability, the slope of the *final development curve* must be flatter than the slope of the *interest parity curve*. The corresponding condition is[30]

$$\frac{d\Omega^D}{dK_1} < \frac{d\Omega^{IP}}{dK_1} \quad \text{that is if} \quad \delta < \alpha. \tag{3.25}$$

## 3.4 Endogenous provincial disparity

### 3.4.1 Preferential policies and international integration

For two provinces, the effects of preferential policy for provincial disparity can be analysed. Many local conditions, including bureaucratic policies, act like non-tariff trade barriers. If a province reduces international transaction and information costs, it may be able to generate a decisive advantage over other provinces. A non-symmetrical reduction in international transaction costs via preferential policy can be translated into the model by $d\tau_1 < 0$ or $d\tau_1^{ex} < 0$. As a result, the *final development curve* $\Omega^D$ in Figure 3·4 shifts upward (see equation(3.18)) and the *interest parity curve* $\Omega^{IP}$ shifts downward (see equation (3.23)).[31] Starting from the original equilibrium point $B_0$, the two provinces will move towards the new equilibrium point $B_1$. The existence of a number of stable inner solutions allows for conditional convergence of provinces. Starting from $B_0$ we find a stable provincial adjustment process.

The economic process is quite simple to describe. The change in international transaction costs will trigger accelerating growth with two mutually dependent processes. First,

[30] See Appendix A3.11.

[31] In this figure $\Omega^D$ shifts upwards and $\Omega^{IP}$ shifts downwards. In order to keep the figure simple, we draw the relative shift of the two curves instead of shifting both curves at the same time.

additional trade or FDI and positive externalities in one province will accelerate relative technological growth in this province. Second, there is arbitrage of domestic capital towards the faster growing province. As an inflow of domestic capital and faster imitation and growth of technologies are mutually favourable, an agglomerating process is initiated. The internationally more integrated province with more inflows of FDI and exports will strongly improve its relative steady state position.

### 3.4.2 Factor mobility, agglomeration and disparity

Since arbitrage and agglomeration determine all other reactions, we start by analysing the shift of domestic capital in province 1[32]

$$\frac{dK_1}{d\tau_1} < 0, \quad \frac{dK_1}{d\tau_1^{ex}} < 0.$$

In province 1, access to domestic capital will grow, while province 2 faces a reduction and shrinks. Decreasing international transaction costs and better access to international technologies in province 1 will increase technology growth and trigger agglomeration advantages for this province. Faster imitation increases productivity growth and an interest gap between the provinces opens up. As domestic capital moves between the two provinces, domestic capital migrates to the high-productivity and high-interest province. Inflowing capital and the resulting additional technological growth will drive a process of both acceleration and agglomeration. In this process, the success of one province is driven at the expense of the other since one province absorbs domestic capital from the other to feed agglomeration. Technological acceleration endogenously terminates when imitation becomes more difficult and a province obtains more sophisticated technologies. Further, factor mobility to the agglomerating province will eventually drive down interest rates by decreasing marginal productivity. At the same time, emigrating domestic capital will drive up marginal productivity in the less favoured province. Eventually, interest adjustment

[32] See Appendix A3.12.

will equalise arbitrage incentives between the two provinces.

### 3.4.3 Analysing the determinants of disparity

The major focus of the paper is to analyse income disparity between provinces. Using the model we can determine relative provincial income of a province $i$ compared to a reference province $j$ ($\Delta^y_{ij} = \frac{y_i}{y_j}$ ). This relative provincial income could be a first indicator of bilateral provincial disparity. With the theoretical model we can explain this income relation by relative differences in policies and relative differences in factor abundance

$$\begin{aligned}
\Delta^y_{ij} &= \frac{y_i}{y_j} = \Omega^*_{ij}\left(\frac{H_i}{H_j}, \frac{K_i}{K_j}, ...\right)\left(\frac{H_i}{H_j}\right)^{\alpha}\left(\frac{\mathcal{F}_i}{\mathcal{F}_j}\right)^{\beta}\left(\frac{K_i}{K_j}\right)^{1-\alpha-\beta} \\
\log\frac{y_i}{y_j} &= \log\Omega^*_{ij}\left(.., \frac{K_i}{K_j}, ..\right) + \alpha\log\frac{H_i}{H_j} + \beta\log\frac{\mathcal{F}_i}{\mathcal{F}_j} + (1-\alpha-\beta)\log\frac{K_i}{K_j}.
\end{aligned} \tag{3.26}$$

Further, using comparative statics, we obtain the effects of policy differentials on mobile factors and relative income. As an example of a policy, we analyse the relative income reaction when international transaction costs are reduced $\frac{dy_1^*}{d\tau_1}$. The reaction of the disparity relation between the two provinces $\Delta^y_{ij}$ is

$$\begin{aligned}
d\log\Delta_{ij} &= d\log y_i^* - d\log y_j^* = \frac{1}{y_1^*}\frac{dy_1^*}{d\tau_1} - \frac{1}{y_2^*}\frac{dy_2^*}{d\tau_1} \\
\frac{dy_1^*}{d\tau_1} &= \overbrace{\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1}}^{\langle 1\rangle} + \left(\overbrace{\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{dK_1}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)\frac{y_1^*}{K_1}}^{\langle 3\rangle}\right)\frac{dK_1}{d\tau_1} < 0, \\
\frac{dy_2^*}{d\tau_1} &= -\left(\overbrace{\frac{y_2^*}{\omega_2^*}\frac{d\omega_2^*}{dK_2}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)\,\frac{y_2^*}{K_2}}^{\langle 3\rangle}\right)\frac{dK_1}{d\tau_1} > 0,
\end{aligned} \tag{3.27}$$

for identical provinces

$$d\ln\Delta^y_{ij} = \frac{1}{y_1^*}\overbrace{\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{d\tau_1}}^{\langle 1\rangle} + \left(\overbrace{\frac{K_1}{y_1^*}\frac{y_1^*}{\omega_1^*}\frac{d\omega_1^*}{dK_1}}^{\langle 2\rangle} + \overbrace{(1-\alpha-\beta)}^{\langle 3\rangle}\right) d\ln\Delta^K_{ij}. \qquad (3.28)$$

Income differentials between provinces are driven by three channels: a direct improvement in technology ⟨1⟩ and two effects from interprovincial factor arbitrage ⟨2⟩ and ⟨3⟩. Both factor mobility effects are mutually reinforcing. Local policies not only affect the province itself but also others. Factor mobility–international and interprovincial–clearly has additional effects on all provinces and on provincial disparity. The effects of policies are not limited to the policy making province. These disparity effects are the focus of the empirical study.

Up to this point we are still close to the standard income and growth analysis. The only difference is that in this approach we add the provincial interactions caused by provincial factor mobility. Factor mobility can be a substantial additional disparity driving factor. Therefore, in contrast to the standard growth regression, identifying the growth-driving factors is not the only point of interest. And which growth driving factor contributes to income divergence because it is diverging itself? In other words, we would like to identify the determinants of disparity directly. In this respect, the goal of this exercise is similar to the objectives of Tsui (2007) and Wan, Lu, and Chen (2007). However, the methodology is different. While Tsui (2007) and Wan, Lu, and Chen (2007) apply a decomposition method, we suggest a variation of the estimation equation. Table 3.1 gives an overview of the most frequently used disparity measures and the properties of each measure.[33]

This table shows that disparity measures are expected to have an appropriate distance concept related to the problem, and certain properties, such as the weak transfer principal, scale independence or well-defined interval. As the different measures emphasise different aspects of disparity they are not equally capable of solving all sorts of questions related to

[33] For more details see Cowell (1995).

**Table 3.1:** Properties of different measures of disparity

| Measure | Definition | decompos. | transfer | scale | interval |
|---|---|---|---|---|---|
| Variance | $V = \frac{1}{n}\sum\left[y_i - \bar{y}\right]^2$ | yes | strong | no | $0, \bar{y}^2\left[n-1\right]$ |
| Coeff. of Var. | $c = V^{1/2}/\bar{y}$ | yes | weak | yes | $0, \left[n-1\right]^{1/2}$ |
| Gen. entropy | $E = \frac{1}{\theta^2-\theta}\left[\frac{1}{n}\sum\left(\frac{y_i}{\bar{y}}\right)^{\theta} - 1\right]$ | yes | strong | yes | $0, \infty$ |
| entropy: Theil | $T = \sum \frac{y_i}{n\bar{y}} \log\left(\frac{y_i}{\bar{y}}\right)$ | yes | strong | yes | $0, \log n$ |
| Atkinson | $A = 1 - \left[\frac{1}{n}\sum\left(\frac{y_i}{\bar{y}}\right)^{1-\varepsilon}\right]^{\frac{1}{(1-\varepsilon)}}$ | yes | weak | yes | $0, -n^{-\varepsilon/(1-\varepsilon)}$ |
| Dalton | | yes | weak | no | $0, \frac{1-n^{1-\varepsilon}}{1-n\bar{y}^{1-\varepsilon}}$ |
| Herfindal | $H = \frac{1}{n}\left[c^2+1\right]$ | yes | strong | no | $0, \frac{1}{n}$ |
| Gini | $G = \frac{1}{2n^2\bar{y}}\sum\sum\lvert y_i - y_j\rvert$ | no | weak | yes | $0, \frac{n-1}{n}$ |
| rel. mean dev | $M = \frac{1}{n}\sum\left\lvert\frac{y_i}{\bar{y}} - 1\right\rvert$ | no | just fails | yes | $0, 2\left[1-\frac{1}{n}\right]$ |
| Log variance | $v = \frac{1}{n}\sum\left[\log\left(\frac{y_i}{\bar{y}}\right)\right]^2$ | no | fails | yes | $0, \infty$ |
| variance of log | $v_1 = \frac{1}{n}\sum\left[\log\left(\frac{y_i}{y^*}\right)\right]^2$ | no | fails | yes | $0, \infty$ |
| Range | $R = y_{\max} - y_{\min}$ | | | | $0, \bar{n}\bar{y}$ |
| | $y^* = e^{\left[\frac{1}{n}\sum \log y_i\right]}$ | | | | |

Source: Cowell (1995)

disparity.

In this paper we aim to explain provincial income disparity (measured by an appropriate disparity index) with the disparity of income determining factors. Since the Theil index is decomposable into the different contributions of each province to the country-wide Theil index of provincial disparity, and since it has an appropriate distance concept and all required properties, we choose it as an appropriate instrument for the empirical analysis. More precisely, we can determine each province's Theil contribution to income disparity. All these provincial contributions add up to the overall measure of provincial income disparity. Moreover, we will explain the Theil contribution of income disparity by the Theil contribution of the disparity determining variables such as capital, human capital etc.

$$\begin{aligned} TH_i^y &= \frac{1}{n}\frac{y_i}{\bar{y}}\log\frac{y_i}{\bar{y}}, \quad TH_i^K = \frac{1}{n}\frac{K_i}{\bar{K}}\log\frac{K_i}{\bar{K}}, ... \\ TH_i^y &= \alpha + \beta_1 TH_i^K + \beta_2 TH_i^{HC} ... \end{aligned} \tag{3.29}$$

As disparity measured in distances is the target, the distance from the mean must be included in the measurement concept. The Theil concept fulfils this requirement using an appropriate weighting scheme. Therefore, we choose an estimation approach where the Theil index contribution of income in each province is determined by the Theil index contribution of each explanatory variable of income derived from the theoretical model above (see equation (3.29)).

## 3.5 Panel data analysis of provincial disparity

For the empirical study we suggest a panel data analysis. More specifically, our point of departure is a simple individual effects model of the form

$$Y_{i,t} = \alpha + \beta X'_{i,t} + u_{i,t}, \tag{3.30}$$

where $Y_{i,t}$ is the dependent variable and $X'_{i,t}$ is a set of explanatory variables. This method allows for an inclusion of individual effects for each province. Hence, $u_{it} = \mu_i + \varepsilon_{it}$ denotes the disturbance term that is composed of the individual effect $\mu_i$ and stochastic white noise disturbance $\varepsilon_{it}$.[34] The Hausman specification test determines whether the fixed or random effects model should be used.

In order to analyse the determinants of inequality within China, it is necessary to use provincial data to consider the provinces' heterogeneity. Our data set covers the period 1991–2004 and includes annual data for 28 Chinese provinces, autonomous provinces and municipalities.[35] These are Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Inner Mongolia, Guangxi, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang. Due to missing values the provinces Tibet and Hainan are excluded. We use new income data reported by Hsueh and Li (1999) as well as various sources of Chinese official statistics provided by the National Bureau of Statistics (NBS) to construct our data set. These are the China Statistical Yearbook (CSY) from 1996–2004 and the China Compendium of Statistics 1949–2004. The variables are described in detail below.

The basic goal is to explain provincial disparity in China. Moreover, disparities in provincial income are caused by disparities in income dependent determining factors. In this context, inequality is measured by the Theil index, and the dependent variable is defined as the provincial contribution to the country's inequality. To account for the distribution of the explanatory variables we calculate the corresponding Theil indices for all inequality factors and likewise compute analogically the provincial contribution to those indices. Hence, we try to explain a province's contribution to income inequality with the

[34] In our case a LM test for the presence of individual effects rejects the hypothesis that $\mu_i = 0$ so we include an individual effect.

[35] The choice of the period makes sense for two reasons. First, the early 1990s saw the latest wave of international integration policy in China. Also in the early 1990s the Chinese government started to prepare for WTO accession and a further opening up of the economy. Second, we want to focus on the period during which China's inequality increased. As can be seen from the development of the Gini coefficient and the Theil index this period started in 1991. Third, with respect to some important indicators some provinces would have had to be excluded if the time period had been expanded to earlier years.

help of the share of inequality of other factors. Our estimation equation is directly derived from the theoretical model presented above. The general equation of motion for the above model (3.26) translates into the estimation equations with the following specification:

$$\begin{aligned} TH\_GDP_{i,t} &= \alpha + \beta_1 TH\_C_{i,t} + \beta_2 TH\_HC_{i,t} + \beta_3 TH\_T_{i,t} \\ &\quad + \beta_4 TH\_FDI_{i,t} + \beta_5 TH\_GOV1_{i,t} + \beta_6 TH\_GOV2_{i,t} \\ &\quad + \beta_7 TH\_HIGHWAY_{i,t} + \mu_i + \varepsilon_{i,t}, \end{aligned} \tag{3.31}$$

where $TH\_GDP_{i,t}$ denotes the contribution of province $i$ to the country's income inequality and $TH\_C_{i,t}$, $TH\_HC_{i,t}$, $TH\_T_{i,t}$, $TH\_FDI_{i,t}$, $TH\_GOV1_{i,t}$, $TH\_GOV2_{i,t}$ and $TH\_HIGHWAY_{i,t}$ are the corresponding contributions to inequality in physical capital, human capital, trade, foreign direct investment, government expenditure and infrastructure measured in highways. The variables are calculated on the basis of the Theil index contribution given by equation (3.2).

What is the interpretation of the coefficients in this estimation equation? A positive coefficient indicates that 'income Theil disparity' is driven by the 'Theil disparity' of the respective potential growth determinant. For example, the provincial 'Theil variation' of income positively relates to the 'Theil variation' of capital, and hence the disparity of capital positively contributes to disparity of income measured by the Theil index. A negative coefficient means that the provincial 'Theil variation' of capital decreases income disparity measured by the Theil index. The notation of the estimation equation is as follows:[36]

**Theil index contribution of income -** $TH\_GDP_{i,t}$ :

$TH\_GDP_{i,t}$ denotes the contribution of province i to the country's Theil index. The provincial income used for the calculation is obtained from Hsueh and Li (1999) covering

[36] The Theil indices and their provincial contributions for all variables for 1991-2004 are presented in Tables A3·4, A3·5, A3·6, A3·7, A3·8, A3·9, A3·10 and A3·11 in the Appendix.

the period 1991–1995 and from various issues of the Statistical Yearbook of China for 1996–2004. GDP per capita expressed in current prices (Yuan) has been deflated with 1995 as the base year.

**Theil index contribution of capital -** $TH\_K_{i,t}$ :

$TH\_K_{i,t}$ denotes the corresponding Theil index of the real capital stock per capita. The real physical capital stock for all provinces is estimated by using the standard perpetual inventory approach. It is accumulated according to:

$$K_{t+1} = I_t + (1 - \delta)K_t \tag{3.32}$$

where $K_t$ and $K_{t+1}$ is the capital stock of year $t$ and $t{+}1$ respectively, $I_t$ denotes investment, and $\delta$ is the depreciation rate. The investment series used is gross fixed capital formation and is taken at current prices. It is taken from Hsueh and Li (1999) and from the Chinese Statistical Yearbooks. Like Miyamoto and Liu (2005) we assume that the depreciation rate $\delta$ is 5 per cent for all provinces. To weight the initial capital stocks for each province, we use the average ratio of provincial GDP to national GDP for each province over the period 1952–1977. Following Wang and Yao (2003) we assume their estimate of 26,609.67 billion Yuan as the initial real capital stock for 1977 at the national level. By multiplying this initial capital stock with the provincial weights we derive the initial capital stock for each province. In order to calculate the real capital stock we use a new investment deflator provided by Hsueh and Li (1999) for the period 1978–1995 and combine it with the price index for fixed asset investment for the period 1996–2004.

**Theil index contribution of human capital -** $TH\_HC_{i,t}$ :

$TH\_HC_{i,t}$ is the Theil index contribution of human capital. The proxy for human capital is enrolment in higher education as log of the share in the total population. We obtain the data from the China Compendium of Statistics 1949–2004.

**Theil index contribution of trade -** $TH\_T_{i,t}$ :

We use the log of trade calculated as the sum of imports and exports in GDP as a measure of economic integration. The data are taken from the China Compendium of Statistics 1949–2004. We again compute the Theil index contribution $TH\_T_{i,t}$ for each province.

**Theil index contribution of FDI -** $TH\_FDI_{i,t}$ :

The second variable measuring economic integration is foreign direct investment measured as the log of FDI in GDP taken from the China Compendium of Statistics 1949–2004. Because FDI data are available only in Yuan, we convert the data into US Dollars using the national exchange rate for each year reported by the National Bureau of Statistics. $TH\_FDI_{i,t}$ denotes the Theil index share of this variable.

**Theil index contribution of government expenditure -** $TH\_GOV1_{i,t}$**,** $TH\_GOV2_{i,t}$ :

Two variables can indicate the effect of government expenditure on income inequality. The first is the Theil contribution of the share of local government general expenditure in administration ($TH\_GOV1_{i,t}$) and the second is the corresponding contribution of the ratio of local government general expenditure on culture, education, science and public health to GDP ($TH\_GOV2_{i,t}$). Again, the source of the data is the China Compendium of Statistics 1949-2004.

**Theil index contribution of highway -** $TH\_HIGHWAY_{i,t}$ :

We use the Theil index contribution of the highway length per square kilometre ($TH\_HIGHWAY_{i,t}$) as a proxy for the inequality in infrastructure. We obtain the data for the highway length and the area in square kilometres from the China Compendium of Statistics 1949-2004.

Table 3.2 presents the descriptive statistics of all variables.

## 3.6 Estimation results

The results of the estimates are summarised in Table 3.3. It reports the results of the fixed effects estimator for the period 1991–2004. We use the Hausman test to make an

**Table 3.2:** Descriptive statistics

| Variable | Obs | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| $TH\_GDP_{i,t}$ | 392 | 0.005948 | 0.035057 | -0.0131382 | 0.178702 |
| $TH\_K_{i,t}$ | 392 | 0.008862 | 0.050197 | -0.0131385 | 0.259247 |
| $TH\_HC_{i,t}$ | 392 | 0.009533 | 0.053248 | -0.0131376 | 0.300175 |
| $TH\_T_{i,t}$ | 392 | 0.019382 | 0.086722 | -0.0131386 | 0.560152 |
| $TH\_FDI_{i,t}$ | 392 | 0.015733 | 0.056073 | -0.0131385 | 0.363280 |
| $TH\_GOV1_{i,t}$ | 392 | 0.006625 | 0.042233 | -0.0131347 | 0.297007 |
| $TH\_GOV2_{i,t}$ | 389 | 0.002112 | 0.013133 | -0.0115511 | 0.051486 |
| $TH\_HIGHWAY_{i,t}$ | 392 | 0.007260 | 0.027821 | -0.0131386 | 0.130035 |

appropriate choice between random and fixed effects. With a p-value of 0.00 the test rejects the hypothesis that the random and fixed effects estimators do not differ substantially, so there is a correlation between $\mu_i$ and $X'_{i,t}$ and the random effects model is inconsistent. Hence, the fixed effects model is the appropriate choice.[37]

Looking at Table 3.3, most explanatory variables enter with the sign predicted from the model, except human capital. Hence, the major findings from these estimates suggest that both mean income and the typical growth determinants tend to have a positive impact on inequality. Furthermore, it is the success of the eastern provinces that to a large extent drives inequality.[38]

1. *Domestic sources of inequality*

    - Controlling for other explanatory variables, the coefficient for the inequality con-

[37] Since the usual $R^2$ or adjusted $R^2$ criteria are only appropriate if the model is estimated by OLS and the fixed effects estimator is chosen to explain the within variation we report the $R^2_{within}$ (Verbeek 2008, p. 369).

[38] To avoid the problem of possible endogeneity of the explanatory variables we also run a system GMM estimation. To check for the robustness of the FE estimator we additionally run an OLS estimation. The results of both estimators are presented in Table A3.1. The coefficient values are similar and confirm the FE results; all significant coefficients show the same signs.

We tested for the presence of multicollinearity calculating variance inflation factors (VIFs). VIF values in excess of 10 often indicate a multicollinearity problem. The VIF values for the independent variables ranged from 1.5 to 7.8 with a mean VIF of 3.5, this indicates that there is no serious multicollinearity problem. See Table A3.2 for more detailed results.

The Breusch Pagan/ Cook-Weisberg test for heteroscedasticity rejects the hypothesis of constant variance, so we use robust standard errors.

**Table 3.3:** Fixed effects estimation (1991-2004)

Dependant variable: $TH\_GDP_{i,t}$

| | Coeff. | Std. Err. |
|---|---|---|
| $TH\_K_{i,t}$ | 0.302*** | (0.017) |
| $TH\_HC_{i,t}$ | -0.015** | (0.007) |
| $TH\_T_{i,t}$ | 0.020*** | (0.005) |
| $TH\_FDI_{i,t}$ | -0.020*** | (0.003) |
| $TH\_GOV1_{i,t}$ | -0.003 | (0.005) |
| $TH\_GOV2_{i,t}$ | -0.028 | (0.022) |
| $TH\_HIGHWAY_{i,t}$ | 0.053*** | (0.011) |
| $CONS$ | 0.003*** | (0.000) |
| $R^2 within$ | 0.594 | |
| Obs | 389 | |
| Hausman test: chi2(7)=531.42 Prob>chi2=0.00 | | |

Note: *, ** and *** denote significance at the 10%, 5% and 1% level.

tribution of physical capital is highly significant and has the strongest positive effect on inequality. This result is consistent with Tsui (2007), especially during the last two decades, and Wan, Lu, and Chen (2007). It indicates that inequality in China is a phenomenon that is not only caused by foreign firms investing in selected provinces of the country. The process of growth and disparity also has strong and important domestic components. Like income disparity, physical capital disparity shows the same pattern. It is also driven by a small number of coastal provinces namely Shanghai, Beijing and Tianjin.

- The same provinces account for a large share of the inequality in human capital. However, in contrast to income disparity, disparity in human capital continuously decreased over the period 1991–2004. The estimated coefficient shows a negative significant impact on the dependent variable. Therefore, provincial disparity in human capital does not contribute to provincial income disparity. The negative sign even suggests that interprovincial disparity in human capital leads to more equality. This result is consistent with Tsui (2007) who found that human capital has made a small contribution to equality in more recent years.

In Wan, Lu, and Chen (2007) education made a positive but small contribution to disparity.

- Both coefficients for provincial disparity of government activities have a negative impact on income disparity. Unlike income Theil disparity, disparity in government activities is driven by completely different provinces. The inequality in expenditure in administration is mainly driven by the provinces Qinghai and Gouizhou. Expenditure on culture, education, science and public health is smaller and distributed more evenly. The provinces that are responsible for income inequality enter with a negative contribution to Theil disparity for government expenditure. However, the effects are not significant in the case of the FE estimator in contrast to the OLS and GMM estimator. This result clearly differs from the findings of Wan, Lu, and Chen (2007).

- Infrastructure inequality, measured by the Theil index contribution of highway length per square kilometres, is highly significant and shows a strong effect on income inequality. The large Theil disparity in infrastructure leads to a large income Theil inequality.

2. *Openness and inequality*

- The coefficient of the inequality contribution of trade is significant and has a clear effect on income inequality. This result supports the findings of Spilimbergo, Londono, and Szekely (1999) at an individual level who suggest that trade is significantly positively associated with inequality.

- Openness inequality measured by the inequality contribution of FDI is also significant but shows a negative effect on income disparity. In comparison to the trade variable this may be due to the more even distribution of the Theil index across the provinces, so the provinces that drive income inequality do not have an accentuated impact on FDI disparity. Furthermore, in contrast to income and trade disparity, FDI disparity shows a decreasing trend. This may suggest that the decreasing provincial FDI disparity contributes to higher provincial income equality.

