Essays in International Macroeconomics

Rudolfs Bems

AKADEMISK AVHANDLING

Som för avläggande av ekonomie doktorsexamen vid Handelshögskolan i Stockholm framläggs för offentlig granskning fredagen den 10 juni, 2005, kl. 10:15 i sal KAW Handelshögskolan Sveavägen 65
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Rudolfs Bems

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I chose to study Economics because, as