## 3.7 Summary and conclusion

The paper explains the growth-inequality nexus for China's provinces. The theoretical model of provincial development consists of two regions and studies the interactions of a mutual development process. Due to positive externalities, incoming trade and FDI induce imitation and hence productivity growth. The regional government can influence the economy by changing international transaction costs and providing public infrastructure. Due to mobile domestic capital, disparity effects are reinforced. The implications of the theoretical model are tested. As the central intention of the paper is to explain provincial disparity, we directly relate income disparity (indicated by the contribution to the income Theil index) to the disparity of selected income determining factors (indicated by the contribution to each of the other Theil indices). We examine the determinants of inequality for 28 Chinese provinces over the period 1991–2004 and apply fixed effects panel estimation. The results confirm the theoretical framework and suggest a direct link between the factors that determine regional income and regional disparity. More specifically, it is apparent that disparities in trade, foreign and domestic capital and infrastructure have an impact on provincial income Theil disparity, whereas disparities in government expenditure and human capital do not seem to drive income Theil disparity. Therefore, on the one hand, three decades of government reforms led to an extraordinary success of some provinces and hence increased disparity, and on the other hand, government expenditures and public human capital investments seem to have had a stabilizing effect on the development of provincial disparity.

# Chapter 4

# Short-run and long-run relations between growth, inequality and poverty in the developing world and China

*This chapter is based on the paper "Short-run and long-run dynamics of growth, inequality and poverty in the developing world" by Gries, T. and Redlin, M. of the Center for International Economics Working Paper Series.*

## 4.1 Introduction

In recent years a series of theoretical and empirical contributions have studied the relationships between growth, inequality and poverty. It has become ever more apparent that successful development strategies should not address each of these phenomena in isolation but rather look at their interdependences and interactions. Bourguignon (2004) refers to this relationship as the poverty-growth-inequality triangle; he points out that there is a two-way relationship between growth and distribution which can be divided into the effects of growth on distribution and the effects of inequality on growth. This interaction, in turn, has an effect on absolute poverty and poverty reduction, so a change in poverty can be shown to be linked to growth, distribution and a change in distribution. Adams (2004) argues that economic growth represents an important means for reducing poverty in the developing world. His results show that since income distributions are relatively stable over time, economic growth has the general effect of raising incomes for all members of society, including the poor. This result is also consistent with Dollar and Kraay (2002) who point out that several determinants of growth, such as the rule of law, openness to international trade, and developed financial markets, have little systematic effect on the share of income that accrues to the bottom quintile. Consequently, these factors benefit the poorest fifth of society as much as they do everyone else. This makes clear that promising development policies and poverty reduction should take account of possible relations between growth, inequality and poverty. These relationships are the focus of numerous empirical studies.

As early as in the 1950s Kuznets (Kuznets 1955) suggested an inverted U-curve relationship between these variables, indicating that economic inequality increases over time while a country is developing. Then, after a certain average income is attained, inequality begins to decrease. Using standard growth regressions augmented by inequality measures, OLS cross country estimates in most cases show a negative impact of inequality on growth (see e.g. Perotti 1993, 1996, Alesina and Rodrik 1994 and Persson and Tabellini 1994). Since these kinds of studies use initial inequality measures and regress it on GDP growth, they disregard the perpetual changes in inequality and its potential interacting permanent effects on growth. Recent panel methods tend to exhibit a positive effect, for instance Li and Zou (1998) and Forbes (2000). The results of Barro (2000) support the U-curve relationship and suggest that for growth, higher inequality tends to retard growth in poor countries and encourage growth in richer places.

Furthermore, the effect of growth on poverty is also not as unambiguous as it appears to be at first sight. Of course, when holding inequality constant, higher economic growth reduces poverty by increasing the income of the poor by the same rate as the income of the total population. However, is growth really pro-poor, or is the combined effect of growth and inequality maybe counterproductive in terms of fighting poverty? Using a large sample of countries spanning the past four decades Dollar and Kraay (2002) find out that the average income of the poorest fifth of a country on average rises or falls at the same rate as the general average. Naschold (2004) argues that the level of development approximated by per capita consumption impacts on the poverty reducing effect of growth.

He shows that consumption growth elasticities in LDCs are only between one third and one half of the level of elasticities in other developing countries. Squire (1993) and Bruno, Ravallion and Squire (1998) argue that economic growth can be expected to reduce poverty, but the latter also point out that poverty is also sensitive to inequality and even small changes in the overall distribution of inequality can lead to sizeable changes in the incidence of poverty. Recent studies such as Heltberg (2002), Bourguignon (2003) and Ravallion (2005) have also shed light on the role of distribution changes in poverty reduction. They emphasise that poverty elasticity depends strongly on the degree of inequality and that growth reduces poverty more efficiently in less inegalitarian countries. To highlight the relationships between inequality and growth as well as between poverty and growth, a possible causality between inequality and poverty should also be taken into consideration.

This paper expands the above literature by considering short-run and long-run dynamics between growth, inequality, and poverty. Contrary to the most often applied regression approach, where the effect of a variable and a set of conditional variables are regressed on the variable of interest, our focus is to identify a possible (Granger) causal relationship. For instance, does higher growth lead to more inequality, or does more inequality reduce growth potentials? Does an increasing inequality lead to more poverty, or does a reduction in poverty also result in a reduction in inequality? Are the causal effect, stationary long-term relations or more short-term transitory observations?

Without awareness of the directions of causality between these important policy targets it remains very difficult to evaluate policies designed to bring about improvements in any single of the three policy areas. Analysing these directions using panel causality methods is the purpose of the paper. Hence, this paper differs from existing studies in three aspects. First, it considers all possible relationships between these three variables by pairs, so we can clearly identify the causal directions of the triangle. Secondly, the study is based on recently developed tests for panel unit roots and heterogeneous panel cointegration. Furthermore, panel-based error correction models are applied to explore the pairwise relationship between growth, inequality and poverty for a large panel of developing countries. Thirdly, in addition to the entire panel of 114 developing countries, we try to capture possible income-related and regional differences by analysing differentiated subsets of countries grouped by income and world regions. And finally, we use a panel data set for rural and urban China to analyse China as one of the developing countries in more detail. The purpose is to first examine a general relationship, so in a first step we analyse the global relations between income growth, inequality and poverty for the developing world using a broad panel of developing countries. In the subsequent step we focus on China and examine the relations for the country separately. This allows us to identify if the relations of growth, inequality and poverty in China are consistent with the general relations of the developing world, or if China has an outstanding relevance compared to other developing countries.

## 4.2 Growth, inequality and poverty triangle

Before we focus on the empirical causality relationships between per capita income growth, poverty reduction and inequality, we first review some fundamental theoretical relations between the elements of this "triangle of development". These fundamental relations from production theory mechanics link up growth, poverty reduction and inequality under rather broad conditions. This review serves as a brief reminder and a benchmark for the subsequent empirical analysis which forms the core of this paper. In order to have a reference system we look at a linear homogeneous production process. For this process we can derive productivity and income for various groups and explain the connection between income growth, inequality and poverty.

**Production and per capita income:** For a linear homogeneous production process $[Y = F(AL, K)]$ the factors are given by the technology $A$, physical labour $L$, and $K$ as accumulated productive asset (capital, human capital). Denoting population $N$ and capital intensity[1] $k$, per capita income is $y = \frac{Y}{N}$, and per capita income growth is

[1] $k$ is capital intensity for labour in efficiency units. $y = \frac{Y}{N} = f(k)An_L$, with $n_L = N/L$ and $\alpha$ being the elasticity of production of capital.

$$\frac{d\ln y}{dt} = \alpha\frac{d\ln k}{dt} + \frac{d\ln A}{dt}. \tag{4.1}$$

As long as the stationary state has not yet been reached, we have two engines of per capita growth, increasing capital intensity $\dot{k} > 0$ and technical progress $\dot{A}$. For most developing economies we can assume that stationarity has not been reached even if $\dot{k}$ is potentially of decreasing importance.

**Inequality:** In this simple view income inequality is generated by differentials in factor productivity and ownership of productive assets $K$. For simplicity we assume that total population $N$ consists of labour and asset owners[2] who earn returns on productive assets $r$. Typically, in developing economies the fraction of asset owners $n_K$ is small and capital income per asset owner is high, such that asset owners represent high income groups and pure labour income can be associated with lower income groups. Therefore, the ratio of capital earnings per asset owner $rK/N_K$ versus wage income per worker $w_L$ can be defined as a simple indicator of inequality[3] $\delta = \frac{rK}{N_K}/w_L = \frac{rk}{w}n_{LK}$, with $n_{LK} = L/N_K$. Changes in inequality over time are determined by[4]

$$\frac{d\ln \delta}{dt} = \left(1 - \frac{1}{\sigma}\right)\frac{d\ln k}{dt} + \frac{d\ln n_{LK}}{dt}. \tag{4.2}$$

According to (4.2) changes in income distribution are driven by two major factors, changes in $k$ and changes in the relative share of asset owners $n_{LK}$. Rising capital intensity would increase inequality if both factors were easy to substitute $\sigma > 1$. In fact it is easy to recall that (4.2) can lead to Kuznets' inverted U-curve relationship if an economy is still in transition towards a stationary state and the share of asset owners continuously increases.

**Poverty:** To identify the link to poverty we look at an absolute poverty level. Labour is not poor if it reaches at least a productivity that is slightly above the poverty level

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[2] $N_K + L = N$, with the fractions $n_L = L/N$ of labour and fraction $n_K = N_K/N$ capital owners $N_K$.

[3] If factor prices are determined by marginal productivities, $w$ describes wage per labour efficiency unit and $w_L$ is wage per worker.

[4] $\sigma = \frac{dk}{d\omega}\frac{\omega}{k} = -\frac{f'}{ff''}\frac{f - f'\frac{K}{AL}}{\frac{K}{AL}}$ is the elasticity of substitution in production with $\omega = w/r$.

$\bar{\varphi} \leqq w_L = A\left(f - f' \frac{K}{AL}\right)$. Again, due to the development process $k$ and $A$ may grow over time and change the number of people who are sufficiently productive to earn income equal to or above the poverty line. Therefore, using the definition of capital intensity $k = K/AL$, we can determine[5] how many additional workers $\frac{d \ln L^{\bar{\varphi}}}{dt} > 0$ could be employed at this or a higher productivity level; the respective increase in employed labour defines a reduction of poverty. Workers who just crossed the poverty line define the level of poverty reduction

$$\frac{\ln L^{\bar{\varphi}}}{dt} = \frac{d \ln k}{dt} + \frac{\sigma}{\alpha} \frac{d \ln A}{dt} > 0. \tag{4.3}$$

An increase in both $k$ and $A$ would improve labour productivity, and hence would shift more people over the poverty line.

According to (4.1), (4.2) and (4.3) all elements of the "triangle of development" have either $\dot{A}$ or $\dot{k}$ or both as common factors. Hence, the respective partial relations between *growth, poverty,* and *inequality* can be discussed in pairs.

*Income growth and inequality:* (4.1) and (4.2) suggest that increasing capital intensity links both income growth and inequality. Per capita income growth goes hand in hand with higher inequality if $\sigma > 1$. In the early stages of development, when capital intensity strongly increases and the share of asset owners remains rather constant, high income growth and increasing inequality seems to be a likely pattern. Note that these conditions describe the dynamics to the left of the maximum of the Kuznets curve. However, when the economy develops $\dot{k}$ may decline,[6] and if simultaneously a higher share of people becomes asset owners the economy may switch to the right of the maximum of the Kuznets curve.

*Income growth and poverty:* From (4.1) and (4.3) we obtain that growth enhancing factors $\dot{k} > 0$ and $\dot{A} > 0$ may simultaneously reduce poverty. Technology growth and increasing capital intensity may improve productivity also of the poor, so a rising number

[5] Therefore, the first step is to find out which relative changes in $\dot{k}$ and $\dot{A}$ allow workers to stay at least at the income level of the poverty line $\frac{d \ln k}{dt} = -\frac{\sigma}{\alpha} \frac{d \ln A}{dt}$. If technical progress is positive $\dot{A} > 0$ productivity is growing. Hence, the productivity of those who are barely above the poverty line ($\bar{\varphi} \leq w_L$) could already be reached even if capital intensity simultaneously declined $\dot{k} < 0$.

[6] E.g. under neoclassical growth conditions.

of people can pass the poverty line while per capita income is generally growing. However, other less positive scenarios are possible particularly if $\sigma < 1$.

*Inequality and poverty:* According to (4.2) and (4.3), inequality and poverty are also connected by capital intensity during non-stationary transition. For $\sigma > 1$, increasing capital intensity favours asset income, which leads to more inequality as long as the share of asset holders remains rather stable. Simultaneously, increasing capital intensity improves labour productivity, and an increasing number of people can pass the poverty line. However, this is not the only possible outcome. Even if an increasing capital intensity $k$ decreases poverty and tends to increase inequality, a positive relation between poverty reduction and more equality could be an observable, consistent phenomenon. If poverty reduction goes along with an increasing share of people holding productive assets,[7] decreasing inequality is consistent with decreasing poverty.

While this discussion looks at consistent theoretical relations we should be aware of that these partial relations could change for other values of $\sigma$. Also, this simple discussion illustrates that there is neither an unequivocal relation suggested broad production theory mechanics, nor is there a theoretical causality direction. In other words, the fact that common driving factors, such as capital accumulation $\dot{k}$ or productivity growth $\dot{A}$, link e.g. income growth and poverty reduction, does not enable us to identify the direction of causalities that are important for policy evaluation. For instance, does an improvement in the productivity of the rural poor, which may lead to poverty reduction, cause an increase in per capita income growth, or do higher per capita income growth rates e.g. in the modern sector lift more people out of poverty (pro-poor growth)? Both causal directions are consistent with fundamental theoretical relations drawn from production mechanics. Therefore, it becomes very difficult to evaluate policies designed to bring about improvements in any of the three policy areas without awareness of the directions of causality between them. Analysing these directions using panel causality methods is the purpose of the paper and the following sections.

[7] Human capital may be such a productive asset that is available to a broader share of the population.

## 4.3 Estimation: Developing world

### 4.3.1 Data

To get a general impression of the relationship between income growth, inequality and poverty we start with an analysis of a broad panel of developing countries. The analysis is based on data from the World Bank's PovcalNet.[8] This data set includes data on income and poverty and inequality measures for several developing countries. To obtain a balanced panel incomplete country time series were dropped so that the data set used in the analysis refers to a balanced panel of 114 countries. The reference years currently available are 1981, 1984, 1987, 1990, 1993, 1996, 1999, 2002, and 2005.[9]

In addition to the entire panel, we segment the data set into three subpanels according to per capita income. We use the World Bank country classification that distinguishes between low-income economies ($1005 or less), lower-middle-income economies ($1006 to $3975), upper-middle-income economies ($3976 to $12275) and high-income economies ($12276 or more). As the country set contains only developing countries, the number of high-income countries is too small for an autonomous analysis, therefore we merge the group of upper-middle-income and high-income economies. Furthermore, to account for regional differences we use the World Bank´s regional segmentation and divide the data into six subpanels according to their geographical location, namely East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, South Asia, and Sub-Saharan Africa. We can then analyse conditions that vary in terms of culture, geography, administration and institutions. The variables used in the analysis are defined in the following. Table 4.1 presents the descriptive statistics including the number of observations, the mean and the standard deviation for the aggregate panel and the subpanels.

[8] See Chen and Ravallion (2007). The data set is available at http://iresearch.worldbank.org/PovcalNet (05-01-2012).

[9] Appendix A4.1 contains a detailed description of the dataset and the countries included in the analysis.

**Table 4.1:** Summary and descriptive statistics

| panel | variable | obs. | mean | std. dev. |
|---|---|---|---|---|
| Developing World | income | 1026 | 143.55 | 123.14 |
| | gini | 1026 | 41.63 | 10.95 |
| | headcount | 1026 | 29.99 | 27.99 |
| low-income | income | 252 | 51.27 | 32.55 |
| | gini | 252 | 44.41 | 9.57 |
| | headcount | 252 | 60.22 | 20.67 |
| lower-middle-income | income | 369 | 93.45 | 55.45 |
| | gini | 369 | 41.96 | 9.54 |
| | headcount | 369 | 33.43 | 22.99 |
| upper-middle- and high-income | income | 405 | 246.62 | 129.46 |
| | gini | 405 | 39.61 | 12.46 |
| | headcount | 405 | 8.06 | 13.33 |
| East Asia and Pacific | income | 117 | 78.77 | 58.23 |
| | gini | 117 | 37.28 | 7.51 |
| | headcount | 117 | 40.38 | 25.44 |
| Europe and Central Asia | income | 243 | 257.57 | 152.75 |
| | gini | 243 | 30.86 | 7.49 |
| | headcount | 243 | 5.12 | 10.66 |
| Latin America and the Caribbean | income | 189 | 210.44 | 91.36 |
| | gini | 189 | 50.40 | 6.05 |
| | headcount | 189 | 13.70 | 13.57 |
| Middle East and North Africa | income | 72 | 151.09 | 46.14 |
| | gini | 72 | 38.51 | 3.79 |
| | headcount | 72 | 5.51 | 4.25 |
| South Asia | income | 54 | 58.36 | 17.61 |
| | gini | 54 | 34.93 | 6.20 |
| | headcount | 54 | 41.56 | 15.10 |
| Sub-Saharan Africa | income | 351 | 61.75 | 38.78 |
| | gini | 351 | 47.49 | 9.66 |
| | headcount | 351 | 55.77 | 21.09 |

**mean income - $y_{i,t}$ :**

Mean income $y_{i,t}$ is measured in average monthly per capita income/consumption expenditure (PPP) from the survey in 2005.

**headcount - $h_{i,t}$ :**

Headcount $h_{i,t}$ denotes the percentage of the population living in households with consumption or income per person below the poverty line. The analysis is based on a \$1.25/day poverty line and income data at 2005 prices, adjusted for purchasing power parity (PPP).[10]

**Gini coefficient - $gini_{i,t}$ :**

We use the Gini coefficient $gini_{i,t}$ in its common definition as a measure of inequality.

To obtain a first impression of the relationships between growth, inequality and poverty we plot these variables by pairs. The diagrams presented in Figures A4.1, A4.2 and A4.3 also include the prediction graphs of the linear regressions. The figures show a weak positive relationship between inequality and growth and between inequality and poverty and a strong negative relationship between growth and poverty. The correlation matrix (Table A4.1) confirms these results, showing a weak positive correlation between growth and inequality and between inequality and poverty and a strong negative correlation between growth and poverty. However, it is a moot point whether and if so to what extent these variables have a causal effect on each other. The concept of the error correction model (ECM) is an adequate methodology to test these causality relations in the short and long run.

### 4.3.2 Methodology

Following Yasar, Nelson and Rejesus (2006) we suggest applying a generalised one-step ECM to explore the pairwise short-run and long-run dynamics between growth, changes in inequality and poverty, and to use a panel data analysis and GMM estimation. We prefer

[10] We also ran the analysis using a \$1/day and \$2/day poverty line. The results are robust to those of the \$1.25/day poverty line.

dynamic panel estimators for various reasons. The dynamic panel procedure allows us to control for country specific effects, whereas the OLS estimator assumes that the intercept that captures the effect of all omitted and unobservable variables is the same for all countries. This individual effect may correlate with the included explanatory variables, hence omitting the individual effect would become part of the error term, which would lead to a bias in the estimates. Furthermore, in comparison to the standard fixed effect estimator, GMM estimation also circumvents the bias associated with including a lagged dependent variable as a regressor and enables us to calculate consistent and efficient estimates. Additionally, by combining the time series dimension with the cross-sectional dimension, the panel data set yields a richer set of information to exploit the relationship between the dependent and independent variables, reduces collinearity among the explanatory variables, increases the degrees of freedom and gives more variability and efficiency. More specifically, our point of departure is a bivariate autoregressive-distributed lag (ADL) model

$$y_{i,t} = \alpha_0 + \sum_{j=1}^{2} \alpha_j y_{i,t-j} + \sum_{j=0}^{2} \delta_j x_{i,t-j} + f_i + u_{i,t} \quad (4.4)$$

$$x_{i,t} = \beta_0 + \sum_{j=1}^{2} \beta_j x_{i,t-j} + \sum_{j=0}^{2} \gamma_j y_{i,t-j} + \eta_i + \nu_{i,t} \quad (4.5)$$

where index i=1...N refers to the country and t=1...T to the period. This method allows us to include specific effects for each country ($f_i$ and $\eta_i$). The disturbances $u_{i,t}$ and $\nu_{i,t}$ are assumed to be independently distributed across countries with a zero mean. They may display heteroskedasticity across time and countries, though. Following Granger (1969) there is Granger causality from $x$ to $y$ if past values of $x$ improve the prediction of $y$ given the past values of $y$. With respect to the model, $x$ Granger causes $y$ if not all $\delta_j$ are zero. Likewise, Granger causality from $y$ to $x$ occurs if not all $\gamma_j$ are equal to zero. However, Engle and Granger (1987) have shown that, if the series $x$ and $y$ are cointegrated, the standard Granger causality test is misspecified. In this case an error correction model should be used instead. So the first step of the standard procedure is a unit root and a cointegration test. On the basis of the results we determine whether to use the Granger causality framework or an ECM model to test for causality.

**Panel unit root test:**

The Granger causality test requires the variables to be stationary. To check the stationarity of the data two common panel unit root tests are used, the IPS test by Im, Pesaran and Shin (2003) and the Fisher-type test by Maddala and Wu (1999) and Choi (2001).

Formally, the test equation of both tests is

$$\triangle y_{i,t} = \mu_i + \beta_i y_{i,t-1} + \varepsilon_{it}. \tag{4.6}$$

The null hypothesis is that each cross-section series in the panel has a unit root. The alternative hypothesis is that there is at least one stationary cross-sectional series in the panel. Additionally, the formulation allows $\beta_i$ to differ across cross-sections so that both tests allow for heterogeneity.

$$H_0 \; : \; \beta_i = 0 \quad for\ all\ i \tag{4.7}$$

$$H_1 \; : \; \beta_i < 0, \quad i = 1, 2, ..., N_1, \quad \beta_i = 0, \quad i = N_1 + 1, N_2 + 1, ...N. \tag{4.8}$$

The IPS test is a t-bar statistic based on the (augmented) Dickey-Fuller (Dickey and Fuller 1979) statistic. It computes the sample mean of the individual unit root tests for each of the N cross-section units. The main idea of the Fisher-type unit root test is to combine p-values from a unit root test applied to each cross-section in the panel data. While both IPS and the Fisher-type test combine information based on individual unit root tests, the crucial difference between the two is that the IPS test combines the test statistics, while the Fisher-type test combines the significance levels of the different tests. Table 4.2 presents the results of both tests for the three variables in levels and in first differences. The results

**Table 4.2:** Panel unit root test: Developing world

| variable | deterministic | IPS | Fisher-type | first diff. IPS | first diff. Fisher-type |
|---|---|---|---|---|---|
| income | constant | -1.3304 | 181.0720 | -2.2473*** | 567.2075*** |
| | const. + trend | -1.4954 | 149.3162 | -2.3798*** | 429.7042*** |
| headcount | constant | -0.7931 | 231.3120 | -2.6250*** | 629.6471*** |
| | const. + trend | -1.7922* | 230.8615 | -2.8992*** | 771.9503*** |
| gini | constant | -0.9227 | 97.2107 | -1.8864*** | 343.2793*** |
| | const. + trend | -1.3753 | 94.5892 | -2.0969*** | 229.6464*** |

Notes:

* Rejects the null of a unit root at the 10% level.

** Rejects the null of a unit root at the 5% level.

*** Rejects the null of a unit root at the 1% level.

indicate that for the variables in levels the null hypothesis of a unit root cannot be rejected. However, the test coefficients of the differenced variables are highly significant and show stationarity in all three cases, regardless of whether a trend is included in the test or not. On this account the following analysis is based on the differenced data, namely income growth and the changes in poverty and inequality.

**Panel cointegration test:**

Since the panel unit root tests indicate that the variables are integrated of order one I(1), the pairwise cointegration is tested using the panel cointegration test developed by Pedroni (1999, 2004). This test allows for heterogeneity in the panel by permitting heterogenous slope coefficients, fixed effects and individual specific deterministic trends. The test contains seven cointegration statistics, four based on pooling the residuals along the "within-dimension", which assume a common value for the unit root coefficient, and three based on pooling the residuals along the "between-dimension", which allow for different values of the unit root coefficient. The basic idea of both classes is to first estimate the hypothesised cointegration relationship separately for each group member of the panel, and then pool the resulting residuals when constructing the test for the null of no cointegration.

**Table 4.3:** Panel cointegration test: Developing world

| | income-gini | income-headcount | gini-headcount |
|---|---|---|---|
| Panel $\upsilon$-test | -2.5645** | -4.2343*** | -2.6806** |
| Panel $\rho$-test | 5.3051*** | 5.2714*** | 6.4547*** |
| Panel $pp$-test | -9.3499*** | -10.4257*** | -4.4079*** |
| Panel $adf$-test | -8.1522*** | -9.3947*** | -4.7184*** |
| Group $\rho$-test | 8.3547*** | 9.0651*** | 9.3222*** |
| Group $pp$-test | 13.2408*** | 12.3244*** | -5.0807*** |
| Group $adf$-test | -4.7604*** | -5.8833*** | 2.2087** |

Notes:

The tests are based on deterministic intercept and trend, and an inclusion of one lag.

* Rejects the null of no cointergation at the 10% level.

** Rejects the null of no cointergation at the 5% level.

*** Rejects the null of no cointergation at the 1% level.

Table 4.3 presents the results for the three pairs of variables. In all cases the null of no cointegration is rejected on at least the 5% significance level, indicating that all three pairs of variables exhibit a cointegration relationship.

**Error correction model:**

Engle and Granger (1987) have shown that, when the series $x$ and $y$ are cointegrated, a standard Granger-causality test, as presented in the equations (4.4) and (4.5), is misspecified. It does not allow for the distinction between the short-run and the long-run effect. At this point an error correction model (ECM) should be used instead. It is a linear transformation of the ADL models above and provides a link between the short-run and the long-run effect (Banerjee et al. 1993, Banerjee, Daldo and Mestre 1998).

$$\begin{aligned} \Delta y_{i,t} &= (\alpha_1 - 1)\Delta y_{i,t-1} + \delta_0 \Delta x_{i,t} + (\delta_0 + \delta_1)\Delta x_{i,t-1} \\ &\quad + \lambda(y_{i,t-2} - \phi x_{i,t-2}) + f_i + u_{i,t} \qquad (4.9) \\ \Delta x_{i,t} &= (\beta_1 - 1)\Delta x_{i,t-1} + \gamma_0 \Delta y_{i,t} + (\gamma_0 + \gamma_1)\Delta y_{i,t-1} \\ &\quad + \kappa(x_{i,t-2} - \phi y_{i,t-2}) + \eta_i + \nu_{i,t} \qquad (4.10) \end{aligned}$$

The coefficients $(\alpha_1 - 1)$, $\delta_0$ and $(\delta_0 + \delta_1)$ as well as $(\beta_1 - 1)$, $\gamma_0$ and $(\gamma_0 + \gamma_1)$ capture the short-run effect, while the coefficients $\lambda$ and $\kappa$ of the error correction term give the adjustment rate at which short-run dynamics converge to the long-run equilibrium relationship. If $\lambda$ and $\kappa$ are negative and significant, a relationship between x and y exists in the long run. The standard procedure is a two-step method where first the error correction term is obtained by saving residuals of separate estimation of the long-run equilibrium, and then the model is estimated. However, the two-stage error correction models have been criticised in the literature. Banerjee, Dolado and Mestre (1998) argue there can be a substantial small-sample bias, compared to a single-equation error correction model where the long-run relation is restricted to being homogeneous. So in this study a one-step procedure is used to indicate the short-run and long-run dynamics. The generalised one-step ECM is transformed as follows:

$$\begin{aligned} \Delta y_{i,t} &= (\alpha_1 - 1)\Delta y_{i,t-1} + \delta_0 \Delta x_{i,t} + (\delta_0 + \delta_1)\Delta x_{i,t-1} \\ &\quad + \lambda(y_{i,t-2} - x_{i,t-2}) + \theta x_{i,t-2} + f_i + u_{i,t} \qquad (4.11) \\ \Delta x_{i,t} &= (\beta_1 - 1)\Delta x_{i,t-1} + \gamma_0 \Delta y_{i,t} + (\gamma_0 + \gamma_1)\Delta x_{i,t-1} \\ &\quad + \kappa(x_{i,t-2} - y_{i,t-2}) + \vartheta x_{i,t-2} + \eta_i + \nu_{i,t} \qquad (4.12) \end{aligned}$$

where the long-run multiplier is restricted to being homogeneous $\phi = 1$. Using this form of the error correction model allows us to calculate the true long-run relationship between $x$ and $y$, which can be written as $1 - (\hat{\theta}/\hat{\lambda})$ and $1 - (\hat{\vartheta}/\hat{\kappa})$, so that the one step ECM permits us to directly calculate the short-run and long-run elasticities between growth, inequality and poverty. To avoid the problem of biased estimates through a possible correlation between the lagged endogenous variable and the error term, we use the Difference GMM estimator developed by Arellano and Bond (1991). The estimator uses all lagged observations to instrument the lagged endogenous variable and circumvent a possible bias. These moment conditions of the instruments can be checked using the Sargan statistic that tests the validity of all instruments. Using the lagged levels dated $t-2$ and earlier as instruments for the equation in first differences, we obtain consistent and efficient parameter estimates.[11]

### 4.3.3 Results

The results of the corresponding error correction regressions are summarised in Table 4.4. Tables A4.2 to A4.7 in the Appendix give the complete picture. They include the coefficients of the regression, the summation of the short-run and the long-run effect with the corresponding Wald test p-values, the Sargan test and the M1 and M2 tests for the regressions. Tables A4.2 and A4.3 explore the dynamics between income growth and changes in inequality, Tables A4.4 and A4.5 investigate the relations between income growth and changes in poverty, and Tables A4.6 and A4.7 reflect the dynamics of changes in inequality and changes in poverty. The tables include the pairwise relationship of two variables, so the first output table contains the results with reference to equation (4.11) whereas the second table is based on equation (4.12). The first column shows the results for the whole panel of 114 developing countries, while the other nine columns show the results for the income and regional subpanels.

To verify GMM consistency, we have to make sure that the instruments are valid. We use the Sargan test of over-identifying restrictions to test the validity of the instrumental variables, which is a general specification test. The hypothesis assumes that the orthogonality conditions of the instrumental variables are satisfied. In the case of the Difference estimator the test indicates that the instruments, as expected, do not correlate with the error term in most of the cases. To check the validity of the System GMM estimator the validity of lagged levels combined with lagged first differences should be considered. In these cases the p-values show less satisfactory results, while the Difference Sargan test, which considers only the additionally used instruments for the System equation, returns insufficient results as well. For this reason we only present the results of the Difference GMM estimator.

[11] For a detailed illustration of the GMM estimator see Chapter 2.3.

The coefficients of the error correction term give the adjustment rate at which short-run dynamics converge to the long-run equilibrium relationship. Generally, except for one value, all these coefficients are negative and highly significant as expected, so the results show that there long-run relationships and provide evidence of a cointegration relationship between all pairs of variables.

The short-run effect can be divided into the effect of the lagged dependent variable and that of the independent variable. The short-time adjustment of the independent variable is measured by the effect of the contemporaneous and lagged change of the independent variable. The significance of the summarised short-run effects, which is simply the sum of the two coefficient values, is tested via a Wald test. It tests if the coefficients are jointly equal to zero. The long-run coefficients indicate the long-run elasticities of the independent on the dependent variable. They are computed by subtracting the ratio of the coefficient of the scale effect (lag of independent variable) from the coefficient of the error correction term; again a Wald test proves the significance of the effect.

In Table 4.4 the short-run and long-run dynamic results are characterised pairwise:

1. With regard to the relationship between per capita income growth and changes in inequality presented in Table 4.4 (Tables A4.2 and A4.3), the results of the short-run effect indicate a positive significant causal effect from changes in inequality on growth and vice versa for the aggregate panel and several subpanels. In other words, higher changes in inequality, measured by changes in the Gini coefficient, generate higher economic growth and higher economic growth causes an increase in the changes of inequality. This is contradictory to the results of Perotti (1993, 1996) and Alesina and Rodrik (1994) who find an overall tendency for inequality to generate lower economic growth in cross-country studies. Whereas these kinds of studies only capture the initial inequality and regress it on average GDP growth, the error correction framework allows detecting permanent changes of inequality over time and their perpetual causal effect on growth. Existing panel studies are in line with our results. Based on growth regressions, these studies show that there is a positive causal effect between growth

**Table 4.4:** Summary of the estimated error correction models: long-run and short-run dynamics

| model | Dev.World | LI | LMI | UMI-HI | EAP | ECA | LAC | MENA | SA | SSA |
|---|---|---|---|---|---|---|---|---|---|---|
| mean income | 143.55 | 51.27 | 93.45 | 246.62 | 78.77 | 257.57 | 210.44 | 151.09 | 58.36 | 61.75 |
| income ← gini | | | | | | | | | | |
| Short-run coefficient | 0.361* | 0.272 | 0.563*** | 0.387 | 1.784*** | 1.052* | 1.712*** | -1.134 | -0.461 | 0.109 |
| Long-run coefficient | 0.177 | 0.206 | -0.058 | 0.322 | 0.981*** | 0.820*** | 0.877** | -1.458 | -0.383 | 0.021 |
| income → gini | | | | | | | | | | |
| Short-run coefficient | 0.053* | 0.039 | 0.098** | 0.010* | 0.268* | 0.131 | 0.111** | -0.045 | -0.223*** | 0.011 |
| Long-run coefficient | 0.018 | 0.046 | 0.066 | -0.031 | 0.247** | 0.061 | 0.261 | 0.025 | -0.066 | -0.008 |
| income ← h | | | | | | | | | | |
| Short-run coefficient | -0.434*** | -1.144*** | -0.674*** | -0.222*** | -0.639*** | -0.310*** | -0.329*** | -0.561*** | -0.751*** | -1.485*** |
| Long-run coefficient | -0.207*** | -0.586*** | -0.344*** | -0.104*** | -0.168 | -0.142* | -0.166*** | -0.302*** | -0.421*** | -0.725*** |
| income → h | | | | | | | | | | |
| Short-run coefficient | -3.619*** | -1.960*** | -4.205*** | -5.114*** | -1.767*** | -4.963*** | -5.335*** | -5.625*** | -3.730*** | -1.617*** |
| Long-run coefficient | -1.622*** | -1.071*** | -1.680*** | -2.580*** | -0.916 | -2.115*** | -2.914*** | -2.710*** | -1.998*** | -0.838*** |
| h ← gini | | | | | | | | | | |
| Short-run coefficient | 3.949** | 0.901 | 4.000** | 5.976** | 1.608** | 4.729** | 2.445 | 3.904 | 5.343 | 0.967* |
| Long-run coefficient | 1.609** | 0.249 | 2.260*** | 2.446 | -0.031 | 1.168 | 0.256 | 8.035 | 1.600*** | 0.386 |
| gini → h | | | | | | | | | | |
| Short-run coefficient | 0.074 | 0.040 | 0.027*** | 0.102 | -0.023 | 0.098** | 0.051*** | -0.003 | 0.201*** | 0.094 |
| Long-run coefficient | 0.050* | 0.006 | 0.009 | 0.070* | -0.059 | 0.099* | 0.038*** | -0.020 | 0.131 | 0.064 |

Notes:
(1) Estimation based on the Arrelano and Bond Difference GMM estimator with robust standard errors.
(2) *, ** and *** denote significance at the 10%, 5% and 1% level.

and inequality, and that faster growth tends to increase inequality. For example, Li and Zou (1998) and Forbes (2000) have reported a positive relationship of inequality on growth and Barro (2001) suggests that higher inequality tends to retard growth in poor countries and encourage growth in richer ones. With respect to the Kuznets relation this also suggests that these countries are situated in the first stage of the Kuznets curve, where inequality increases. Economic development involves a shift of persons and resources from agriculture to the industrial sector. So at the early stage of development the urban and industrial sector, as a small and relatively rich group of persons, expand and lead to a shift that induces a rise in the average per capita income and simultaneously this change raises the overall degree of inequality. Consequently, at early stages of development, the relation between the level of per capita product and the extent of inequality tends to be positive. According to Galor and Tsiddon (1997) inequality and growth are positively related during periods of major technological inventions. They argue that in these periods a decline in the relative importance of initial conditions raises inequality, enhances mobility, and generates a larger concentration of high-ability individuals in technologically advanced sectors, stimulating future technological progress and growth. Only the subpanel for South Asia exhibits a negative significant effect of growth on inequality, which indicates that the capital intensifying process is less dominant, pushing the economy to the right of the maximum of the Kuznets curve and allowing for decreasing inequality. By contrast, the short-run effect of the lagged first difference of the dependent variable is negative and highly significantly related to the simultaneous change of the dependent variable for both income and inequality. This means that in the short run rising inequality is harmful for growth and likewise an increase in income growth causes a reduction in inequality. Concerning the results of the subpanels, the long-run coefficient is significant only in the case of a few subpanels and the effect is positive. The error correction term is always negative and significant. However, as shown in Table 4.4, the results of the income subpanels show that the short-run growth adjustment is faster the higher the average income while the adjustment of inequality is slower with growing income. This is in line with the results of the regional subpanels that show that regions with lower income and higher poverty, namely South Asia, Sub-Saharan Africa and East Asia and Pacific, exhibit a faster short-run growth adjustment, while the adjustment of inequality is slower compared to the regions with higher income.

2. Concerning the dynamics between *income growth* and changes in *poverty* presented in Table 4.4 (Tables A4.4 and A4.5), the results show a clear negative short-run and long-run relationship between these variables. In other words, higher economic growth reduces the extent of poverty measured by changes in the headcount, and in turn falling poverty generates higher income growth. This is consistent with the evidence in the empirical literature which suggests that economic growth is in practice the main tool for fighting poverty (Squire 1993 and Bruno, Ravallion and Squire 1998). Nearly all parameter coefficients in the regressions of the aggregate panel and the subpanels show a negative effect at the 1% significance level. The results further reveal that there is bidirectional causality between growth and changes in poverty, indicating that higher growth reduces poverty and vice versa, although the long-run effect is only half as strong as the short-run effect. Consequently, it becomes apparent that the growth process raises not only the mean income of the country but also the income of the poor and lifts a fraction of the poor population out of poverty. Furthermore, it is evident that in poorer regions poverty reduction has a stronger effect on growth, yet growth has a weaker effect on poverty reduction compared with the wealthier subpanels. This indicates that the level of development impacts on the poverty-reducing effect of growth. Income growth has benefited the poor regions far less. On the other hand poverty decelerates income growth much more slowly in countries with higher average income. So altogether the positive effect of growth on poverty increases with average income and the negative effect of poverty on growth diminishes with average income. However, it must be pointed out that here we measure poverty using an absolute poverty line, so we account only for the

section of the population that moves from one side of the poverty line to the other. We have no information about the redistribution effect of growth below and above the poverty line. The short-run effect of the lagged first difference of the dependent variable is again negative and highly significant related to the simultaneous change of the dependent variable for both directions.

3. Finally, Table 4.4 (Tables A4.6 and A4.7) presents the relationship between changes in inequality and changes in poverty. The long-run effect is positive and significant in both cases indicating that higher inequality generates higher poverty and reversed a rise in the headcount causes a rise in the Gini coefficient. However, the short-run effect is only significant and positive when poverty is the dependent variable. Also, some of the subpanels exhibit a positive short-run and/or long-run effect. In summary, the results suggest a positive causal effect of poverty on inequality and vice versa, confirming recent literature. Ravallion (2001, 2005) and Bourguignon (2004) suggest that the elasticity of poverty to growth declines appreciably as the extent of initial inequality rises. Ravallion (1997) concludes that at any positive rate of growth, the higher the initial inequality, the lower the rate at which income-poverty falls. Deininger and Squire (1997) show that inequality reduces income growth for the poor. Hence, our findings confirm the suggestion that poverty reduction depends strongly on the degree of inequality and that growth reduces poverty more efficiently in more egalitarian countries. Consequently, poverty reduction is determined by growth, income distribution and the change in distribution.

In summary, the results of the study show that all pairs of variables exhibit a causal relationship in both directions and that growth, distribution and poverty reduction are strongly interrelated, so rapid poverty reduction requires a country-specific combination of growth and redistribution policies.

## 4.4 Estimation: China

### 4.4.1 Data

After analysing general relations in a panel of developing countries, in this section we want to focus on China as one of the developing countries and examine the causal relationships between growth, inequality and poverty using more differentiated data for the country. In the previous analysis China was classified as one of the upper-middle income countries, geographically it belongs to the subpanel of East Asia and Pacific. By analysing China separately we want to investigate if the country data reflects the results of the previous analysis. In an optimal way the analysis should be based on provincial data. This would allow accounting for the disparity in the development levels of the provinces and would make the results more comparable to the results of chapter 2 and 3. Unfortunately, inequality and poverty variables are not available for China at provincial level. However, to maximise the number of observation points and so the degrees of freedom we differentiate the data by distinguishing between rural and urban China. And notwithstanding we are aware of the big limitation of pooling rural and urban since the rural and urban regions can exhibit different cause-effect relationships between the variables of interest, the length of the available time period is insufficient for a pure time series analysis. The analysis is based on data from Ravallion and Chen (2007). They provide a data set on income and poverty and inequality measures for urban and rural China based on the Urban Household Surveys and the Rural Household Surveys of China's National Bureau of Statistics (NBS) over the period 1981-2001. In the following, the variables used in the analysis are defined and described. To make the analysis comparable to the country panel analysis we base it on nearly the same variables and time period. Table 4.5 presents the descriptive statistics including the mean and the standard deviation for the aggregate panel and the urban and rural subpanels.

**mean income** $y_{i,t}$ :

Mean income $y_{i,t}$ is measured by the average yearly per capita income in Yuan at 1980

**Table 4.5:** Summary and descriptive statistics: China

| panel | variable | mean | std. dev. |
|---|---|---|---|
| China | income | 547.8852 | 207.7598 |
| | gini | 27.51762 | 5.578252 |
| | headcount | 13.68119 | 15.05609 |
| Urban | income | 672.1267 | 203.7168 |
| | gini | 24.2619 | 5.3354 |
| | headcount | 1.8400 | 1.7172 |
| Rural | income | 423.6438 | 120.7081 |
| | gini | 30.7733 | 3.6144 |
| | headcount | 25.5224 | 12.9348 |

prices.

**headcount** $h_{i,t}$ :

Headcount $h_{i,t}$ denotes the percentage of population living in households with consumption or income per person below the poverty line. Ravallion and Chen (2007) distinguish between an urban and a rural poverty line. The poverty line for the urban region is 1,200 Yuan and the poverty line for the rural region is 850 Yuan per person and year in 2002 prices. The data is deflated by the urban and rural Consumer Price Indices produced by NBS.

**Gini coefficient** $gini_{i,t}$ :

We use the Gini coefficient $gini_{i,t}$ in its common definition as a measure of inequality.

### 4.4.2 Methodology

Again we use the panel unit root tests and cointegration tests to determine whether to use the Granger causality framework or an ECM model to test for causality.

**Panel unit root test:**

Table 4.6 presents the results of the tests for the variables in levels and in differences. The results indicate that while the level data is non-stationary the test coefficients of the

**Table 4.6:** Panel unit root test: China

| variable | deterministic | IPS | Fisher-type | first diff. IPS | first diff. Fisher-type |
|---|---|---|---|---|---|
| income | constant | 2.1980 | 0.5810 | -2.3828*** | 22.5510*** |
| | const. + trend | -0.3226 | 1.0246 | -2.2453** | 15.9358*** |
| headcount | constant | -0.2755 | 3.0440 | -2.9026*** | 34.1741*** |
| | const. + trend | -1.0820 | 3.4818 | -2.8535*** | 24.2197*** |
| gini | constant | -0.0262 | 2.5881 | -3.7319*** | 56.8305*** |
| | const. + trend | -1.5495* | 4.8650 | -3.7473*** | 45.9044*** |

Notes:

* Rejects the null of a unit root at the 10% level.

** Rejects the null of a unit root at the 5% level.

*** Rejects the null of a unit root at the 1% level.

differenced variables are highly significant and show stationarity in all three cases regardless of whether a trend is included in the test or not. Since the variables are integrated of order one I(1), in the next step we test for cointegration.

**Panel cointegration test:**

To test for cointegration once more we use the panel cointegration test developed by Pedroni (1999, 2004). Table 4.7 presents the results of the three pairs of variables. In nearly all cases the null hypothesis of no cointegration is accepted. This result is contradictory to the result of the previous analysis and indicates that all three pairs of variables exhibit no cointegration relationship. In this case a standard Granger causality test can be performed to identify the causal relationship between the variables.

**Granger causality test: Lag length selection:**

The Granger causality test is based on the following bivariate model

**Table 4.7:** Panel cointegration test: China

| | income-gini | income-headcount | gini-headcount |
|---|---|---|---|
| Panel $\upsilon$-test | -2.9736*** | 2.5538*** | 1.4290* |
| Panel $\rho$-test | 0.7694 | 1.1264 | -0.3459 |
| Panel $pp$-test | 0.8562 | 1.0151 | -1.2845* |
| Panel $adf$-test | 1.11663 | 2.8399 | -0.3648 |
| Group $\rho$-test | 1.2716 | 1.5992 | 0.3083 |
| Group $pp$-test | 1.3438 | 1.7288 | -0.9327 |
| Group $adf$-test | 1.4113 | 3.3154 | -0.8635 |

Notes:

The tests are based on deterministic intercept and trend, and an inclusion of one lag.

* Rejects the null of no cointergation at the 10% level.

** Rejects the null of no cointergation at the 5% level.

*** Rejects the null of no cointergation at the 1% level.

$$y_{i,t} = \alpha_0 + \sum_{j=1}^{n} \alpha_j y_{i,t-j} + \sum_{j=0}^{n} \delta_j x_{i,t-j} + f_i + u_{i,t} \qquad (4.13)$$

$$x_{i,t} = \beta_0 + \sum_{j=1}^{m} \beta_j x_{i,t-j} + \sum_{j=0}^{m} \gamma_j y_{i,t-j} + \eta_i + \nu_{i,t}. \qquad (4.14)$$

It is generally acknowledged that the results of the Granger causality test are sensitive to the specification of the lag length. We check for the lag length selection using a sequential Wald test on the results for each of the six equations. Table 4.8 presents the results of the sequential Wald test for one up to four lags based on the Blundell and Bond estimator. The results indicate that for all models except the third two lags should be taken into consideration. The third model should be based on only one lag.

### 4.4.3 Results

Table 4.9 presents a summary of the Granger tests based on the lag length selection.[12] It includes the coefficients of the regression on which the Wald Non-causality test is based,

[12] Detailed results of the corresponding regressions are listed in Tables A4.8 to A4.13 in the Appendix.

**Table 4.8:** Lag length selection

| model | chi2( 1) | chi2( 2) | chi2( 3) | chi2( 4) |
|---|---|---|---|---|
| inequality does | 9.45 | 5.57 | 0.74 | 1.36 |
| not cause growth | (0.0089) | (0.0616) | (0.6902) | (0.5068) |
| growth does | 12.78 | 6.95 | 1.50 | 8.74 |
| not cause inequality | (0.0017) | (0.0309) | (0.4718) | (0.0127) |
| growth does | 30.73 | 4.11 | 4.79 | 10.63 |
| not cause poverty | (0.0000) | (0.1278) | (0.0912) | (0.0049) |
| poverty does | 11.90 | 6.20 | 2.70 | 1.24 |
| not cause growth | (0.0026) | (0.0451) | (0.2588) | (0.5377) |
| inequality does | 205.50 | 5.63 | 0.75 | 6.11 |
| not cause poverty | (0.0000) | (0.0599) | (0.6867) | (0.0471) |
| poverty does | 4.72 | 8.68 | 2.94 | 11.37 |
| not cause inequality | (0.0943) | (0.0131) | (0.2296) | (0.0034) |

the results of the Wald test, the Sargan test and the AR1 and AR2 test for the regressions. For all models the Sargan statistics are satisfactory and the AR2 tests indicate that the instruments, as expected, do not correlate with the error term.

1. The first two rows show the causality relations between changes in inequality and income growth. Although all coefficients show a negative effect, only the direction running from growth to changes in inequality is significant.[13] The hypothesis that growth does not cause inequality is rejected at the 1% significance level. This means that higher income growth Granger causes a decline in inequality measured by changes in the Gini coefficient.[14] According to the Kuznets (Kuznets 1955) inverted U-curve inequality rises with growth at least at the initial stages of the development process. Then, after a certain average income is attained, inequality begins to decrease. So increased inequality is an undesirable consequence of the growth process because it

[13] Correlation coefficient between growth and the lagged value of changes in inequality which are 0.01 for the whole panel, 0.06 for urban China and -0.09 for rural China also indicates that the impact of the lagged inequality measure on growth is very small.

[14] This result is mainly driven by the urban sector. While the correlation coefficient of changes in inequality and the lagged value of growth is -0.25 for the whole panel, the urban sector shows a correlation of -0.62, however, with a correlation coefficient of 0.24 the rural sector shows a positive impact of lagged growth on inequality. It becomes apparent that the mechanism of action is not the same for the urban and rural sector.

**Table 4.9:** Granger causality test

| Null hypothesis | coeff. | Wald test | Sargan | AR1 | AR2 |
|---|---|---|---|---|---|
| inequality does | -0.0663 | chi2( 2) = 3.69 | 44.7523 | -1.4132 | -0.9117 |
| not cause growth | -0.2322 | (0.1577) | (0.6067) | (0.1576) | (0.3619) |
| growth does | -0.5398 | chi2( 2) = 13.36 | 40.0319 | -1.3881 | 0.8241 |
| not cause inequality | -0.3067 | (0.0003) | (0.7864) | (0.1651) | (0.4099) |
| growth does | -5.0525 | chi2( 1) = 4.47 | 52.7787 | -1.1409 | -1.3629 |
| not cause poverty | | (0.0344) | (0.4438) | (0.2539) | (0.1729) |
| poverty does | -0.0247 | chi2( 2) = 6.09 | 46.8215 | -1.4142 | 1.3886 |
| not cause growth | -0.0173 | (0.0477) | (0.5211) | (0.1573) | (0.1650) |
| inequality does | -2.6571 | chi2( 2) = 4.31 | 50.3973 | -1.1189 | -1.0608 |
| not cause poverty | 1.9821 | (0.1159) | (0.3788) | (0.2632) | (0.2888) |
| poverty does | -0.0124 | chi2( 2) =5.61 | 49.5234 | -1.2514 | -0.6424 |
| not cause inequality | -0.0516 | (0.0605) | (0.4122) | (0.2108) | (0.5206) |

may imply that certain population groups are left behind and do not enjoy the fruits of growth. With reference to China our results show that the country has already passed the turning point. After a period of rising inequality due to the preferential open door policy that promoted mainly the coastal region now China, in particular the urban sector, seems to be on a path of decreasing inequality.[15] Using the urban–rural income ratio as a measure of inequality Wan, Lu and Chen (2006) also find a negative effect of growth on inequality, they conclude that amongst others income growth reduces the rural–urban income gap, however in contrast to our results they also find a negative effect of inequality on growth.

2. The rows three and four show the causalities between income growth and poverty. The coefficients are negative and the Wald test rejects the non-causality hypothesis for both directions. So the results reveal that there is bidirectional causality between growth and poverty. The coefficients of the test equations for poverty and the income variable show negative signs in both directions, indicating that higher income growth

[15] However this development is contradictory with the results of Wan, Lu and Chen (2006) and Wan (2004) who argue that a U-pattern is supported by the Chinese data.

Granger causes a reduction in poverty and vice versa. This result supports the current literature and indicates that changes in mean income consistently play the main role in securing changes in poverty. This result is also in line with the results of the previous analysis where we find negative short-run and long-run effects between growth and poverty for a panel of developing countries and all income and geographic subpanels. With regard to the other direction an increase in poverty Granger causes an economic slowdown. It becomes apparent that prevalent poverty has a detrimental impact on productivity and erodes the productive capacity of the economy. Goudie and Ladd (1999) argue that credit market imperfections arising from asymmetric information prevent the poor from taking up productive investment options, particularly in human capital. So a reduction in poverty would reduce the number of typically credit constrained people, and lead to greater economic growth.

3. Finally, the last two rows of Table 4.9 present the results concerning the causal relationships between inequality and poverty. Whereas the hypothesis that inequality does not cause poverty cannot be rejected,[16] the Wald test rejects the non-causality hypothesis for the direction running from poverty to inequality. This means that decreasing poverty generates an increase in inequality. Although for the last years the headcount index shows a decreasing trend, this decline could not generate a beneficial effect on inequality reduction. This means that though the income of the poor increased and a fraction of the poor could pass the poverty line the income of the non-poor increased in such a degree that even so the extent of inequality increased. With regard to the theory the results confirm the fundamental theoretical relations and indicate that increasing capital intensity favours asset income, which leads to more inequality as long as the share of asset holders remains rather stable. At the same time, increasing capital intensity improves labour productivity, and an

[16] A reason for this insignificant result could be attributed to opposite impacts of inequality on poverty for the rural and urban sector. While the correlation between the lagged value of inequality and poverty is negative (-0.27) for the urban sector the rural sector exhibits only a small positive correlation (0.01).

increasing number of people can pass the poverty line, so that decreasing poverty and increasing inequality are connected through capital intensity. Furthermore, Yao, Zhang and Hanmer (2004) suggest that the speed of poverty reduction is affected by the degree of inequality. They argue that the slow progress in reducing poverty has been caused by rising inequality, particularly the urban–rural divide and interregional inequality. However, recapitulatory the results are quite unexpected particularly with regard to the results of the general analysis of the developing world where we identify positive causal relations between inequality and poverty in both directions. Possible causes for these contradictory results are the use of two different methodologies based on the presence of a cointegration and the pooling of the urban and rural data since it ignores possible heterogenous mechanics of action.

The transfer of the general analysis on the case of China turns out to be problematic particularly with regard to data availability. Since inequality and poverty variables are not available for China at provincial level the procedural method applied on the panel of developing countries is adopted on a differently structured panel of urban and rural growth, inequality and poverty in China. Besides that the cointegration relationship identified in the case of the developing world is missing on the rural-urban level in China which translates into a selection of different empirical methodologies. Consequently, the comparability of the results is limited since the analysis is based on the concept of Granger causality whereas the analysis of the developing world is based on ECM. In summary, the results of the Granger causality tests reveal that despite different methodological conditions to some extent the causality relations in China are in line with the general results for the developing world. In particular, the Granger tests between income growth and poverty confirm the negative relationship between both variables, however, inequality and growth and inequality and poverty show different interdependencies.

## 4.5 Summary and conclusion

Growth, inequality and poverty are central elements for evaluating development. After reviewing the current literature, we recall some fundamental theoretical relations between growth, income inequality and poverty. In the empirical section we check the stationarity of the data using two common panel unit root tests, the IPS test by Im, Pesaran and Shin (2003) and the Fisher-type test by Maddala and Wu (1999) and Choi (2001). Pairwise cointegration is tested using the panel cointegration test developed by Pedroni (1999, 2004). This test allows for heterogeneity in the panel by permitting heterogenous slope coefficients, fixed effects and individual specific deterministic trends. In a further step the causality relations are analysed by applying GMM techniques to an error correction model (ECM) to estimate the pairwise short-run and long-run dynamics for income growth and changes in inequality and poverty. First, we apply the methodology on a large panel of developing countries. The analysis is based on the World Bank´s PovcalNet database. This database, the result of the work of Chen and Ravallion (2007), includes data on income and poverty and inequality measures for a large number of developing countries. Our analysis uses a balanced panel of 114 countries for the period 1981-2005; also the panel is split into three subpanels according to per capita income and six subpanels according to its geographical location. The results of the error correction regressions confirm the theoretical model and show that all pairs of variables exhibit a causal relationship in both directions and that growth, distribution and poverty reduction are strongly interrelated. While growth and inequality exhibit a positive bidirectional causal effect, the relationship between growth and poverty is negative, indicating that growth indeed reduces poverty. Yet the results also show that the level of development affects the poverty-reducing effect of growth. Income growth has benefited the poor regions far less. Furthermore, there appears to be a positive causality between inequality and poverty, suggesting that a successful poverty reduction strategy requires both economic growth and a sound redistribution policy. The second part of the analysis focuses on China and uses rural and urban data form 1981 to 2001 to investigate the interdependencies between growth, inequality and poverty for a single country. The results for China support the negative relationship between growth and poverty, however inequality and growth and inequality and poverty show negative interdependencies.

# Chapter 5

# Concluding remarks

Since the economic reform the People's Republic of China has recorded a remarkably high level of economic growth. As industrialisation, specialisation, FDI and trade raised economic growth and living standards in China, poverty has fallen dramatically over the last two decades. Since 1978, China alone accounted for most of the world's decline in poverty. Even though there has been a huge rise in income inequality within the country, between the provinces and between rural and urban China, economic growth has been so strong that hundreds of millions of people have risen out of extreme poverty and the poverty headcount has sunk. However, since the favourable open door policy was restricted mainly to the coastal region, the eastern provinces have experienced much higher growth rates than the central and western region. This uneven development strategy has caused rising inequality within China and poverty reduction has been very uneven across provinces.

It becomes apparent that economic growth, inequality and poverty are mutually interdependent phenomena: growth rate affects distribution and distribution affects growth, in turn both have an impact on poverty reduction, and poverty in turn effects inequality and growth. For this reason this thesis highlights all three aspects and their potential relationships to reveal a complete picture of China's development process. The goal of the thesis is to identify sources of successful development. Furthermore, we analyse how the unequal distribution of these development sources across China's provinces attributes to the interprovincial inequality in income. Finally, we focus on the interdependence of these variables and analyse the causal directions in the long and in the short run.

The uneven provincial development raises the question concerning the sustainability of the successful development process. We find a catching up, non-steady state process across China's provinces indicating that the provinces are on a converging path. This result shows promise for a comprehensive expansion of the successful development. The poorer provinces can catch up to the richer ones, leading to a decline in the country's inequality. Analysing the factors of provincial growth we find two sources of development. On the one hand international integration in terms of trade and FDI is driving growth through the channels of imitation of international technologies, technology spill-overs and dynamic scale effects. On the other hand domestic capital in terms of physical capital and human capital also shows a highly significant positive effect on GDP growth. This result indicates that China's success story is not solely driven by internationalisation and opening up but also by domestic sources. Regarding human capital, higher education seems to play a far more important role than primary and secondary education, this result is also reflected in the analysis of the determinants of inequality where secondary education enters insignificantly while the falling inequality in higher education has a significant contribution to the reduction of inequality.

The inequality analysis identifies a falling inequality between 1978 and 1990 and a rise in inequality in the subsequent period, which is mainly driven by the inequality between the western, central and eastern region and within the eastern region. This result indicates that the preferential policy of the coastal region accelerated the development process on the one hand, on the other hand the uneven promotion led to a rising inequality not only across China but also in the eastern region itself. The distributions of physical capital, trade and infrastructure also show a rise in inequality in this period, these variables enter positively significant as determinants of income inequality. On the contrary FDI and human capital inequality show a decreasing trend leading to a decline in income inequality, which is identified by negative significant regression coefficients. More specifically, it is apparent that disparities in growth determinants raise income inequality while a decline in the factor inequality involves a decline in income inequality.

The analysis of the causal directions between growth, inequality and poverty confirms the interdependent relationship of these variables, the results show that income growth, distribution and poverty reduction are strongly interrelated. Concerning the long-run relationship between growth, inequality and poverty we find a cointegration relationship between these variables for a panel of 114 developing countries, however, analysing solely China there is a lack of long-run relations. With regard to income growth and poverty the results show a negative causal connection in both directions in the long and in the short run. Furthermore, the level of development affects the causal effects. While the poverty-reducing effect of growth is stronger for wealthier countries, the growth effect of poverty reduction is stronger in poorer countries. For China the short-run results are consistent with the country panel findings. As expected growth has a poverty reducing effect, the growth process raises not only the mean income but also the income of the poor leading to a decrease in the headcount. Besides that, we find positive causality relations between growth and inequality and between inequality and poverty in the country panel analysis; however, the analysis of China shows negative causality directions running from growth to inequality and from poverty to inequality. This indicates that the rural region is in the process of catching up to the urban region which reduces the inequality in China.

In summary, the challenge for policy makers is to create an incentive scheme that promotes not only the eastern region but in particular the central and western region. The government has to find the right combination of growth-promoting policies with the right policies to assure that the poor can participate fully in the opportunities unleashed, and so contribute to that growth. The right combination can help China to continue the rapid poverty reduction of the last decades, to broaden growth across China and so to reduce interprovincial inequality. For example, China has started a wave of preferential policies for China's western development, which is mainly focused on taxation, land and favourable conditions for foreign capital utilisation. Future research can help to identify the gains and implications of these policy directions.

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# Appendix

## A1.1 Divisions of administrative areas and geographical classification in China

With an area of 9.6 Million square kilometres the People's Republic of China, in the following abbreviated as China, is the third biggest country in the world, next to Russia and Canada, and with a population of 1.3 Billion the most populous country in the world. China's capital is Beijing and the country abuts on 14 neighbour states. It ranges 4500 km from north to south and 4200 km from east to west with a coast line of 18000 km of the mainland and 14000 km of the island. Because of its size it does not astonish that within the country there are huge distinctions in climate, habitability and physical altitude. Regarding the subdivision of the country on the provincial level China is divided into 23 provinces, 5 municipalities and 2 autonomous regions. Administratively, the country is classified into three regions: east, central and west. The eastern region consists of nine coastal provinces Liaoning, Hebei, Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, Hainan and Guangxi and three municipalities Tianjin, Beijing, and Shanghai. The central region includes nine provinces and autonomous regions consisting of Heilongjiang, Jilin, Inner Mongolia, Shanxi, Henan, Anhui, Hubei, Hunan and Jiangxi. Lastly, the western region covers the ten provinces and autonomous regions of Shaanxi, Gansu, Ningxia, Sichuan, Chongqing, Yunnan, Guizhou, Qinghai, Xinjiang and Tibet.[1] Another classification divides China into two regions, the coastal and the interior. Here the coastal region is equivalent to the eastern region, the central and western regions correspond to the interior region. Table A1.1 and Figure A1.1 give a recapitulatory overview of the provinces and their characteristics.

[1] In 1997 Chongqing which used to be part of Sichuan became a separate province.

**Table A1.1:** China's provinces and their characteristics

| Province | Area in km$^2$ | Population | Capital |
|---|---|---|---|
| Liaoning | 148000 | 4375 | Shenyang |
| Hebei | 188000 | 7194 | Shijiazhuang |
| Tianjin | 11900 | 1299 | Tianjin |
| Beijing | 16410 | 1962 | Beijing |
| Shandong | 157000 | 9588 | Jinan |
| Jiangsu | 103000 | 7869 | Nanjing |
| Shanghai | 6000 | 2303 | Shanghai |
| Zhejiang | 102000 | 5447 | Hangzhou |
| Fujian | 121400 | 3693 | Fuzhou |
| Guangdong | 180000 | 10441 | Guangzhou |
| Hainan | 35000 | 869 | Haikou |
| Guangxi | 237000 | 4610 | Nanning |
| Heilongjiang | 454000 | 3833 | Harbin |
| Jilin | 187000 | 2747 | Changchun |
| Inner Mongolia | 1183000 | 2472 | Hohhot |
| Shanxi | 156000 | 3735 | Taiyuan |
| Henan | 167000 | 9405 | Zhengzhou |
| Anhui | 139000 | 5957 | Hefei |
| Hubei | 186000 | 5728 | Wuhan |
| Hunan | 211800 | 6570 | Changsha |
| Jiangxi | 167000 | 4462 | Nanchang |
| Shaanxi | 206000 | 3735 | Xi'an |
| Gansu | 454000 | 2560 | Lanzhou |
| Ningxia | 66000 | 633 | Yinchuan |
| Sichuan | 485000 | 8045 | Chengdu |
| Chongqing | 82000 | 2885 | Chongquing |
| Yunnan | 394000 | 4602 | Kunming |
| Guizhou | 176000 | 3479 | Guiyang |
| Qinghai | 697000 | 563 | Xining |
| Xinjiang | 1665000 | 2185 | Urumqi |
| Tibet | 1228000 | 301 | Lhasa |

Population in 10000 (2010)

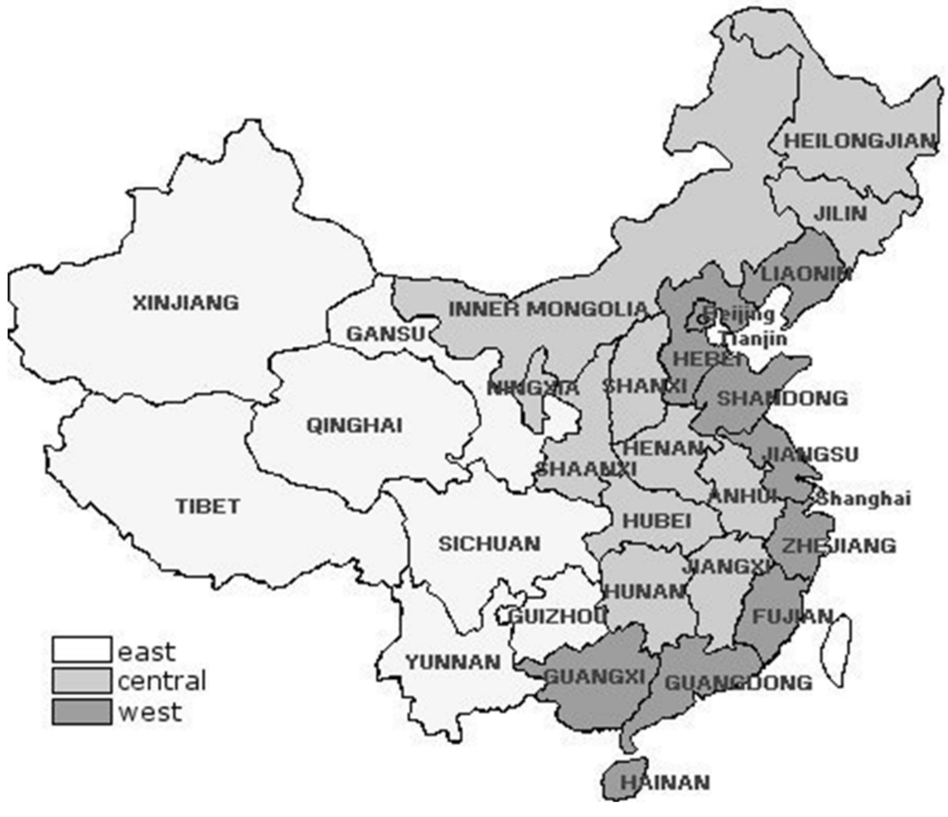


**Figure A1·1:** China's provinces

## A1.2 Economic development in China

Economic development in China can be divided into two periods, i.e., the pre-reform period (1949 – 1977) and the reform period (after 1978).

The pre-reform period began on Oct, 1st 1949 when the Chinese Communist Party (CCP) under Mao Zedong formally established the People's Republic of China. Economic development was impressive in this period. The main targets that Mao had were adapting Marxism-Leninism to the Chinese conditions, abatement of inflation, improvement of infrastructure and building up of agriculture. The economic history since 1953 is characterized by Five-Year-Plans in which the economic and social objectives were set for the following five years.

The First-Five-Year-Plan (1953-1957) designates the transition to socialism based on the Soviet model. The economic policy under Mao Zedong was affected by the introduction of a centrally planned economy that called for collectivisation of agriculture and political centralisation. The main objective of this plan was a quickest possible industrialisation, which was to be supported by a socialized agriculture.

A new economic campaign under the name "The Great Leap Forward" instituted the second Five-Year period in 1958. This social and economic plan aimed to accomplish the technical progress and economic development of the country and transform China from a primarily agrarian economy into a modern, leading industrial power.

Following the Soviet model, Mao saw grain and steel production and a massive supply of cheap labour as the main sources of success for the industrial sector. However, the concentration on the heavy industry led to a disregard of the agricultural sector. To resolve the disadvantages, Mao introduces a new socioeconomic and political system - the people's communes. Each commune was planned as an independent and self-contained economic unit and assumed the responsibility for trade, investment, education, industry, agriculture and planning. Decentralisation of agriculture, basic technologies and co-operation of mechanical and manpower should be the key to economic development. "The Great Leap Forward" was an economic disaster, the produced commodities were of inferior quality and the chaos of the restructuring and the rural collectivisation disabled the agriculture and resulted in a famine, it is estimated that the number of dead constituted several millions. The failure of the campaign resulted in a change of government. As a political consequence Mao Zedong resigned his position as president in 1959, although remained chairman of the CCP and Liu Shaqi was elected as his successor. With a readjustment the economy recovered rapidly and the agricultural achievements strengthen the new president.

However, with the support of the Lin Biao and Jiang Qing counter-revolutionary cliques, Mao gradually regained more and more control and initiated the "cultural revolution" in 1966. With the objective of establishing a "communistic world" all culture which didn't comply with the proletarian pattern was oppressed and prohibited, millions of intellectuals who were blamed for the capitalistic idea were relocated to rural areas, adverse literature, art and cultural assets were destroyed. The isolated foreign policy and the calamity brought by the revolution resulted in massive setbacks for China and manifested into an economic, political and social chaos.

The reform period started in 1978. After the death of Mao Zedong in 1976 a power struggle broke out in which Deng Xiaoping prevailed and became the leader of the new government. This political change ushered in a new era. The new government implemented scores of economic reforms which are known as the "Four Modernisations". The goal was to strengthen the sectors of agriculture, industry, technology and defence. The first stage from 1978 to 1983 is characterised by a reform in the agricultural sector as a result of the replacement of the Commune system with the household responsibility system. Thereupon the government also promoted non-agricultural activities such as village enterprises in rural areas and forward the more self-management for the state-owned enterprises (SOEs). Emphasis was put on the development of the home market as well as on the opening to the outside world. In this phase China established a stable relationship to foreign trading enterprises, developed its economic relations with the rest of the world and began to promote an open-door policy. As the centrally planned actions encountered its limits and lost effectiveness, an important component of the economic reforms was the formation of Special Economic Zones (SEZs). In 1979 the government started a stepwise opening up of China's domestic markets with the objective of integrating them into the global economy. The first four SEZs were set up in the provinces Guangdong and Fujian as an experiment and aimed to introduce an external market-oriented economic system. To attract foreign capital these zones were encouraged with preferential policies such as duty and tax incentives, build-up of a better infrastructure, reduction of bureaucracy and more flexible labour and wage policy and gained autonomy of decision. Economic development in the SEZs proved to be extremely successful so that the government decided to extend further preferential zones and opened 14 coastal cities in 1984 followed by Hainan in 1988 and Shanghai in 1989. SOEs had to rival with private and foreign enterprises.

Since the implementation of economic reforms and opening up to the world market China experienced a continuously high rate of annual growth. The unprecedented boom in foreign direct investment (FDI), and the sustained increase in trade were of impressive dimensions. This positive economic development induced an enormous improvement in the standard of living for China and had an important impact on the global economy regarding the effect of foreign investment decision and international trade.

However, because the open door policy was restricted to only a few cities and the economic boom did not spread out across the rest of China, it promoted only a few provinces in the coastal area. The shady side of this economic success story was a rising inequality within the country and lasting poverty in rural areas.

## A2.1 Determining the aggregate production level of the region

$$
\begin{aligned}
y_i &= A_i H_i^{\alpha} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} y_i \right)^{\beta} K_i^{1-\alpha-\beta} \\
y_i &= A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \\
Y_i &= \frac{y_i}{A^{\frac{1}{1-\beta}}} \quad \text{hence} \quad Y_i = \omega_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}
$$

### A2.2 Steady state determination and reactions of $\omega_i^*$ when $H_i, K_i$, $\tau_i$, $\tau_i^{ex}$ and $\gamma$ are changing

Solve for $\dot{\omega}$ by plugging in:

$$\begin{aligned}
\dot{\omega}_i(t) &= G(t)_i^{\delta_G} F(t)_i^{\delta_F} - \omega(t), \\
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left( \frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r} \right)^{\delta_F} y(t)_i^{\delta} - \omega(t)
\end{aligned}$$

$$y_i = \omega_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left( \frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r} \right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}$$

$$\begin{aligned}
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left( \frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r} \right)^{\delta_F} \\
&\quad \left[ \omega(t)_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left( \frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r} \right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} - \omega(t)
\end{aligned}$$

$$\begin{aligned}
\dot{\omega}_i(t) &= \gamma^{\delta_G} \left( \frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t). \\
\frac{d\dot{\omega}_i(t)}{d\omega(t)} &= \frac{\delta}{1-\beta} \Psi_i \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)_i^{\frac{\delta-1+\beta}{1-\beta}} - 1 < 0 \\
&\quad \text{as } H_i \text{ and } K_i \text{ are assumed to be sufficiently small}
\end{aligned}$$

To simplify, this equation is rewritten as

$$\begin{aligned}
\dot{\omega}_i(t) &= \Psi_i \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega(t)^{\frac{\delta}{1-\beta}} - \omega(t) \qquad \text{see} \qquad (2.7) \\
\text{with} \quad \Psi_i &:= \gamma^{\delta_G} \left( \frac{\left(1-\tau_i^{ex}\right)\left(1-\gamma_i\right)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta}.
\end{aligned}$$

solve for the steady state position:

$$\begin{aligned}
0 &= \dot{\omega}_i(t) = \Psi_i \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega^{\frac{\delta}{1-\beta}} - \omega \\
\omega &= \Psi_i \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega^{\frac{\delta}{1-\beta}} \\
\omega^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}
\end{aligned}$$

$$\Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} = \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} (\varphi_i)^{\frac{\delta_F(1-\beta)+\delta\beta}{(1-\beta-\delta)}}$$

$$\omega_i^* = \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} (\varphi_i)^{\frac{\delta_F(1-\beta)+\delta\beta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \qquad \text{see} \qquad (2.8)$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial K_i}$:

$$\begin{aligned}
\omega_i^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \\
\frac{\partial \omega_i^*}{\partial K_i} &= \frac{\delta(1-\beta)}{1-\beta-\delta} \frac{1-\beta-\alpha}{1-\beta} \Psi_i^{\frac{1-\beta}{1-\beta-\delta}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}-1} K_i^{\frac{1-\beta-\alpha}{1-\beta}-1} H_i^{\frac{\alpha}{1-\beta}} \\
&= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* K_i^{-1} > 0,
\end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \tau_i}$:

$$\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i} &= \frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \frac{\partial \Psi_i}{\partial \tau_i} \\
\frac{\partial \Psi_i}{\partial \tau_i} &= -\left[ \delta_F + \frac{\beta}{1-\beta}\delta \right] \gamma^{\delta_G} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta - 1} \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \tau_i^{-1} \\
&= -\left[ \delta_F + \frac{\beta}{1-\beta}\delta \right] \gamma^{\delta_G} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \tau_i^{-1} = -\left[ \delta_F + \frac{\beta}{1-\beta}\delta \right] \Psi_i \tau_i^{-1}
\end{aligned}$$

$$\begin{aligned}\frac{\partial \omega_i^*}{\partial \tau_i} &= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}}\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_F+\frac{\beta}{1-\beta}\delta\right]\Psi_i\tau_i^{-1}\\ &= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right]\left[\delta_F+\frac{\beta}{1-\beta}\delta\right]\omega^*\tau_i^{-1}<0 \qquad \text{see} \qquad (2.9)\end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \tau_i^{ex}}$:

$$\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} = \frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}}\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\frac{\partial \Psi_i}{\partial \tau_i^{ex}}$$

$$\begin{aligned}\frac{\partial \Psi_i}{\partial \tau_i^{ex}} &= -\left[\delta_F+\frac{\beta}{1-\beta}\delta\right]\gamma^{\delta_G}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta-1}\frac{\beta}{\tau_i r}\\ &= -\left[\delta_F+\frac{\beta}{1-\beta}\delta\right]\Psi_i(1-\tau_i^{ex})^{-1}\end{aligned}$$

$$\begin{aligned}\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)}\Psi_i^{\frac{\delta}{(1-\beta-\delta)}}\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\left[\delta_F+\frac{\beta}{1-\beta}\delta\right]\Psi_i(1-\tau_i^{ex})^{-1}\\ &= -\frac{(1-\beta)}{(1-\beta-\delta)}\left[\delta_F+\frac{\beta}{1-\beta}\delta\right]\omega_i^*(1-\tau_i^{ex})^{-1} \qquad \text{see} \qquad (2.11)\end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \gamma_i}$:

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \Psi_i^{-1} \frac{\partial \Psi_i}{\partial \gamma_i}$$

$$\begin{aligned}
\frac{d\Psi_i}{d\gamma_i} &= \delta_G \gamma_i^{\delta_G - 1} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \\
&\quad - \left( \delta_F + \frac{\beta}{1-\beta}\delta \right) \gamma_i^{\delta_G} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta - 1} \frac{(1-\tau_i^{ex})\beta}{\tau_i r} \\
&= \Psi_i \left[ \delta_G \gamma_i^{-1} - \left( \delta_F + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right]
\end{aligned}$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \left[ \delta_G \gamma_i^{-1} - \left( \delta_F + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right] \quad \text{see} \quad (2.12)$$

## A2.3 Optimal level of government activities

$$\begin{aligned}
\max_{\gamma_i} \; \omega^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \qquad \Psi_i := \gamma_i^{\delta_G} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \\
\frac{\partial \omega_i^*}{\partial \gamma_i} &= \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)} \Psi_i^{-1} \frac{\partial \Psi_i}{\partial \gamma_i} \\
\frac{d\Psi_i}{d\gamma_i} &= \Psi_i \left[ \delta_G \gamma_i^{-1} - \left( \delta_F + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1} \right] = 0 \\
\delta_G &= \gamma_i \left( \delta_F + \frac{\beta}{1-\beta}\delta \right) (1-\gamma_i)^{-1}
\end{aligned}$$

$$\gamma_i^* = \frac{\delta_G}{\left( \delta_F + \frac{\beta}{1-\beta}\delta + \delta_G \right)}$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{\omega_i^*}{1-\delta} \Psi_i^{-1} \frac{\partial \Psi_i}{\partial \gamma_i} \quad \text{with}$$

$$\frac{\partial \Psi_i}{\partial \gamma_i} \begin{cases} > 0 & \qquad \gamma_i < \gamma_i^* \qquad \text{underinvestment, undertaxation} \\ = 0 \quad \text{for} & \qquad \gamma_i = \gamma_i^* \qquad \text{growth maximizing tax rate} \\ < 0 & \qquad \gamma_i > \gamma_i^* \qquad \text{overinvestment, overtaxation} \end{cases}$$

**Table A2.1:** Correlation matrix

| Variable | $\triangle y_{i,t}$ | $y_{i,t-1}$ | $\triangle K_{i,t}$ | $\triangle POP_{i,t}$ | $\triangle HC_{i,t}$ | $\triangle FDI_{i,t}$ | $\triangle T_{i,t}$ | $\triangle GOV1_{i,t}$ | $\triangle GOV2_{i,t}$ | $POPKM2$ | $URBAN$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| $\triangle y_{i,t}$ | 1.0000 | | | | | | | | | | |
| $y_{i,t-1}$ | -0.0216 | 1.0000 | | | | | | | | | |
| $\triangle K_{i,t}$ | 0.5615 | -0.0344 | 1.0000 | | | | | | | | |
| $\triangle POP_{i,t}$ | -0.0159 | 0.1507 | -0.1039 | 1.0000 | | | | | | | |
| $\triangle HC_{i,t}$ | 0.2123 | -0.2146 | 0.1969 | -0.0538 | 1.0000 | | | | | | |
| $\triangle FDI_{i,t}$ | 0.1333 | 0.0209 | 0.0671 | 0.0023 | 0.2313 | 1.0000 | | | | | |
| $\triangle T_{i,t}$ | 0.4445 | 0.1171 | 0.1114 | 0.0406 | 0.1325 | 0.2138 | 1.0000 | | | | |
| $\triangle GOV1_{i,t}$ | -0.2412 | 0.1741 | -0.1662 | -0.0362 | 0.2362 | 0.0183 | -0.1166 | 1.0000 | | | |
| $\triangle GOV2_{i,t}$ | -0.3789 | -0.0997 | -0.2215 | 0.0550 | 0.2566 | -0.1041 | -0.3417 | 0.5995 | 1.0000 | | |
| $POPKM2_{i,t}$ | -0.0117 | 0.6374 | -0.0295 | 0.0200 | -0.1421 | -0.0275 | 0.1593 | 0.1353 | -0.0508 | 1.0000 | |
| $URBAN_{i,t}$ | 0.0690 | 0.8002 | -0.1208 | 0.1614 | -0.2573 | 0.0383 | 0.1507 | 0.1221 | -0.1149 | 0.5193 | 1.0000 |
| $\triangle MARKET_{i,t}$ | 0.3529 | 0.0518 | 0.0274 | 0.1095 | -0.0561 | 0.2361 | 0.2992 | -0.0974 | -0.2638 | -0.0430 | 0.1815 |

**Table A2.2:** Variance inflation factors

| Variable | model 1 | model 2 | model 3 |
|---|---|---|---|
| $y_{i,t-1}$ | 3.65 | 3.40 | 3.67 |
| $\triangle K_{i,t}$ | 1.23 | 1.24 | 1.17 |
| $\triangle POP_{i,t}$ | 1.05 | 1.05 | 1.09 |
| $\triangle HC_{i,t}$ | 1.04 | 1.43 | 1.35 |
| $\triangle FDI_{i,t}$ | 1.19 | | |
| $\triangle T_{i,t}$ | | 1.09 | 1.34 |
| $\triangle GOV1_{i,t}$ | 1.75 | 1.73 | 1.83 |
| $\triangle GOV2_{i,t}$ | 1.79 | 1.74 | 2.10 |
| $POPKM2_{i,t}$ | 1.67 | 1.68 | 1.76 |
| $URBAN_{i,t}$ | 2.76 | 2.69 | 3.10 |
| $\triangle MARKET_{i,t}$ | | | 1.24 |
| Mean VIF | 1.83 | 1.78 | 1.87 |

## A3.1 Determining the aggregate production level of the province

$$
\begin{aligned}
y_i &= A_i H_i^{\alpha} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} y_i \right)^{\beta} K_i^{1-\alpha-\beta} \\
y_i^{1-\beta} &= A_i H_i^{\alpha} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\beta} K_i^{1-\alpha-\beta} \\
y_i &= A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \\
Y_i &= \frac{y_i}{A^{\frac{1}{1-\beta}}} \quad \text{hence} \quad Y_i = \omega_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}
$$

## A3.2 Determining export values by a household decision and international capital costs

$$
\begin{aligned}
\max &: U = C^{\lambda}\, \mathrm{Im}^{1-\lambda}, \\
s.t. &: 0 = y(1-\gamma_i) - \tau_i r \mathcal{F}_i - C_i - p_i(1-\tau_i^{ex})\, \mathrm{Im}_i
\end{aligned}
$$

**Table A2.3:** OLS and FE estimates

Dependent variable: $\triangle y_{i,t}$

| | model 1 | | | | model 2 | | | | model 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OLS | | FE | | OLS | | FE | | OLS | | FE | |
| | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. | Coef. | Std. Err. |
| $y_{i,t-1}$ | -0.049*** | (0.007) | -0.256*** | (0.014) | -0.062*** | (0.008) | -0.241*** | (0.012) | -0.016*** | (0.006) | -0.206*** | (0.051) |
| $\triangle K_{i,t}$ | 0.598*** | (0.088) | 0.599*** | (0.084) | 0.575*** | (0.094) | 0.569*** | (0.084) | 0.535*** | (0.079) | 0.683*** | (0.092) |
| $\triangle POP_{i,t}$ | 0.561** | (0.187) | 0.635** | (0.265) | 0.515*** | (0.193) | 0.687** | (0.294) | 0.031 | (0.213) | 0.428** | (0.202) |
| $\triangle HC_{i,t}$ | -0.099*** | (0.028) | -0.051** | (0.019) | -0.126*** | (0.026) | -0.064*** | (0.019) | 0.073** | (0.030) | 0.049 | (0.030) |
| $\triangle FDI_{i,t}$ | 0.044*** | (0.005) | 0.007 | (0.005) | | | | | | | | |
| $\triangle T_{i,t}$ | | | | | 0.099*** | (0.013) | 0.055*** | (0.009) | 0.053*** | (0.013) | 0.049*** | (0.016) |
| $\triangle GOV1_{i,t}$ | -0.020 | (0.025) | -0.057** | (0.021) | 0.004 | (0.026) | -0.057*** | (0.019) | -0.030 | (0.026) | -0.025 | (0.027) |
| $\triangle GOV2_{i,t}$ | -0.238*** | (0.044) | -0.155*** | (0.032) | -0.271*** | (0.045) | -0.147*** | (0.030) | -0.066* | (0.039) | -0.046 | (0.040) |
| $POPKM2_{i,t}$ | -0.000*** | (0.000) | -0.000 | (0.000) | 0.000*** | (0.000) | -0.000 | (0.000) | 0.000 | (0.000) | 0.000 | (0.000) |
| $URBAN_{i,t}$ | -0.082*** | (0.020) | -0.011 | (0.051) | 0.101*** | (0.020) | -0.021 | (0.043) | 0.063*** | (0.018) | 0.139** | (0.053) |
| $\triangle MARKET_{i,t}$ | | | | | | | | | 0.108*** | (0.029) | 0.088*** | (0.031) |
| $R^2$ | 0.5569 | | | | 0.5361 | | | | 0.5720 | | | |
| adj. $R^2$ | 0.5453 | | | | 0.5239 | | | | 0.5486 | | | |
| $R^2_{within}$ | | | 0.7683 | | | | 0.7922 | | | | 0.6659 | |
| Obs | 353 | | 353 | | 353 | | 353 | | 194 | | 194 | |

Note: *, ** and *** denote significance at the 10%, 5% and 1% level.

Robust standard errors

$$\begin{aligned}
FOC &: \\
\frac{dU_i}{dC_i} &= \lambda C_i^{\lambda-1}\,\mathrm{Im}_i^{1-\lambda} = 1, \qquad \frac{dU_i}{d\,\mathrm{Im}_i} = (1-\lambda)\,C_i^{\lambda}\,\mathrm{Im}_i^{-\lambda} = p_i(1-\tau_i^{ex}) \\
[1-\beta]\,(1-\gamma_i)\,y_i - C_i &= (1-\lambda)\,[1-(1-\tau_i^{ex})\beta]\,(1-\gamma_i)\,y_i \\
\frac{\mathcal{E}x_i}{y_i} &= \varepsilon_i = (1-\lambda)\,[1-(1-\tau_i^{ex})\beta]\,(1-\gamma_i)
\end{aligned}$$

### A3.3 Steady state determination and reactions of $\omega_i^*$ when $H_i, K_i$, $\tau_i$, $\tau_i^{ex}$ and $\gamma$ are changing

Solve for $\dot{\omega}$ by plugging in:

$$\begin{aligned}
\dot{\omega}_i(t) &= (G(t)_i)^{\delta_G}\,(F(t)_i)^{\delta_F}\,(Ex(t)_i)^{\delta_{Ex}} - \omega(t), \\
\dot{\omega}_i(t) &= A^{\frac{\delta}{1-\beta}}\left(A^{-\frac{1}{1-\beta}}\gamma y(t)_i\right)^{\delta_G}\left(A^{-\frac{1}{1-\beta}}\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}y(t)_i\right)^{\delta_F}\left(A^{-\frac{1}{1-\beta}}\varepsilon_i y(t)_i\right)_i^{\delta_{Ex}} - \omega(t)
\end{aligned}$$

$$y_i = A_i^{\frac{1}{1-\beta}}H_i^{\frac{\alpha}{1-\beta}}\left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\frac{\beta}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}$$

$$\begin{aligned}
\dot{\omega}_i(t) &= \gamma^{\delta_G}\left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta}\varepsilon_i^{\delta_{Ex}}\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\omega(t)_i^{\frac{\delta}{1-\beta}} - \omega(t). \\
\frac{d\dot{\omega}_i(t)}{d\omega(t)} &= \frac{\delta}{1-\beta}\Psi_i\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\omega(t)_i^{\frac{\delta-1+\beta}{1-\beta}} - 1 < 0 \\
&\quad \text{as } H_i \text{ and } K_i \text{ are assumed to be suff. small}
\end{aligned}$$

To simplify, this equation is rewritten as

$$\begin{aligned}
\dot{\omega}_i(t) &= \Psi_i\left[H_i^{\frac{\alpha}{1-\beta}}K_i^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta}\omega(t)^{\frac{\delta}{1-\beta}} - \omega(t) \qquad \text{see} \qquad (3.10) \\
\text{with}\quad \Psi_i &:= \gamma_i^{\delta_G}\left(\frac{(1-\tau_i^{ex})\,(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta}\varepsilon_i^{\delta_{Ex}}. \qquad \text{see} \qquad (3.12)
\end{aligned}$$

Solve for the steady state position:

$$\begin{aligned} 0 &= \dot{\omega}_i(t) \\ 0 &= \Psi_i \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\delta} \omega^{\frac{\delta}{1-\beta}} - \omega \\ \omega^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \end{aligned}$$

$$\Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} = \left[ \gamma_i^{\delta_G} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \varepsilon_i^{\delta_{Ex}} \right]^{\frac{(1-\beta)}{(1-\beta-\delta)}}$$

$$\omega_i^* = \gamma_i^{\delta_G \frac{(1-\beta)}{(1-\beta-\delta)}} (\varphi_i)^{\frac{\delta_F(1-\beta)+\delta\beta}{(1-\beta-\delta)}} \varepsilon_i^{\delta_{Ex} \frac{(1-\beta)}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \qquad \text{see} \qquad (3.11)$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial K_i}$:

$$\begin{aligned} \omega_i^* &= \Psi_i^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \\ \frac{\partial \omega_i^*}{\partial K_i} &= \frac{\delta(1-\beta)}{1-\beta-\delta} \frac{1-\beta-\alpha}{1-\beta} \Psi_i^{\frac{1-\beta}{1-\beta-\delta}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}-1} K_i^{\frac{1-\beta-\alpha}{1-\beta}-1} H_i^{\frac{\alpha}{1-\beta}} \end{aligned}$$

$$\begin{aligned} &= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* K_i^{-\frac{1-\beta-\alpha}{1-\beta}} K_i^{\frac{-\alpha}{1-\beta}} \\ &= \frac{\delta(1-\beta-\alpha)}{1-\beta-\delta} \omega_i^* K_i^{-1} > 0, \quad \text{see} \quad (3.13) \end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \tau_i}$:

$$\frac{\partial \omega_i^*}{\partial \tau_i} = \frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \frac{\partial \Psi_i}{\partial \tau_i}$$

$$\begin{aligned}
\frac{\partial \Psi_i}{\partial \tau_i} &= -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \gamma^{\delta_G} \varepsilon_i^{\delta_{Ex}} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta - 1} \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \tau_i^{-1} \\
&= -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \gamma^{\delta_G} \varepsilon_i^{\delta_{Ex}} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta} \tau_i^{-1} = -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \Psi_i \tau_i^{-1}
\end{aligned}$$

$$\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \Psi_i \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right] \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \Psi_i^{\frac{1-\beta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \tau_i^{-1} \\
&= -\left[\frac{(1-\beta)}{(1-\beta-\delta)}\right] \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \omega^* \tau_i^{-1} < 0 \qquad \text{see} \qquad (3.14)
\end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \tau_i^{ex}}$:

$$\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} = \frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \frac{\partial \Psi_i}{\partial \tau_i^{ex}}$$

$$\begin{aligned}
\frac{\partial \Psi_i}{\partial \tau_i^{ex}} &= -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \gamma^{\delta_G} \varepsilon_i^{\delta_{Ex}} \left( \frac{(1-\tau_i^{ex})(1-\gamma_i)\beta}{\tau_i r} \right)^{\delta_F + \frac{\beta}{1-\beta}\delta - 1} \frac{\beta}{\tau_i r} \\
&= -\left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \Psi_i (1-\tau_i^{ex})^{-1}
\end{aligned}$$

$$\begin{aligned}
\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \Psi_i (1-\tau_i^{ex})^{-1} \\
&= -\frac{(1-\beta)}{(1-\beta-\delta)} \Psi_i^{\frac{\delta}{(1-\beta-\delta)} + \frac{(1-\beta-\delta)}{(1-\beta-\delta)}} \left[ H_i^{\frac{\alpha}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}} \right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] (1-\tau_i^{ex})^{-1} \\
\frac{\partial \omega_i^*}{\partial \tau_i^{ex}} &= -\frac{(1-\beta)}{(1-\beta-\delta)} \left[\delta_F + \frac{\beta}{1-\beta}\delta\right] \omega_i^* (1-\tau_i^{ex})^{-1} \qquad \text{see} \qquad (3.15)
\end{aligned}$$

Steady state reactions $\frac{\partial \omega_i^*}{\partial \gamma_i}$:

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)}\Psi_i^{-1}\frac{\partial \Psi_i}{\partial \gamma_i}$$

$$\begin{aligned}\frac{d\Psi_i}{d\gamma_i} &= \delta_G \gamma_i^{\delta_G - 1}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta} \\ &\quad -\left(\delta_F+\frac{\beta}{1-\beta}\delta\right)\gamma_i^{\delta_G}\varepsilon_i^{\delta_{Ex}}\left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r}\right)^{\delta_F+\frac{\beta}{1-\beta}\delta-1}\frac{(1-\tau_i^{ex})\beta}{\tau_i r} \\ &= \Psi_i\left[\delta_G\gamma_i^{-1}-\left(\delta_F+\frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right]\end{aligned}$$

$$\frac{\partial \omega_i^*}{\partial \gamma_i} = \frac{(1-\beta)\,\omega_i^*}{(1-\beta-\delta)}\left[\delta_G\gamma_i^{-1}-\left(\delta_F+\frac{\beta}{1-\beta}\delta\right)(1-\gamma_i)^{-1}\right] \quad see \quad (3.16)$$

## A3.4 Slope of the final development curve $\Omega^D$

$$\Omega^D = \frac{\omega_1^*}{\omega_2^*} = \frac{\Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[H_1^{\frac{\alpha}{1-\beta}}K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}}{\Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}}\left[H_2^{\frac{\alpha}{1-\beta}}K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}} \quad \text{and} \quad (3.17)$$

$$d\Omega^D = \frac{\omega_2^*}{(\omega_2^*)^2}\frac{\partial\omega_1}{\partial K_1}dK_1 - \frac{\omega_1^*}{(\omega_2^*)^2}\frac{\partial\omega_2}{\partial K_2}dK_2 = \frac{1}{(\omega_2^*)^2}(\omega_2^*\frac{\partial\omega_1}{\partial K_1}+\omega_1^*\frac{\partial\omega_2}{\partial K_2})adK_1$$

$$\frac{d\Omega^D}{dK_1} = \frac{1}{(\omega_2^*)^2}(\omega_2^*\frac{\partial\omega_1^*}{\partial K_1}+\omega_1^*\frac{\partial\omega_2^*}{\partial K_2}a) > 0 \quad \text{since} \quad \frac{\partial\omega_i^*}{\partial K_i} > 0.$$

Properties of the curve:

$$\begin{aligned}
\lim_{K_1\to 0}\Omega^D &= 0, \lim_{K_1\to K}\Omega^D = \infty \\
\lim_{K_1\to o}\frac{d\Omega^D}{dK_1} &: \\
\frac{d\Omega^D}{dK_1} &= \frac{1}{(\omega_2^*)^2}\left[\omega_2^*\frac{\partial\omega_1^*}{\partial K_1}+\omega_1^*\frac{\partial\omega_2^*}{\partial K_2}a\right] \\
&= \frac{1}{\omega_2^*}\left[\frac{\partial\omega_1^*}{\partial K_1}+\Omega^D\frac{\partial\omega_2^*}{\partial K_2}a\right] \\
\text{since } \lim_{K_1\to o}\frac{\partial\omega_1^*}{\partial K_1} &= \lim_{K_1\to o}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_1^*K_1^{-1}=\infty \\
&\Longrightarrow \lim_{K_1\to o}\frac{d\Omega^D}{dK_1}=\infty
\end{aligned}$$

$$\begin{aligned}
\lim_{K_1\to K}\frac{d\Omega^D}{dK_1} &: \\
\text{since } \lim_{K_1\to K}\frac{\partial\omega_2^*}{\partial K_2} &= \lim_{K_1\to K}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega_2^*K_2^{-1}=\infty \quad \text{and} \\
\lim_{K_1\to K}a(K_1,K_2) &= \frac{\left[1+\left(1+\frac{\mu_1}{(1-\varepsilon_1)}\right)\sigma K_1^{\left(\frac{\mu_1}{(1-\varepsilon_1)}\right)}\right]}{\left[1+\left(1+\frac{\mu_2}{(1-\varepsilon_2)}\right)\sigma K_2^{\left(\frac{\mu_2}{(1-\varepsilon_2)}\right)}\right]}=\infty \\
&\Longrightarrow \lim_{K_1\to K}\frac{d\Omega^D}{dK_1}=\infty
\end{aligned}$$

### A3.5 Slope of the final development curve $\Omega^D$, identical provinces: $\omega_1^*=\omega_2^*$

$$\begin{aligned}
\frac{d\Omega^D}{dK_1} &= \frac{1}{(\omega_2^*)^2}\left(\omega_2^*\frac{\partial\omega_1^*}{\partial K_1}+\omega_1^*\frac{\partial\omega_2^*}{\partial K_2}\right) \\
&= \frac{2}{\omega_i^*}\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}\omega^*K_i^{-1} \\
&= 2\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}K_i^{-1}>0 \qquad \text{for identical provinces}
\end{aligned}$$

## A3.6 Dynamic adjustment

$$\begin{aligned}\frac{\dot{\Omega}}{\Omega} &= \frac{\dot{\omega}_1}{\omega_1} - \frac{\dot{\omega}_2}{\omega_2} \\ &= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \omega_1^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \omega_2^{-\frac{1-\beta-\delta}{1-\beta}}\end{aligned}$$

$$a_i(t) = \omega_i(t)/\omega_i^*$$

$$\begin{aligned}\frac{\dot{\Omega}}{\Omega} &= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} [a_1\omega_1^*]^{-\frac{1-\beta-\delta}{1-\beta}} - \Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} [a_2\omega_2^*]^{-\frac{1-\beta-\delta}{1-\beta}} \\ &= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \left[a_1 \Psi_1^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\right]^{-\frac{1-\beta-\delta}{1-\beta}} \\ &\quad -\Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} \left[a_2 \Psi_2^{\frac{(1-\beta)}{(1-\beta-\delta)}} \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\frac{\delta(1-\beta)}{(1-\beta-\delta)}}\right]^{-\frac{1-\beta-\delta}{1-\beta}}\end{aligned}$$

$$\begin{aligned}&= \Psi_1 \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} a_1^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_1^{-1} \left[H_1^{\frac{\alpha}{1-\beta}} K_1^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{-\delta} \\ &\quad -\Psi_2 \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{\delta} a_2^{-\frac{1-\beta-\delta}{1-\beta}} \Psi_2^{-1} \left[H_2^{\frac{\alpha}{1-\beta}} K_2^{\frac{1-\beta-\alpha}{1-\beta}}\right]^{-\delta}\end{aligned}$$

$$\begin{aligned}&= a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} \\ \text{for} \quad \Omega(t) &= \frac{a(t)_1}{a(t)_2}\Omega^D > \Omega^D \Longrightarrow a(t)_1 > a(t)_2 \\ &\Longrightarrow a(t)_1^{-\frac{1-\beta-\delta}{1-\beta}} - a(t)_2^{-\frac{1-\beta-\delta}{1-\beta}} < 0 \Longrightarrow \frac{\dot{\Omega}(t)}{\Omega(t)} < 0 \quad \text{see} \quad (3.19)\end{aligned}$$

## A3.7 Reaction of the final development curve $\Omega^D$, $\frac{d\Omega^D}{d\tau_1}, \frac{d\Omega^D}{d\tau_1^{ex}}$

$$\begin{aligned}
\frac{d\Omega^D}{d\tau_1} &= \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1} < 0 \quad \text{see} \quad (3.14) \\
\frac{d\Omega^D}{d\tau_1^{ex}} &= \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{with} \quad \frac{\partial\omega_1^*}{\partial\tau_1^{ex}} < 0 \quad \text{see} \quad (3.15)
\end{aligned}$$

## A3.8 Determining the domestic interest rate

$$\begin{aligned}
\pi_i &= (1-\gamma_i)\, y_i - i_i K_i - \rho_i H_i \\
\text{with} \quad y_i &= A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha}{1-\beta}}
\end{aligned}$$

$$\begin{aligned}
i_i &= \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_i)\, A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{1-\beta-\alpha-1+\beta}{1-\beta}} \\
i_i &= \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_i)\, A_i^{\frac{1}{1-\beta}} H_i^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_i^{ex})(1-\gamma_i)\,\beta}{\tau_i r_i}\right)^{\frac{\beta}{1-\beta}} K_i^{\frac{-\alpha}{1-\beta}}
\end{aligned}$$

Derive the *interest parity curve*:

$$\begin{aligned}
i_1 &= i_2 \\
& \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_1)\, A_1^{\frac{1}{1-\beta}} H_1^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\,\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} K_1^{\frac{-\alpha}{1-\beta}} \\
&= \frac{1-\beta-\alpha}{1-\beta}(1-\gamma_2)\, A_2^{\frac{1}{1-\beta}} H_2^{\frac{\alpha}{1-\beta}} \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\,\beta}{\tau_2 r_2}\right)^{\frac{\beta}{1-\beta}} K_2^{\frac{-\alpha}{1-\beta}}
\end{aligned}$$

$$
\begin{aligned}
\frac{A_1{}^{\frac{1}{1-\beta}}}{A_2{}^{\frac{1}{1-\beta}}} &= \frac{p_2\,(1-\gamma_2)\,H_2^{\frac{\alpha}{1-\beta}}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\frac{\beta}{1-\beta}} K_2^{\frac{-\alpha}{1-\beta}}}{p_1\,(1-\gamma_1)\,H_1^{\frac{\alpha}{1-\beta}}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\frac{\beta}{1-\beta}} K_1^{\frac{-\alpha}{1-\beta}}} \\
\Omega^{IP} &= \frac{A_1}{A_2} = \frac{(1-\gamma_2)^{1-\beta}\,H_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_2^{-\alpha}}{(1-\gamma_1)^{1-\beta}\,H_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_1^{-\alpha}}
\end{aligned}
$$

Slope of the *interest parity curve* :

$$
\begin{aligned}
\Omega^{IP} &= \Omega^{IP}(K_1, K_2) \quad \text{and (3.17)} \\
\Omega^{IP} &= \frac{\omega_1}{\omega_2} = \frac{(1-\gamma_2)^{1-\beta}\,H_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta} K_1^{\alpha}}{(1-\gamma_1)^{1-\beta}\,H_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta} K_2^{\alpha}} \\
\Omega^{IP} &= C\frac{K_1^{\alpha}}{K_2^{\alpha}} = CK_1^{\alpha}K_2^{-\alpha} \quad \text{.with} \quad C = \frac{(1-\gamma_2)^{1-\beta}\,H_2^{\alpha}\left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^{\beta}}{(1-\gamma_1)^{1-\beta}\,H_1^{\alpha}\left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^{\beta}}
\end{aligned}
$$

$$
\begin{aligned}
d\Omega^{IP} &= \alpha C\frac{K_1^{\alpha-1}}{K_2^{\alpha}}dK_1 - \alpha C\frac{K_1^{\alpha}K_2^{\alpha-1}}{[K_2^{\alpha}]^2}dK_2 = \alpha C\left[\frac{K_1^{\alpha-1}}{K_2^{\alpha}}dK_1 - \frac{K_1^{\alpha}K_2^{-1}}{K_2^{\alpha}}dK_2\right] \\
&= \alpha C\frac{K_1^{\alpha}}{K_2^{\alpha}}\left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0
\end{aligned}
$$

Properties of the curve:

$$
\lim_{K_1\to 0}\Omega^{IP} = 0, \lim_{K_1\to 0}\frac{d\Omega^{IP}}{dK_1} = \infty, \lim_{K_1\to K}\Omega^{IP} = \infty, \lim_{K_1\to K}\frac{d\Omega^{IP}}{dK_1} = \infty.
$$

## A3.9 Slope of the interest parity curve, identical provinces

$$
\begin{aligned}
&= \alpha C\frac{K_1^{\alpha}}{K_2^{\alpha}}\left[\frac{1}{K_1} + \frac{1}{K_2}\right] > 0 \\
C &= 1, \qquad \text{for identical provinces} \\
\frac{d\Omega^{IP}}{dK_1} &= \alpha C\left[\frac{2}{K} + \frac{2}{K}\right] = \frac{4\alpha}{K} > 0
\end{aligned}
$$

### A3.10 Reactions of the interest parity curve

$$\Omega^{IP} = \frac{(1-\gamma_2)^{1-\beta} H_2^\alpha \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^\beta K_1^\alpha}{(1-\gamma_1)^{1-\beta} H_1^\alpha \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^\beta K_2^\alpha},$$

$$\text{with} \quad C = \frac{(1-\gamma_2)^{1-\beta} H_2^\alpha \left(\frac{(1-\tau_2^{ex})(1-\gamma_2)\beta}{\tau_2 r_2}\right)^\beta}{(1-\gamma_1)^{1-\beta} H_1^\alpha \left(\frac{(1-\tau_1^{ex})(1-\gamma_1)\beta}{\tau_1 r_1}\right)^\beta}, \quad \text{and} \quad B = \frac{K_1^\alpha}{K_2^\alpha}$$

$$\frac{d\Omega^{IP}}{d\tau_1} = B\frac{\partial C}{\partial \tau_1} > 0, \frac{d\Omega^{IP}}{d\tau_1^{ex}} = B\frac{\partial C}{\partial \tau_1^{ex}} > 0, \frac{d\Omega^{IP}}{d\tau_1} = B\frac{\partial C}{\partial \gamma_1} > 0$$

### A3.11 Relative slope of the final development position and the interest parity condition for identical provinces

$$\frac{d\Omega^D}{dK_1} < \frac{d\Omega^{IP}}{dK_1}$$

$$4\frac{\delta(1-\beta-\alpha)}{1-\beta-\delta}K^{-1} < \frac{4\alpha}{K}$$

$$\delta - \delta\beta < \alpha - \alpha\beta$$

$$\delta < \alpha$$

### A3.12 Equilibrium reaction of local capital allocation

As we start from point $B_0$ in fig 3·4 we have identical provinces in the starting position:

Reaction $\frac{dK_1}{d\tau_1}$

$$\frac{\partial\Omega^{IP}}{\partial K_1}dK_1 + \frac{\partial\Omega^{IP}}{\partial \tau_1}d\tau_1 = \frac{\partial\Omega^{D}}{\partial K_1}dK_1 + \frac{\partial\Omega^{D}}{\partial \tau_1}d\tau_1$$

$$\frac{dK_1}{d\tau_1} = \frac{\frac{\partial\Omega^D}{\partial\tau_1} - \frac{\partial\Omega^{IP}}{\partial\tau_1}}{\frac{\partial\Omega^{IP}}{\partial K_1} - \frac{\partial\Omega^D}{\partial K_1}}$$

$$\frac{\partial\Omega^D}{\partial\tau_1} = \frac{1}{\omega_2^*}\frac{\partial\omega_1^*}{\partial\tau_1} < 0, \quad \frac{\partial\Omega^{IP}}{\partial\tau_1} > 0$$

$$\frac{\partial \Omega^{IP}}{\partial K_1} - \frac{\partial \Omega^{D}}{\partial K_1} > 0, \quad \text{since (3.25) holds}$$

and hence

$$\frac{dK_1}{d\tau_1} = \frac{\frac{\partial \Omega^{D}}{\partial \tau_1} - \frac{\partial \Omega^{IP}}{\partial \tau_1}}{\frac{\partial \Omega^{IP}}{\partial K_1} - \frac{\partial \Omega^{D}}{\partial K_1}} < 0$$

Reaction $\frac{dK_1}{d\gamma_1}$ (for $\gamma_i > \gamma_i^*$)

$$\frac{\partial \Omega^{IP}}{\partial K_1} dK_1 + \frac{\partial \Omega^{IP}}{\partial \gamma_1} d\gamma_1 = \frac{\partial \Omega^{D}}{\partial K_1} dK_1 + \frac{\partial \Omega^{D}}{\partial \tau_1} d\gamma_1$$

$$\frac{dK_1}{d\gamma_1} = \frac{\frac{\partial \Omega^{D}}{\partial \gamma_1} - \frac{\partial \Omega^{IP}}{\partial \gamma_1}}{\frac{\partial \Omega^{IP}}{\partial K_1} - \frac{\partial \Omega^{D}}{\partial K_1}}$$

$$\frac{\partial \Omega^{D}}{\partial \gamma_1} = \frac{1}{\omega_2^*} \frac{\partial \omega_1^*}{\partial \gamma_1} < 0 \quad \text{for } \gamma_i > \gamma_i^*, \quad \frac{\partial \Omega^{IP}}{\partial \tau_1} > 0$$

$$\frac{\partial \Omega^{IP}}{\partial K_1} - \frac{\partial \Omega^{D}}{\partial K_1} > 0, \quad \text{since (3.25) holds}$$

and hence

$$\frac{dK_1}{d\gamma_1} = \frac{\frac{\partial \Omega^{D}}{\partial \gamma_1} - \frac{\partial \Omega^{IP}}{\partial \gamma_1}}{\frac{\partial \Omega^{IP}}{\partial K_1} - \frac{\partial \Omega^{D}}{\partial K_1}} < 0$$

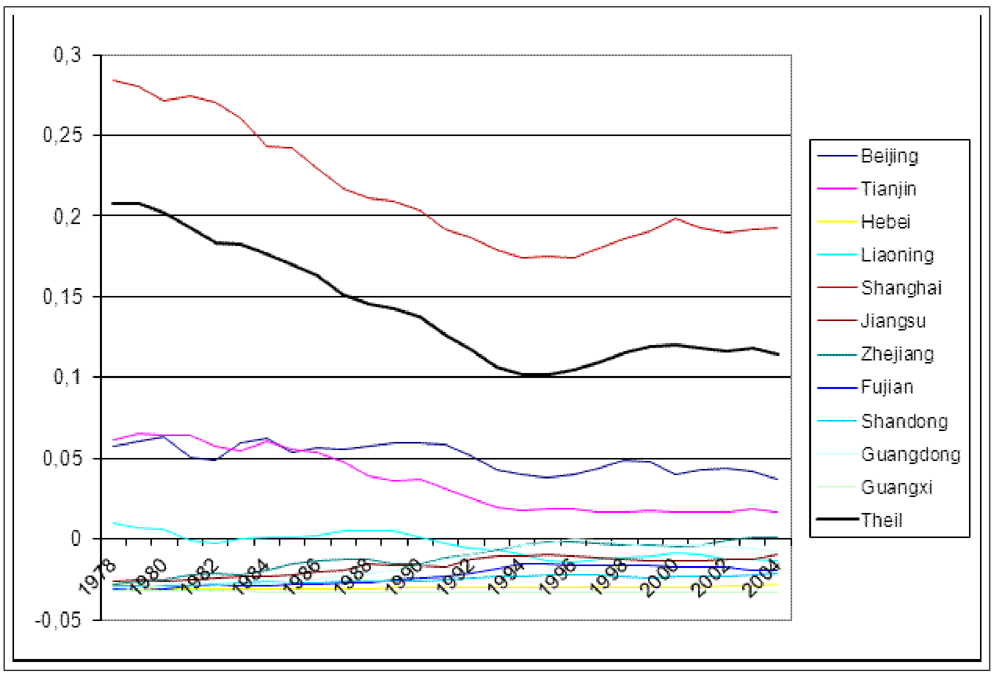


**Figure A3·1:** Theil index of eastern China and provincial contribution (1978-2004)

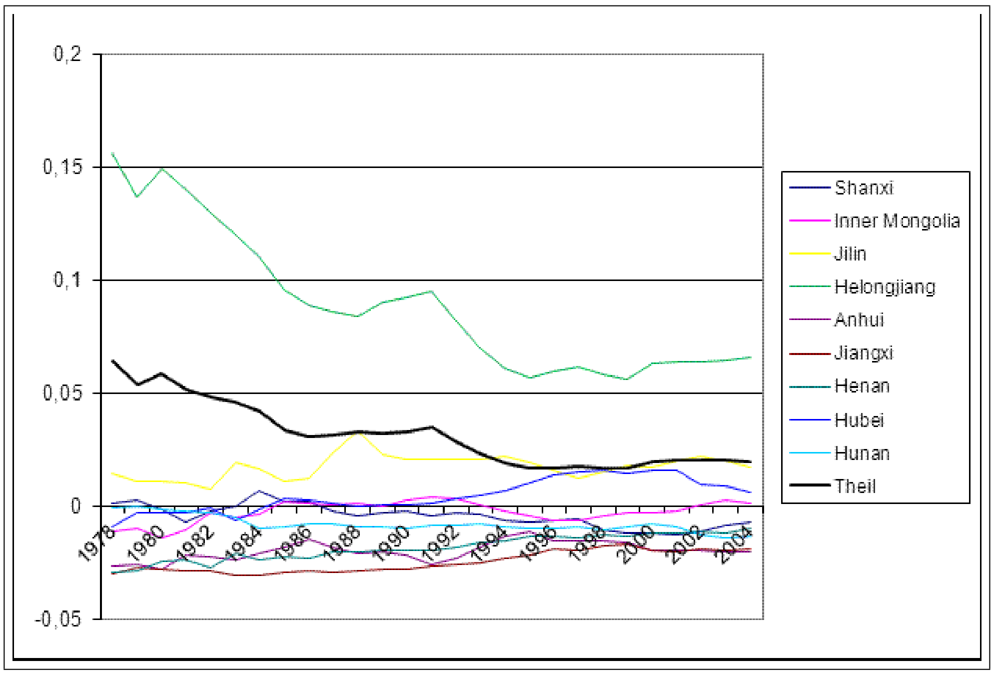


**Figure A3·2:** Theil index of central China and provincial contribution (1978-2004)

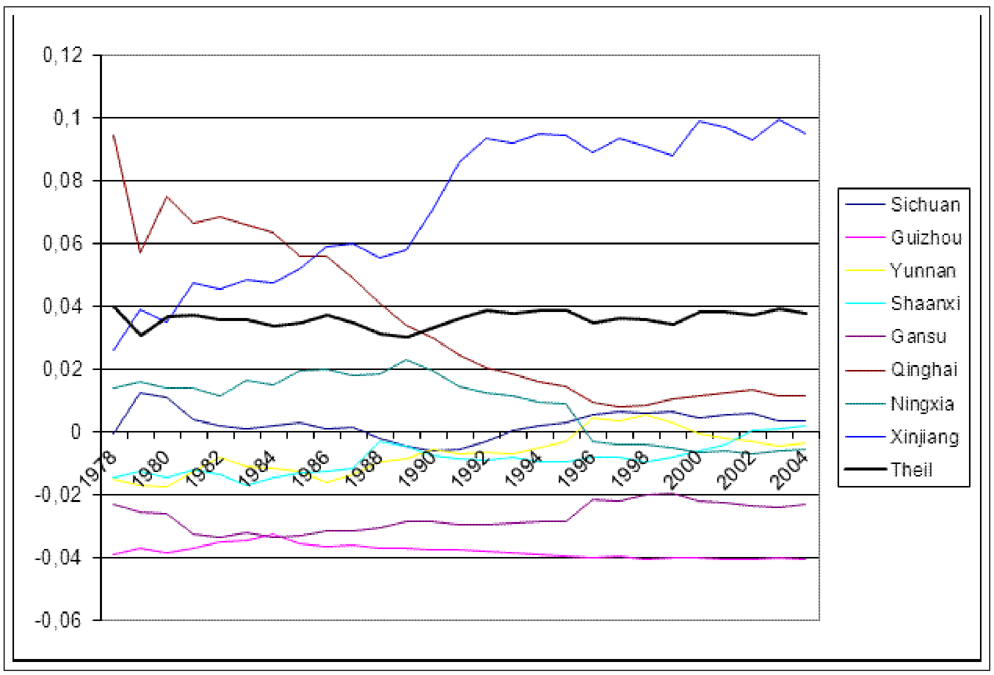


**Figure A3·3:** Theil index of western China and provincial contribution (1978-2004)

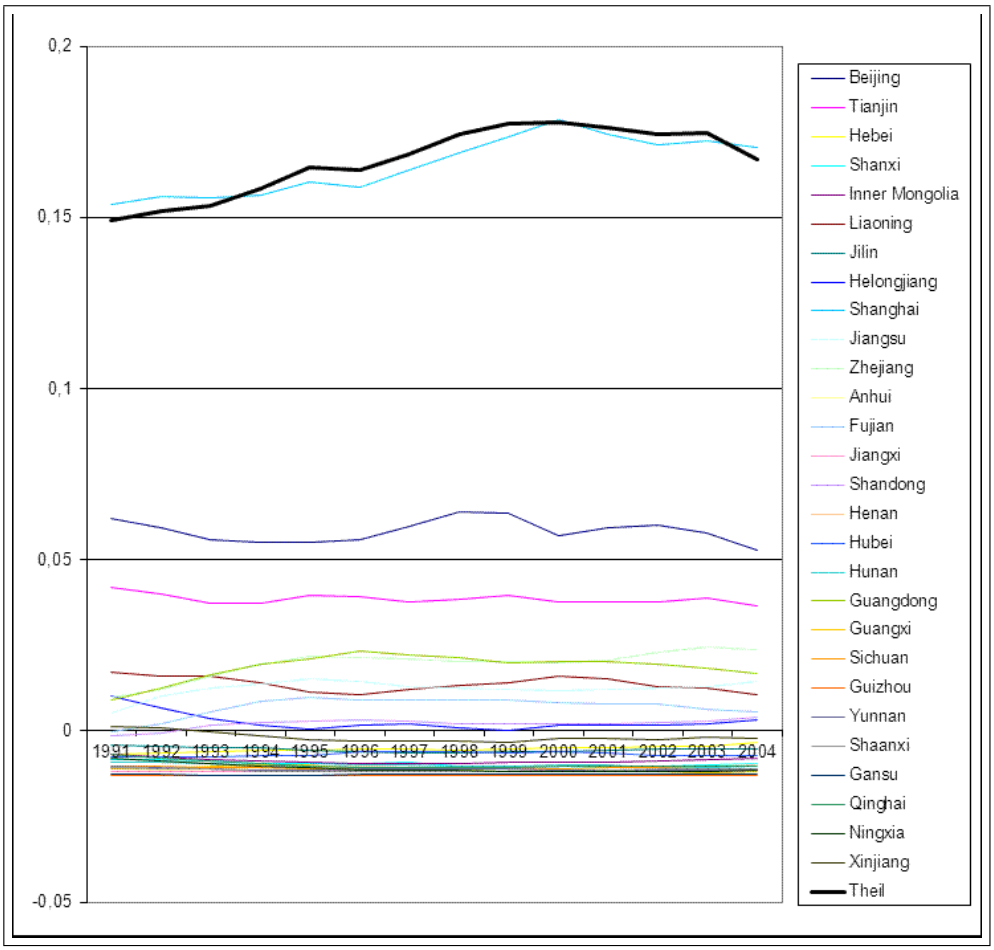


**Figure A3·4:** GDP Theil index and provincial contribution (1991-2004)

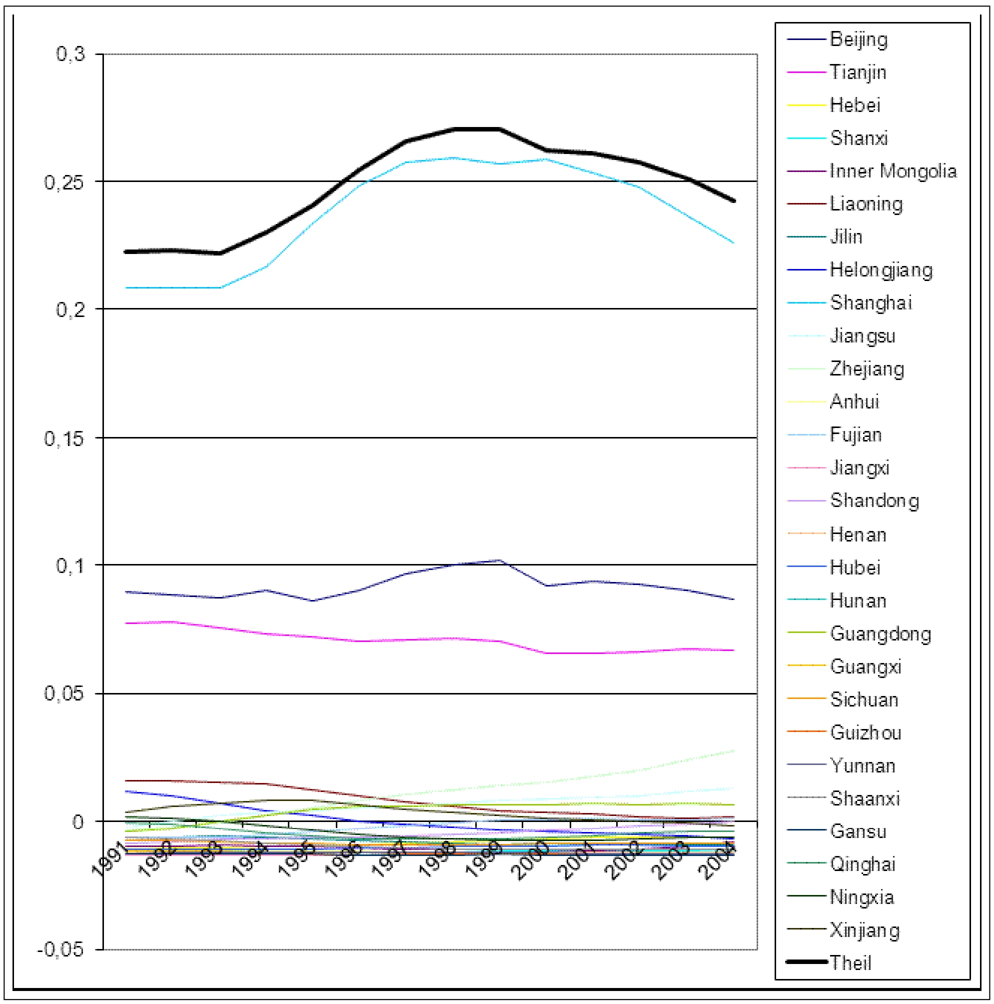


**Figure A3·5:** Capital Theil index and provincial contribution (1991-2004)

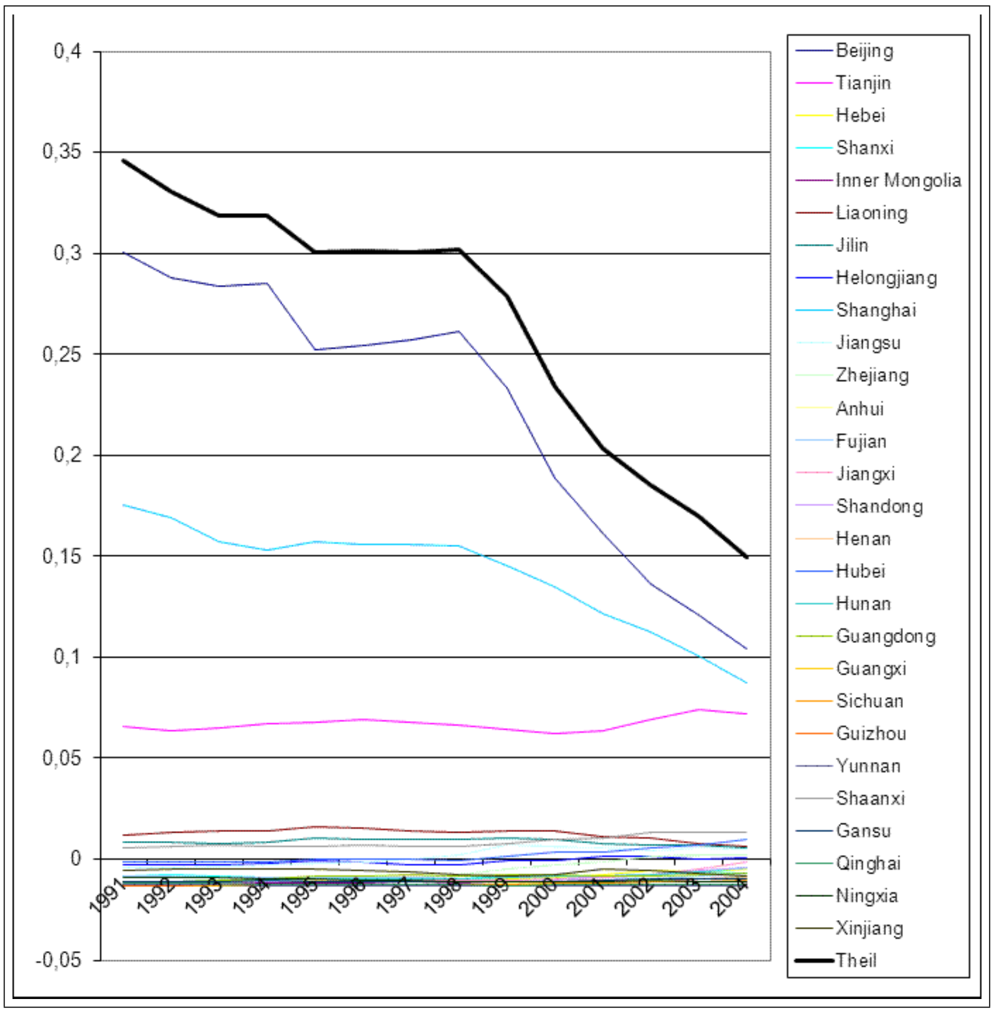


**Figure A3·6:** Human capital (higher education) Theil index and provincial contribution (1991-2004)

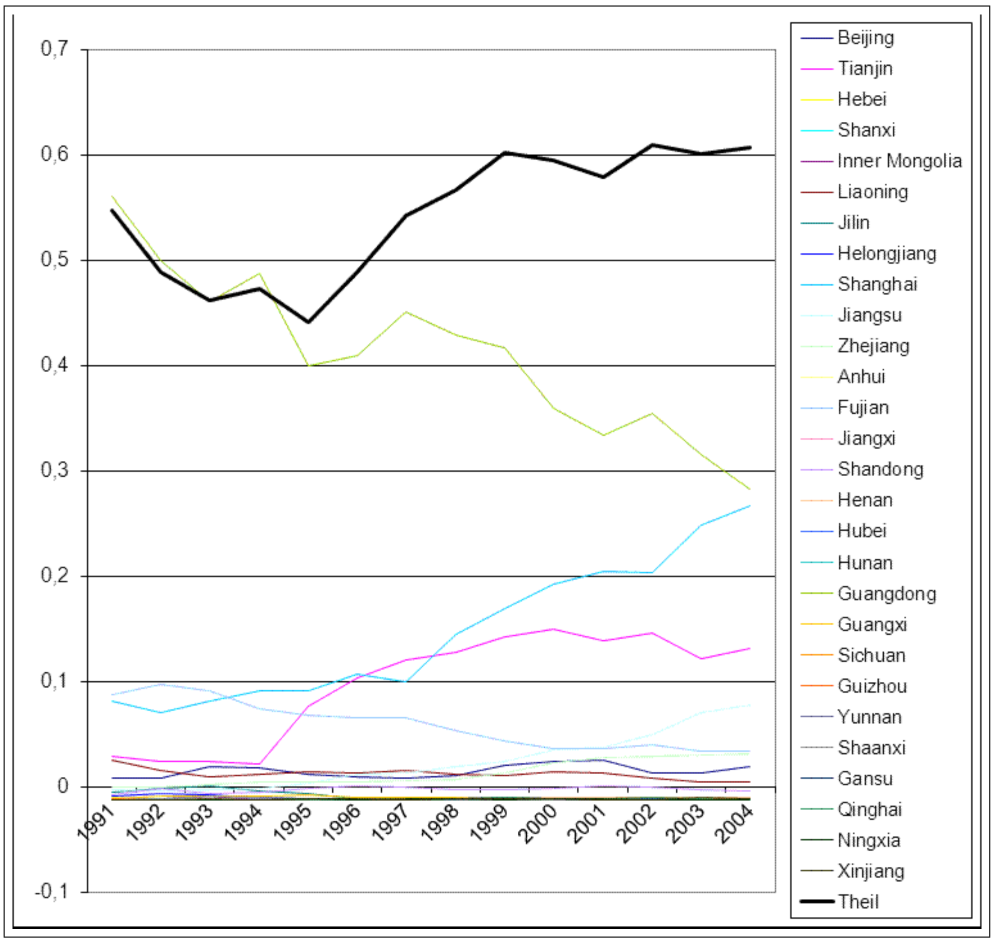


**Figure A3·7:** Trade Theil index and provincial contribution (1991-2004)

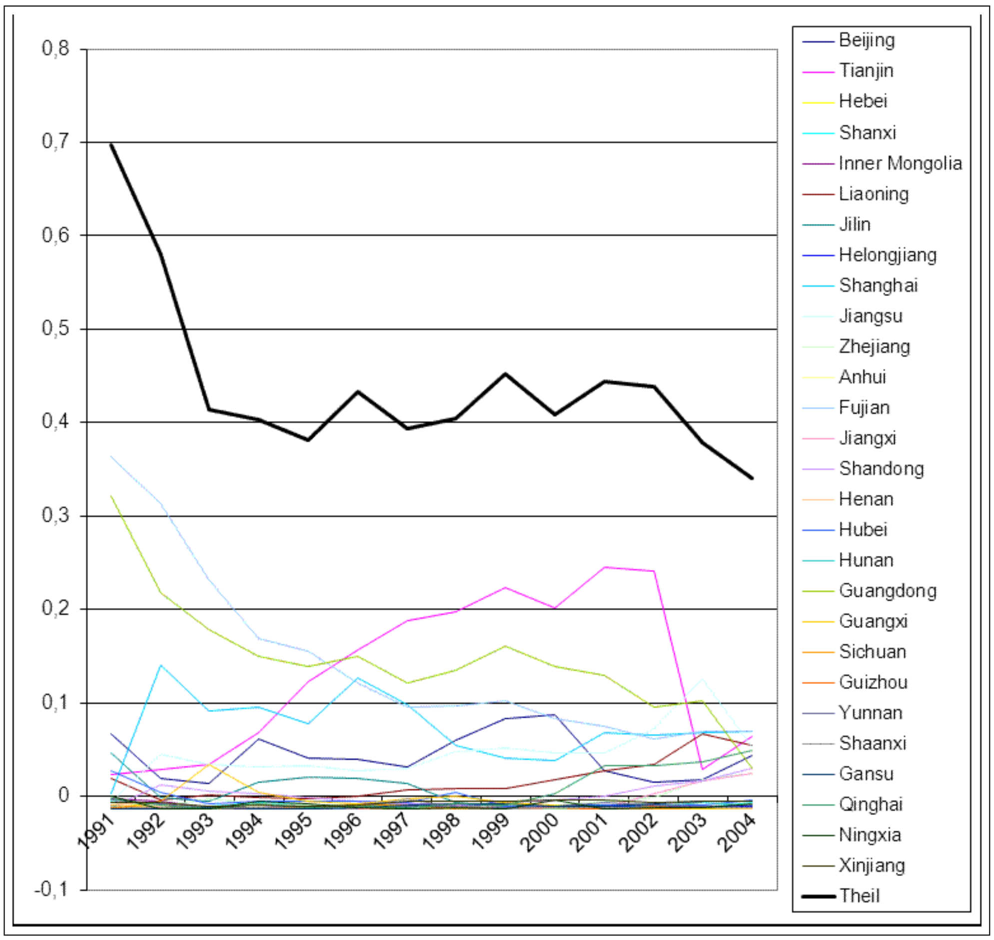


**Figure A3·8:** FDI Theil index and provincial contribution (1991-2004)

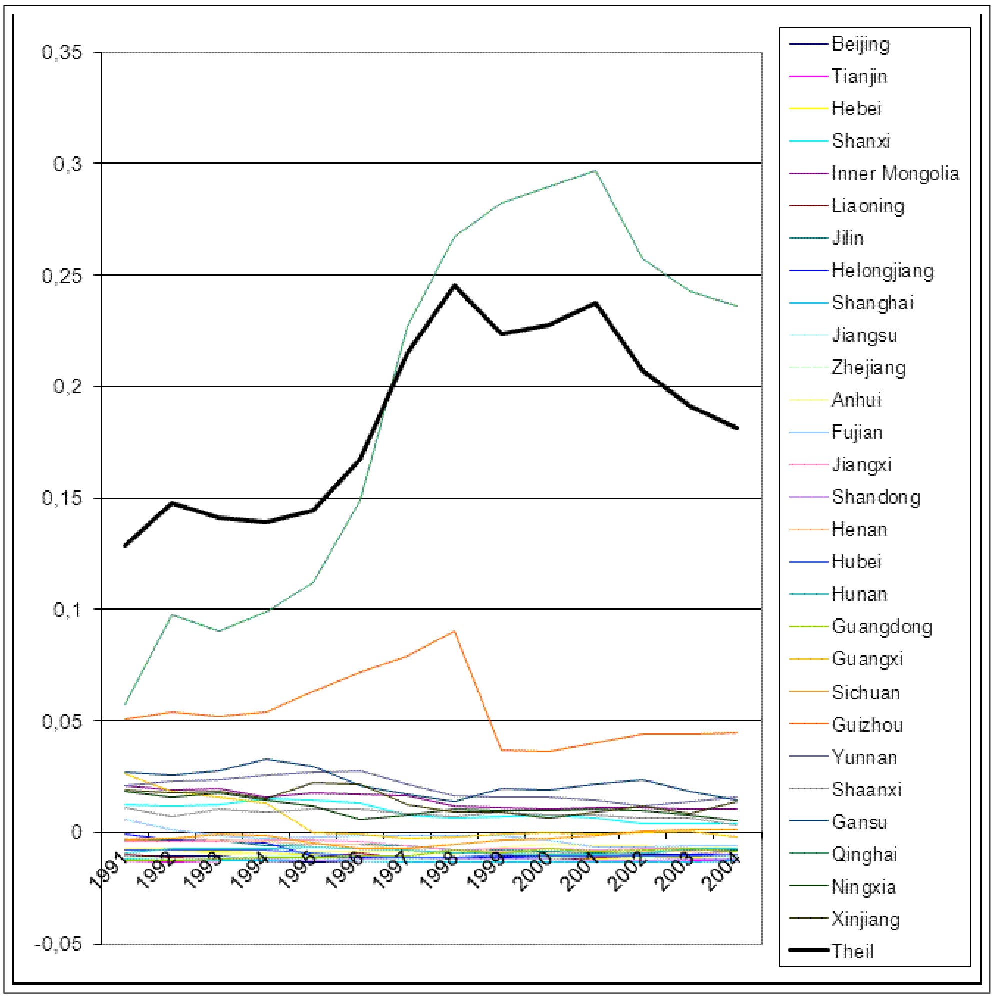


**Figure A3·9:** Government expenditure (administration) Theil index and provincial contribution (1991-2004)

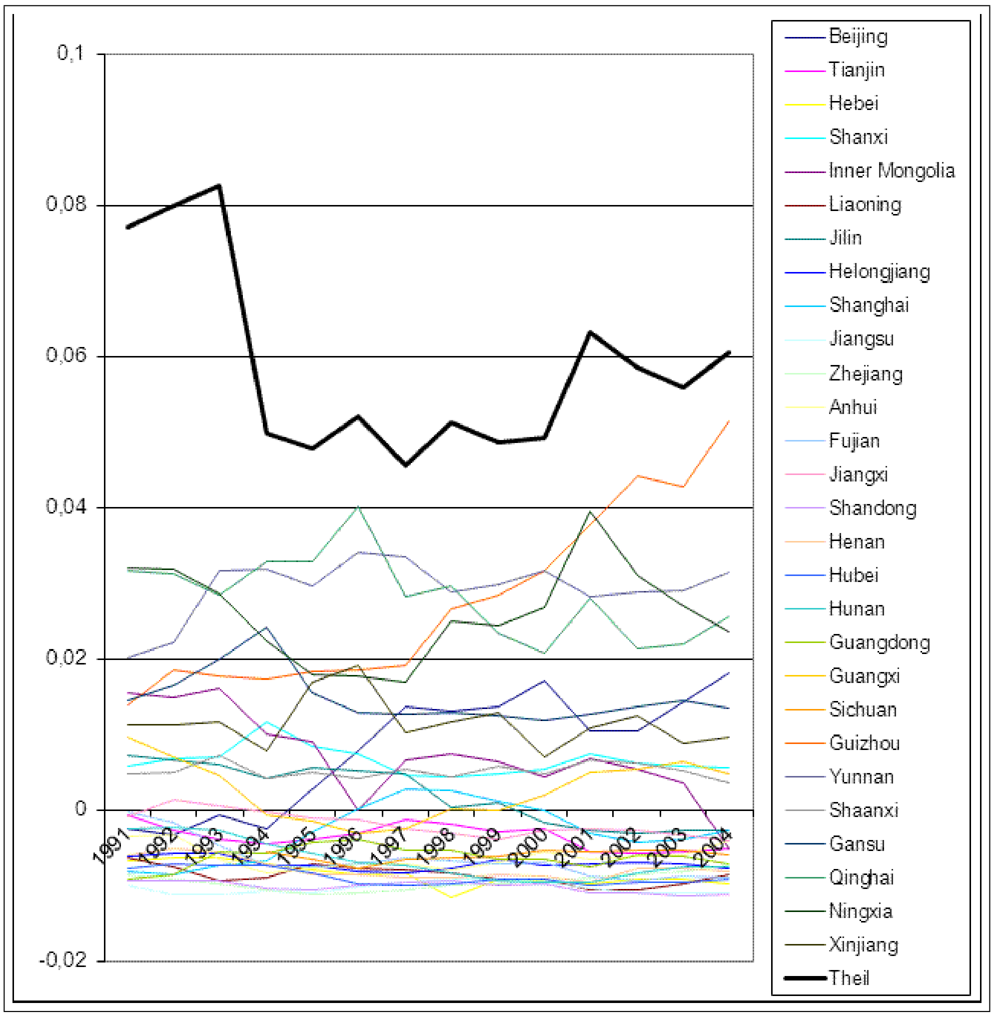


**Figure A3·10:** Government expenditure (culture, education, science and public health) Theil index and provincial contribution (1991-2004)

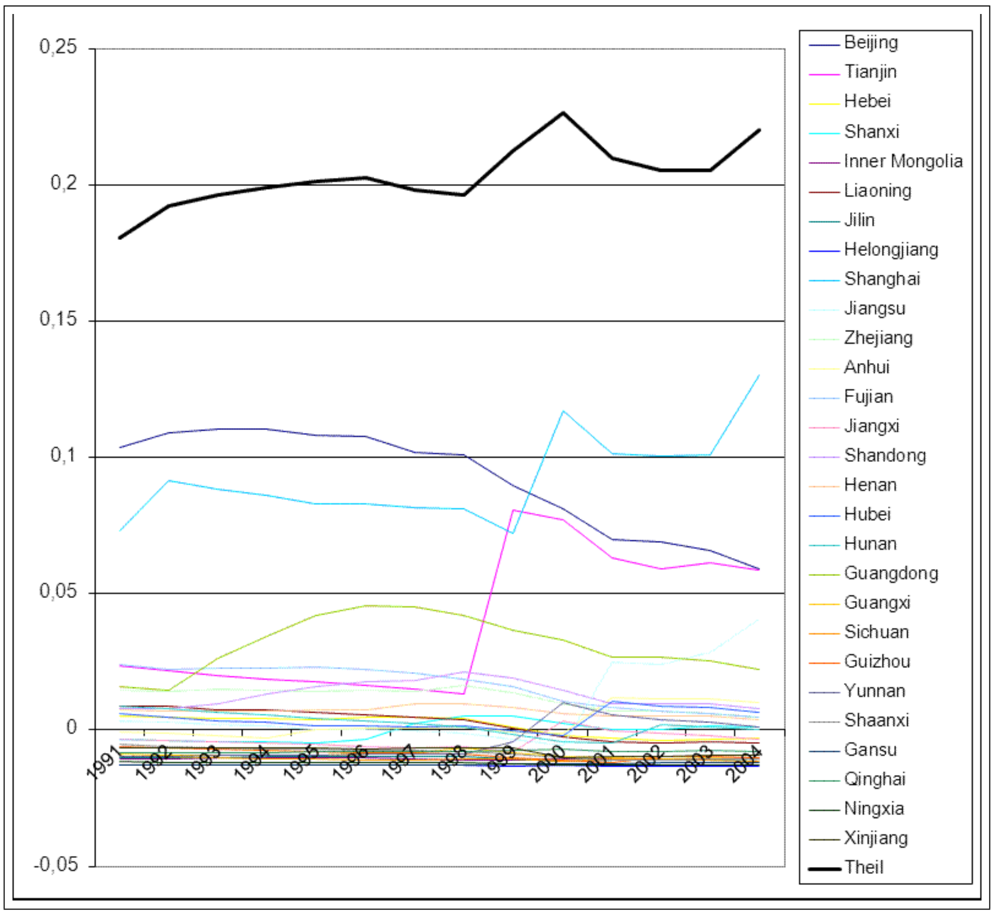


**Figure A3·11:** Highway Theil index and provincial contribution (1991-2004)

**Table A3.1:** OLS and GMM estimation

Dependent variable: $TH\_GDP_{i,t}$

| | OLS | | GMM-DIFF | |
|---|---|---|---|---|
| | Coeff. | Std. Err. | Coeff. | Std. Err. |
| $TH\_K_{i,t}$ | 0.660*** | (0.011) | 0.379*** | (0.147) |
| $TH\_HC_{i,t}$ | -0.047*** | (0.012) | 0.041 | (0.032) |
| $TH\_T_{i,t}$ | 0.029*** | (0.005) | 0.097*** | (0.024) |
| $TH\_FDI_{i,t}$ | -0.010 | (0.010) | -0.036* | (0.021) |
| $TH\_GOV1_{i,t}$ | -0.002 | (0.003) | -0.284 | (0.350) |
| $TH\_GOV2_{i,t}$ | -0.194*** | (0.021) | -0.528*** | (0.186) |
| $TH\_HIGHWAY_{i,t}$ | 0.101*** | (0.034) | -0.030 | (0.070) |
| $R^2$ | 0.9827 | | | |
| adj. $R^2$ | 0.9824 | | | |
| Sargan test (P-value) | | | 0.353 | |
| AR1 (P-value) | | | 0.464 | |
| AR2 (p-value) | | | 0.475 | |
| Obs. | 389 | | 361 | |

Note: *, ** and *** denote significance at the 10%, 5% and 1% level.
Robust standard errors
GMM based on the two-step difference estimator

**Table A3.2:** Variance inflation factors

| Variable | VIF |
|---|---|
| theilc | 3.40 |
| theilhc2 | 5.45 |
| theiltrade | 2.61 |
| theilfdi | 2.23 |
| theilgov1 | 1.54 |
| theilgov2 | 1.64 |
| theilhighway | 7.78 |
| Mean VIF | 3.52 |

### A4.1 Country set

The countries included in the analysis are:

**low-income:**

Bangladesh, Benin, Burkina Faso, Burundi, Cambodia, Central African Republic, Chad, Comoros, Dem. Rep. Congo, Ethiopia, The Gambia, Guinea-Bissau, Guinea, Haiti, Kenya, Kyrgyz Republic, Liberia, Madagascar, Malawi, Mali, Mozambique, Niger, Rwanda, Sierra Leone, Tajikistan, Tanzania, Togo, Uganda.

**lower-middle-income:**

Angola, Armenia, Bhutan, Bolivia, Cameroon, Cape Verde, Congo, Côte d'Ivoire, Djibouti, Arab Rep. Egypt, El Salvador, Georgia, Ghana, Guatemala*, Guyana*, India-Rural, India-Urban, Indonesia-Rural, Indonesia-Urban, Lao PDR, Lesotho, Mauritania, Moldova, Mongolia, Morocco, Nicaragua, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, Senegal, Sri Lanka, Swaziland, Timor-Leste, Turkmenistan, Ukraine, Uzbekistan, Vietnam, Yemen, Zambia.

**upper-middle-income and high-income:**

Albania, Algeria, Argentina-Urban, Azerbaijan, Belarus, Bosnia and Herzegovina, Botswana, Brazil, Bulgaria, Chile, China-Rural, China-Urban, Costa Rica, Croatia, Czech Republic, Dominican Republic, Ecuador, Estonia, Gabon, Hungary, Islamic Rep. Iran, Jamaica, Jordan, Kazakhstan, Latvia, Lithuania, FYR Macedonia, Malaysia, Mexico, Namibia, Panama, Peru, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, South Africa, St. Lucia, Suriname, Thailand, Trinidad and Tobago, Tunisia, Turkey, RB Venezuela.

**East Asia and Pacific:**

Cambodia, China-Rural, China-Urban, Indonesia-Rural, Indonesia-Urban, Lao PDR, Malaysia, Mongolia, Papua New Guinea, Philippines, Thailand, Timor-Leste, Vietnam.

**Europe and Central Asia:**

Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Macedonia, Moldova, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, Tajikistan, Turkey, Turkmenistan, Ukraine, Uzbekistan.

**Latin America and the Caribbean:**

Argentina, Bolivia, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Panama, Paraguay, Peru, St. Lucia, Trinidad and Tobago, Uruguay, Venezuela.

**Middle East and North Africa:**

Algeria, Djibouti, Egypt, Arab Republic, Iran, Islamic Republic, Jordan, Morocco, Tunisia, Yemen.

**South Asia:**

Bangladesh, Bhutan, India-Rural, India-Urban, Pakistan, Sri Lanka.

**Sub-Saharan Africa:**

Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Dem. Rep. Congo, Côte d'Ivoire, Ethiopia, Gabon, Gambia, Ghana, Guinea-Bissau, Guinea, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, South Africa, Swaziland, Tanzania, Togo, Uganda, Zambia.

**Table A4.1:** Correlation matrix

| | growth | inequality |
|---|---|---|
| growth | 1.0000 | |
| inequality | 0.0796 | 1.0000 |
| poverty | -0.7533 | 0.1104 |

**Figure A4·1:** Change in inequality and growth

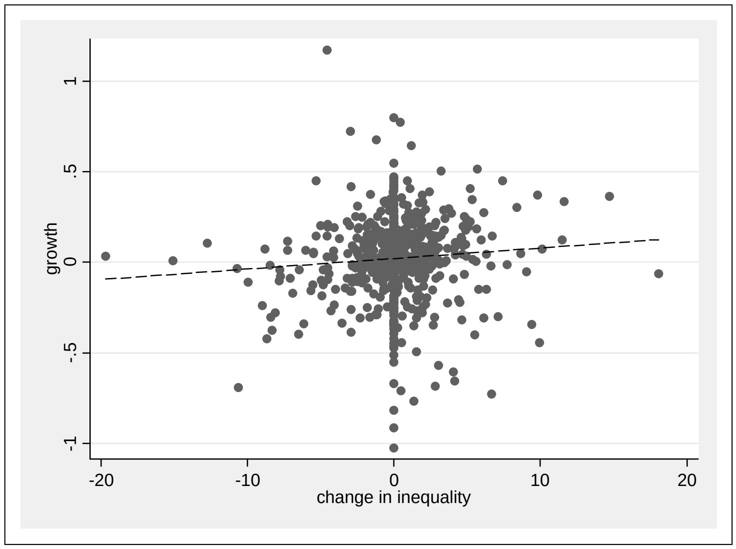


**Figure A4·2:** Change in poverty and growth

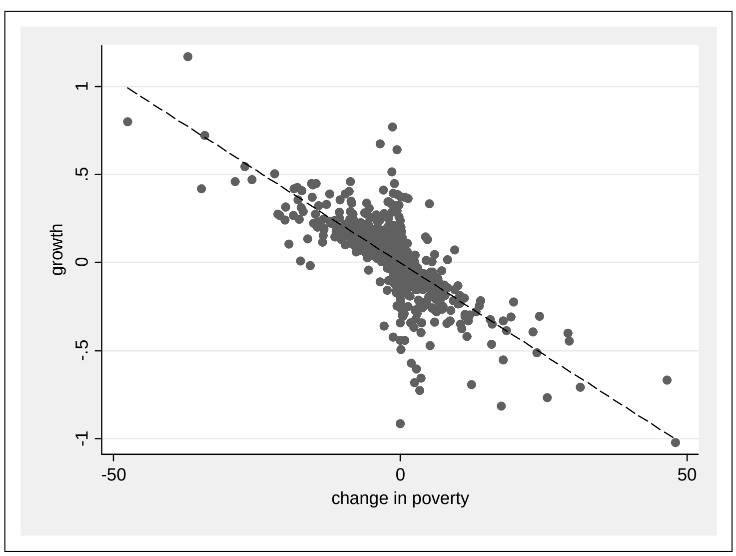

**Table A4.2:** Estimated error correction model: long-run and short-run dynamics of growth and changes in inequality

| | Dependent Variables $\Delta$ ln *income* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dev.World | LI | LMI | UPI-HI | EAP | ECA | LAC | MENA | SA | SSA |
| $\Delta \ln income_{t-1}$ | -0.997*** | -0.989*** | -1.024*** | -0.922*** | -1.234*** | -0.925*** | -0.864*** | -0.853*** | -1.196*** | -1.039*** |
| | (0.047) | (0.104) | (0.078) | (0.072) | (0.124) | (0.095) | (0.119) | (0.103) | (0.345) | (0.082) |
| $\Delta$ ln *gini* | 0.246* | 0.152 | 0.463*** | 0.193 | 1.010*** | 0.451** | 0.865*** | -0.587 | -0.156 | 0.088 |
| | (0.133) | (0.321) | (0.163) | (0.196) | (0.326) | (0.197) | (0.314) | (0.896) | (0.627) | (0.219) |
| $\Delta$ ln $gini_{t-1}$ | 0.115 | 0.120 | 0.101 | 0.194 | 0.774** | 0.601* | 0.847*** | -0.547 | -0.305 | 0.021 |
| | (0.190) | (0.331) | (0.272) | (0.279) | (0.372) | (0.320) | (0.271) | (0.738) | (0.563) | (0.249) |
| $\ln income_{t-2} - \ln gini_{t-2}$ | -1.062*** | -1.085*** | -1.026*** | -0.997*** | -1.268*** | -1.089*** | -0.810*** | -0.776*** | -1.133*** | -1.188*** |
| | (0.059) | (0.084) | (0.114) | (0.098) | (0.201) | (0.108) | (0.094) | (0.167) | (0.249) | (0.079) |
| ln $gini_{t-2}$ | -0.874*** | -0.862 | -1.086*** | -0.676*** | -0.024 | -0.197 | -0.099 | -1.901 | -1.567** | -1.163*** |
| | (0.220) | (0.514) | (0.376) | (0.240) | (0.340) | (0.327) | (0.292) | (1.256) | (0.711) | (0.364) |
| Summation | | | | | | | | | | |
| Short-run coefficient | 0.361 | 0.272 | 0.563 | 0.387 | 1.784 | 1.052 | 1.712 | -1.134 | -0.461 | 0.109 |
| Wald test (P-value) | 0.063 | 0.851 | 0.000 | 0.614 | 0.008 | 0.068 | 0.003 | 0.750 | 0.862 | 0.548 |
| Long run coefficient | 0.177 | 0.206 | -0.058 | 0.322 | 0.981 | 0.820 | 0.877 | -1.458 | -0.383 | 0.021 |
| Wald test (P-value) | 0.353 | 0.638 | 0.875 | 0.141 | 0.000 | 0.007 | 0.015 | 0.350 | 0.313 | 0.940 |
| Sargan test (P-value) | 0.746 | 0.597 | 0.025 | 0.655 | 0.104 | 0.001 | 0.166 | 0.027 | 0.202 | 0.010 |
| AR1 (P-value) | 0.677 | 0.119 | 0.704 | 0.016 | 0.010 | 0.009 | 0.075 | 0.057 | 0.123 | 0.186 |
| AR2 (p-value) | 0.339 | 0.259 | 0.957 | 0.791 | 0.155 | 0.507 | 0.186 | 0.081 | 0.341 | 0.093 |
| Observations | 684 | 168 | 246 | 270 | 78 | 162 | 126 | 48 | 36 | 234 |

Notes:
(1) Estimation based on the Arrelano and Bond Difference GMM estimator.
(2) Asymptotically robust standard errors reported in parentheses.
(3) Sargan test of over-identifying restrictions is based on the estimation with GMM standard errors.
(4) AR1 and AR2 are based on the estimation with asymptotically robust standard errors.
(5) *, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.3:** Estimated error correction model: long-run and short-run dynamics of changes in inequality and growth

| | Dependent Variables $\Delta \ln gini$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dev.World | LI | LMI | UMI-HI | EAP | ECA | LAC | MENA | SA | SSA |
| $\Delta \ln gini_{t-1}$ | -0.778*** | -0.774*** | -0.845*** | -0.731*** | -0.583*** | -0.813*** | -0.676*** | -0.755*** | -0.467*** | -0.846*** |
| | (0.055) | (0.061) | (0.104) | (0.101) | (0.183) | (0.123) | (0.067) | (0.096) | (0.103) | (0.071) |
| $\Delta \ln income$ | 0.037* | 0.011 | 0.048** | 0.038 | 0.109** | 0.070* | 0.091** | -0.011 | -0.015 | 0.010 |
| | (0.020) | (0.032) | (0.019) | (0.039) | (0.052) | (0.038) | (0.040) | (0.063) | (0.063) | (0.029) |
| $\Delta \ln income_{t-1}$ | 0.016 | 0.028 | 0.051* | -0.029 | 0.159** | 0.061 | 0.020 | -0.034 | -0.208* | 0.001 |
| | (0.028) | (0.045) | (0.028) | (0.046) | (0.072) | (0.050) | (0.032) | (0.102) | (0.115) | (0.036) |
| $\ln gini_{t-2} - \ln income_{t-2}$ | -0.869*** | -0.774*** | -0.853*** | -0.969*** | -0.663*** | -0.998*** | -0.921*** | -1.179*** | -0.364*** | -0.869*** |
| | (0.056) | (0.106) | (0.087) | (0.074) | (0.139) | (0.151) | (0.099) | (0.073) | (0.075) | (0.112) |
| $\ln income_{t-2}$ | -0.853*** | -0.738*** | -0.797*** | -0.999*** | -0.450*** | -0.937*** | -0.897*** | -1.149*** | -0.388*** | -0.876*** |
| | (0.067) | (0.126) | (0.078) | (0.097) | (0.122) | (0.155) | (0.103) | (0.094) | (0.075) | (0.133) |
| Summation | | | | | | | | | | |
| Short-run coef. | 0.053 | 0.039 | 0.098 | 0.010 | 0.268 | 0.131 | 0.111 | -0.045 | -0.223 | 0.011 |
| Wald test (P-value) | 0.058 | 0.721 | 0.034 | 0.058 | 0.084 | 0.174 | 0.018 | 0.679 | 0.000 | 0.788 |
| Long run coefficient | 0.018 | 0.046 | 0.066 | -0.031 | 0.247 | 0.061 | 0.261 | 0.025 | -0.066 | -0.008 |
| Wald test (P-value) | 0.617 | 0.484 | 0.183 | 0.450 | 0.029 | 0.279 | 0.560 | 0.696 | 0.774 | 0.877 |
| Sargan test (P-value) | 0.294 | 0.169 | 0.822 | 0.480 | 0.258 | 0.964 | 0.034 | 0.416 | 0.147 | 0.017 |
| AR1 (P-value) | 0.693 | 0.433 | 0.172 | 0.023 | 0.364 | 0.369 | 0.090 | 0.328 | 0.081 | 0.043 |
| AR2 (p-value) | 0.162 | 0.133 | 0.791 | 0.976 | 0.020 | 0.614 | 0.671 | 0.386 | 0.164 | 0.135 |
| Observations | 684 | 168 | 246 | 270 | 78 | 162 | 126 | 48 | 36 | 234 |

Notes:
(1) Estimation based on the Arrelano and Bond Difference GMM estimator.
(2) Asymptotically robust standard errors reported in parentheses.
(3) Sargan test of over-identifying restrictions is based on the estimation with GMM standard errors.
(4) AR1 and AR2 are based on the estimation with asymptotically robust standard errors.
(5) *, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.4:** Estimated error correction model: long-run and short-run dynamics of growth and changes in poverty

| | Dependent Variables $\Delta$ ln *income* | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dev.World | LI | LMI | UMI-HI | EAP | ECA | LAC | MENA | SA | SSA |
| $\Delta \ln income_{t-1}$ | -1.077*** | -0.987*** | -1.235*** | -0.953*** | -0.773*** | -0.944*** | -0.988*** | -1.026*** | -0.694*** | -1.053*** |
| | (0.069) | (0.072) | (0.115) | (0.093) | (0.165) | (0.161) | (0.082) | (0.105) | (0.237) | (0.059) |
| $\Delta$ ln $h$ | -0.208*** | -0.582*** | -0.279*** | -0.128*** | -0.430*** | -0.159*** | -0.172*** | -0.264*** | -0.461*** | -0.723*** |
| | (0.038) | (0.138) | (0.062) | (0.030) | (0.102) | (0.046) | (0.034) | (0.023) | (0.057) | (0.152) |
| $\Delta$ ln $h_{t-1}$ | -0.226*** | -0.562*** | -0.395*** | -0.094** | -0.209* | -0.151** | -0.157*** | -0.297*** | -0.290 | -0.762*** |
| | (0.049) | (0.110) | (0.056) | (0.044) | (0.110) | (0.074) | (0.048) | (0.042) | (0.196) | (0.159) |
| $\ln income_{t-2} - \ln h_{t-2}$ | -1.115*** | -1.110*** | -1.238*** | -1.131*** | -0.656*** | -1.009*** | -1.099*** | -0.951*** | -0.845*** | -1.242*** |
| | (0.059) | (0.079) | (0.120) | (0.110) | (0.117) | (0.140) | (0.090) | (0.125) | (0.117) | (0.079) |
| ln $h_{t-2}$ | -1.346*** | -1.761*** | -1.665*** | -1.248*** | -0.766*** | -1.153*** | -1.281*** | -1.239*** | -1.202*** | -2.142*** |
| | (0.087) | (0.223) | (0.153) | (0.128) | (0.189) | (0.204) | (0.130) | (0.161) | (0.241) | (0.167) |
| Summation | | | | | | | | | | |
| Short-run coefficient | -0.434 | -1.144 | -0.674 | -0.222 | -0.639 | -0.310 | -0.329 | -0.561 | -0.751 | -1.485 |
| Wald test (P-value) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 |
| Long run coefficient | -0.207 | -0.586 | -0.344 | -0.104 | -0.168 | -0.142 | -0.166 | -0.302 | -0.421 | -0.725 |
| Wald test (P-value) | 0.000 | 0.000 | 0.000 | 0.008 | 0.269 | 0.056 | 0.000 | 0.000 | 0.000 | 0.000 |
| Sargan test (P-value) | 0.411 | 0.927 | 0.017 | 0.823 | 0.765 | 0.043 | 0.305 | 0.688 | 0.160 | 0.272 |
| AR1 (P-value) | 0.409 | 0.046 | 0.885 | 0.482 | 0.138 | 0.272 | 0.055 | 0.141 | 0.073 | 0.953 |
| AR2 (p-value) | 0.400 | 0.161 | 0.669 | 0.163 | 0.266 | 0.571 | 0.216 | 0.924 | 0.166 | 0.118 |
| Observations | 590 | 165 | 243 | 182 | 78 | 76 | 121 | 45 | 36 | 234 |

Notes:
(1) Estimation based on the Arrelano and Bond Difference GMM estimator.
(2) Asymptotically robust standard errors reported in parentheses.
(3) Sargan test of over-identifying restrictions is based on the estimation with GMM standard errors.
(4) AR1 and AR2 are based on the estimation with asymptotically robust standard errors.
(5) *, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.5:** Estimated error correction model: long-run and short-run dynamics of changes in poverty and growth

| | Dependent Variables $\Delta \ln h$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dev.World | LI | LMI | UMI-HI | EAP | ECA | LAC | MENA | SA | SSA |
| $\Delta \ln h$ | -1.111*** | -0.842*** | -1.362*** | -0.957*** | -0.491*** | -1.121*** | -1.197*** | -0.907*** | -0.936*** | -0.934*** |
| | (0.148) | (0.097) | (0.259) | (0.140) | (0.086) | (0.207) | (0.139) | (0.101) | (0.325) | (0.040) |
| $\Delta \ln income$ | -1.694*** | -1.059*** | -1.771*** | -2.536*** | -1.258*** | -2.271*** | -2.287*** | -3.056*** | -1.932*** | -0.850*** |
| | (0.182) | (0.249) | (0.249) | (0.411) | (0.171) | (0.344) | (0.354) | (0.283) | (0.215) | (0.105) |
| $\Delta \ln income_{t-1}$ | -1.925*** | -0.901*** | -2.434*** | 2.578*** | -0.509 | -2.692*** | -3.048*** | -2.569*** | -1.798*** | -0.767*** |
| | (0.438) | (0.205) | (0.802) | (0.904) | (0.398) | (0.959) | (0.630) | (0.508) | (0.390) | (0.078) |
| $\ln h_{t-2} - \ln income_{t-2}$ | -1.167*** | -1.020*** | -1.482*** | -1.039*** | -0.206 | -1.234*** | -1.256*** | -0.787*** | -0.966*** | -1.176*** |
| | (0.176) | (0.129) | (0.428) | (0.113) | (0.152) | (0.218) | (0.178) | (0.157) | (0.114) | (0.134) |
| $\ln income_{t-2}$ | -3.059*** | -2.113*** | -3.971*** | -3.719*** | -0.395 | -3.844*** | -4.918*** | -2.921*** | -2.896*** | -2.162*** |
| | (0.549) | (0.237) | (1.318) | (0.883) | (0.291) | (0.904) | (1.023) | (0.881) | (0.088) | (0.264) |
| Summation | | | | | | | | | | |
| Short-run coefficient | -3.619 | -1.960 | -4.205 | -5.114 | -1.767 | -4.963 | -5.335 | -5.625 | -3.730 | -1.617 |
| Wald test (P-value) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Long run coefficient | -1.622 | -1.071 | -1.680 | -2.580 | -0.916 | -2.115 | -2.914 | -2.710 | -1.998 | -0.838 |
| Wald test (P-value) | 0.000 | 0.000 | 0.000 | 0.000 | 0.554 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| Sargan test (P-value) | 0.158 | 0.079 | 0.000 | 0.846 | 0.095 | 0.767 | 0.869 | 0.431 | 0.250 | 0.000 |
| AR1 (P-value) | 0.693 | 0.1164 | 0.077 | 0.387 | 0.183 | 0.171 | 0.192 | 0.089 | 0.146 | 0.251 |
| AR2 (p-value) | 0.162 | 0.1758 | 0.840 | 0.543 | 0.954 | 0.279 | 0.1693 | 0.319 | 0.479 | 0.234 |
| Observations | 590 | 165 | 243 | 182 | 78 | 76 | 121 | 45 | 36 | 234 |

Notes:
(1) Estimation based on the Arrelano and Bond Difference GMM estimator.
(2) Asymptotically robust standard errors reported in parentheses.
(3) Sargan test of overi-dentifying restrictions is based on the estimation with GMM standard errors.
(4) AR1 and AR2 are based on the estimation with asymptotically robust standard errors.
(5) *, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.6:** Estimated error correction model: long-run and short-run dynamics of changes in poverty and changes in inequality

| | Dependent Variables $\Delta$ ln $h$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dev.World | LI | LMI | UMI-HI | EAP | ECA | LAC | MENA | SA | SSA |
| $\Delta \ln h_{t-1}$ | -1.103*** | -0.845*** | -1.140*** | -1.101*** | -0.844*** | -0.934*** | -1.100*** | -0.781*** | -1.695*** | -0.992*** |
| | (0.092) | (0.203) | (0.126) | (0.124) | (0.149) | (0.104) | (0.121) | (0.062) | (0.336) | (0.056) |
| $\Delta$ ln $gini$ | 1.956** | 0.445* | 1.581** | 3.158** | 0.126 | 3.249*** | 1.431 | 0.984 | 2.893 | 0.490** |
| | (0.819) | (0.261) | (0.677) | (1.299) | (0.853) | (1.129) | (1.515) | (2.239) | (1.912) | (0.232) |
| $\Delta$ ln $gini_{t-1}$ | 1.993*** | 0.456** | 2.419*** | 2.818*** | 1.482** | 1.480 | 1.014 | 2.920 | 2.450* | 0.477** |
| | (0.710) | (0.214) | (0.867) | (1.000) | (0.679) | (1.103) | (1.950) | (2.407) | (1.476) | (0.210) |
| $\ln h_{t-2} - \ln gini_{t-2}$ | -1.165*** | -0.966*** | -1.188*** | 1.165*** | -0.470* | -1.175*** | -0.952*** | -0.581*** | -1.445*** | -1.156*** |
| | (0.150) | (0.115) | (0.271) | (0.147) | (0.271) | (0.183) | (0.141) | (0.130) | (0.303) | (0.113) |
| ln $gini_{t-2}$ | 0.709 | -0.726*** | 1.497 | 1.685 | -0.484 | 0.977 | -0.709 | 4.090 | 0.867 | -0.710*** |
| | (0.906) | (0.270) | (0.939) | (1.841) | (1.081) | (1.617) | (1.972) | (3.462) | (1.071) | (0.272) |
| Summation | | | | | | | | | | |
| Short-run coefficient | 3.949 | 0.901 | 4.000 | 5.976 | 1.608 | 4.729 | 2.445 | 3.904 | 5.343 | 0.967 |
| Wald test (P-value) | 0.018 | 0.102 | 0.018 | 0.015 | 0.030 | 0.016 | 0.132 | 0.242 | 0.236 | 0.076 |
| Long run coefficient | 1.609 | 0.249 | 2.260 | 2.446 | -0.031 | 1.168 | 0.256 | 8.035 | 1.600 | 0.386 |
| Wald test (P-value) | 0.039 | 0.386 | 0.001 | 0.124 | 0.988 | 0.189 | 0.899 | 0.243 | 0.010 | 0.110 |
| Sargan test (P-value) | 0.010 | 0.002 | 0.000 | 0.148 | 0.179 | 0.002 | 0.014 | 0.081 | 0.590 | 0.000 |
| AR1 (P-value) | 0.726 | 0.249 | 0.233 | 0.750 | 0.013 | 0.485 | 0.191 | 0.232 | 0.480 | 0.347 |
| AR2 (p-value) | 0.792 | 0.751 | 0.153 | 0.224 | 0.106 | 0.359 | 0.657 | 0.150 | 0.032 | 0.203 |
| Observations | 590 | 165 | 243 | 182 | 78 | 76 | 121 | 45 | 36 | 234 |

Notes:
(1) Estimation based on the Arrelano and Bond Difference GMM estimator.
(2) Asymptotically robust standard errors reported in parentheses.
(3) Sargan test of over-identifying restrictions is based on the estimation with GMM standard errors.
(4) AR1 and AR2 are based on the estimation with asymptotically robust standard errors.
(5) *, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.7:** Estimated error correction model: long-run and short-run dynamics of changes in inequality and changes in poverty

| | Dependent Variables $\Delta \ln gini$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Dev.World | LI | LMI | UMI-HI | EAP | ECA | LAC | MENA | SA | SSA |
| $\Delta$ ln $gini_{t-1}$ | -0.799*** | -0.778*** | -0.883*** | -0.675*** | -0.535*** | -0.598*** | -0.733*** | -0.874*** | -0.518*** | -0.848*** |
| | (0.062) | (0.062) | (0.094) | (0.100) | (0.149) | (0.095) | (0.068) | (0.122) | (0.080) | (0.071) |
| $\Delta \ln h$ | 0.033** | 0.025 | 0.024*** | 0.038 | -0.003 | 0.049** | 0.010 | 0.004 | 0.047* | 0.046 |
| | (0.017) | (0.022) | (0.007) | (0.025) | (0.022) | (0.025) | (0.014) | (0.011) | (0.028) | (0.029) |
| $\Delta \ln h_{t-1}$ | 0.041* | 0.016 | 0.003 | 0.064* | -0.027 | 0.049 | 0.041*** | -0.007 | 0.154*** | 0.048 |
| | (0.025) | (0.017) | (0.021) | (0.033) | (0.020) | (0.040) | (0.011) | (0.017) | (0.051) | (0.030) |
| $\ln gini_{t-2} - \ln h_{t-2}$ | -0.893*** | -0.791*** | -0.912*** | -0.893*** | -0.562*** | -0.866*** | -0.994*** | -1.163*** | -0.383*** | -0.872*** |
| | (0.080) | (0.103) | (0.108) | (0.163) | (0.127) | (0.170) | (0.071) | (0.204) | (0.089) | (0.111) |
| $\ln h_{t-2}$ | -0.849*** | -0.786*** | -0.904*** | -0.831*** | -0.595*** | -0.780*** | -0.956*** | -1.186*** | -0.333*** | -0.816*** |
| | (0.077) | (0.099) | (0.107) | (0.160) | (0.132) | (0.161) | (0.074) | (0.223) | (0.093) | (0.100) |
| Summation | | | | | | | | | | |
| Short-run coefficient | 0.074 | 0.040 | 0.027 | 0.102 | -0.023 | 0.098 | 0.051 | -0.003 | 0.201 | 0.094 |
| Wald test (P-value) | 0.132 | 0.502 | 0.000 | 0.123 | 0.233 | 0.034 | 0.000 | 0.401 | 0.000 | 0.268 |
| Long run coefficient | 0.050 | 0.006 | 0.009 | 0.070 | -0.059 | 0.099 | 0.038 | -0.020 | 0.131 | 0.064 |
| Wald test (P-value) | 0.080 | 0.814 | 0.697 | 0.089 | 0.421 | 0.083 | 0.002 | 0.256 | 0.248 | 0.100 |
| Sargan test (P-value) | 0.136 | 0.213 | 0.912 | 0.144 | 0.248 | 0.889 | 0.036 | 0.433 | 0.097 | 0.014 |
| AR1 (P-value) | 0.195 | 0.155 | 0.760 | 0.793 | 0.221 | 0.112 | 0.147 | 0.789 | 0.144 | 0.041 |
| AR2 (p-value) | 0.186 | 0.085 | 0.724 | 0.379 | 0.056 | 0.485 | 0.901 | 0.345 | 0.098 | 0.105 |
| Observations | 590 | 165 | 243 | 182 | 78 | 76 | 121 | 45 | 36 | 234 |

Notes:
(1) Estimation based on the Arrelano and Bond Difference GMM estimator.
(2) Asymptotically robust standard errors reported in parentheses.
(3) Sargan test of over-identifying restrictions is based on the estimation with GMM standard errors.
(4) AR1 and AR2 are based on the estimation with asymptotically robust standard errors.
(5) *, ** and *** denote significance at the 10%, 5% and 1% level.

**Figure A4·3:** Change in poverty and change in inequality

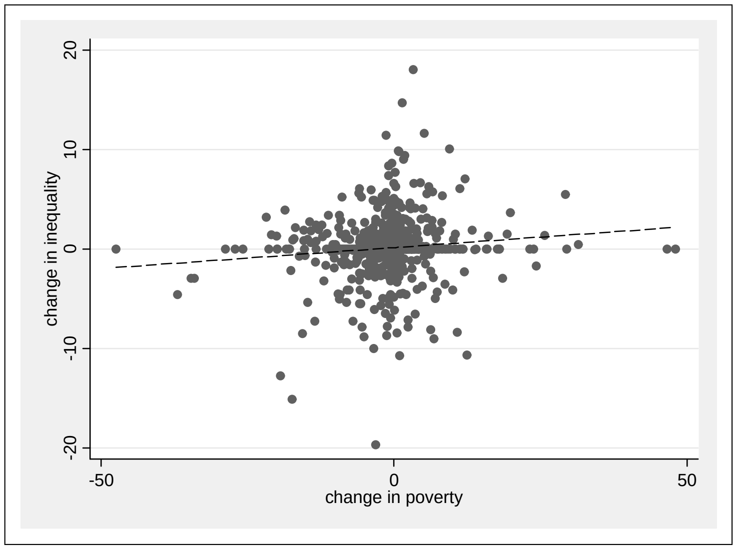


**Table A4.8:** Estimated Granger causality model: changes in inequality and income growth

| | Dependent Variables $\Delta$ ln *income* | |
|---|---|---|
| | Coef. | Std. Err. |
| $\Delta \ln income_{t-1}$ | 0.3202* | (0.1826) |
| $\Delta \ln income_{t-2}$ | 0.1416*** | (0.0350) |
| $\Delta$ ln $gini_{t-1}$ | -0.0663*** | (0.0063) |
| $\Delta$ ln $gini_{t-2}$ | -0.2322*** | (0.0635) |
| | | |
| Wald test | 3.69 | (0.1577) |
| Sargan test (P-value) | 44.7523 | (0.6067) |
| AR1 test | -1.4132 | (0.1576) |
| AR2 test | -0.9117 | (0.3619) |
| Observations | 36 | |

Asymptotically robust standard errors reported in parentheses.
*, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.9:** Estimated Granger causality model: income growth and changes in inequality

| | Dependent Variables $\Delta$ ln *gini* | |
|---|---|---|
| | Coef. | Std. Err. |
| $\Delta$ ln $gini_{t-1}$ | -0.2427*** | (0.0899) |
| $\Delta$ ln $gini_{t-2}$ | -0.1667*** | (0.0414) |
| $\Delta \ln income_{t-1}$ | -0.5398** | (0.2239) |
| $\Delta \ln income_{t-2}$ | -0.3067** | (0.1396) |
| | | |
| Wald test | 13.36 | (0.0003) |
| Sargan test (P-value) | 40.0319 | (0.7864) |
| AR1 test | -1.3881 | (0.1651) |
| AR2 test | 0.8241 | (0.4099) |
| Observations | 36 | |

Asymptotically robust standard errors reported in parentheses.
*, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.10:** Estimated Granger causality model: income growth and changes in poverty

| | Dependent Variables $\Delta$ ln $h$ | |
|---|---|---|
| | Coef. | Std. Err. |
| $\Delta$ ln $h_{t-1}$ | -0.3571*** | (0.0145) |
| $\Delta \ln income_{t-1}$ | -5.0525** | (2.3890) |
| | | |
| Wald test | 4.47 | (0.0344) |
| Sargan test (P-value) | 52.7787 | (0.4438) |
| AR1 test | -1.1409 | (0.2539) |
| AR2 test | -1.3629 | (0.1729) |
| Observations | 38 | |

Asymptotically robust standard errors reported in parentheses.
*, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.11:** Estimated Granger causality model: changes in poverty and income growth

| | Dependent Variables $\Delta$ ln *income* | |
|---|---|---|
| | Coef. | Std. Err. |
| $\Delta \ln income_{t-1}$ | 0.3504* | (0.1859) |
| $\Delta \ln income_{t-2}$ | 0.2008** | (0.0929) |
| $\Delta$ ln $h_{t-1}$ | -0.0247*** | (0.0033) |
| $\Delta$ ln $h_{t-2}$ | -0.0173*** | (0.0032) |
| | | |
| Wald test | 6.09 | (0.0477) |
| Sargan test (P-value) | 46.8215 | (0.5211) |
| AR1 test | -1.4142 | (0.1573) |
| AR2 test | 1.3886 | (0.1650) |
| Observations | 36 | |

Asymptotically robust standard errors reported in parentheses.
*, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.12:** Estimated Granger causality model: changes in inequality and changes in poverty

| | Dependent Variables $\Delta$ ln $h$ | |
|---|---|---|
| | Coef. | Std. Err. |
| $\Delta$ ln $h_{t-1}$ | -0.0702** | (0.0305) |
| $\Delta$ ln $h_{t-2}$ | -0.4190*** | (0.0822) |
| $\Delta$ ln $gini_{t-1}$ | -2.6571*** | (0.2849) |
| $\Delta$ ln $gini_{t-2}$ | 1.9821*** | (0.4676) |
| | | |
| Wald test | 4.31 | (0.1159) |
| Sargan test (P-value) | 50.3973 | (0.3788) |
| AR1 test | -1.1189 | (0.2632) |
| AR2 test | -1.0608 | (0.2888) |
| Observations | 36 | |

Asymptotically robust standard errors reported in parentheses.
*, ** and *** denote significance at the 10%, 5% and 1% level.

**Table A4.13:** Estimated Granger causality model: changes in poverty and changes in inequality

| | Dependent Variables $\Delta$ ln $gini$ | |
|---|---|---|
| | Coef. | Std. Err. |
| $\Delta$ ln $gini_{t-1}$ | -0.3309*** | (0.0775) |
| $\Delta$ ln $gini_{t-2}$ | 0.1113** | (0.0553) |
| $\Delta$ ln $h_{t-1}$ | -0.0124*** | (0.0041) |
| $\Delta$ ln $h_{t-2}$ | -0.0516*** | (0.0103) |
| | | |
| Wald test | 5.61 | (0.0605) |
| Sargan test (P-value) | 49.5233 | (0.4122) |
| AR1 test | -1.2514 | (0.2108) |
| AR2 test | -0.6424 | (0.5206) |
| Observations | 36 | |

Asymptotically robust standard errors reported in parentheses.
*, ** and *** denote significance at the 10%, 5% and 1% level.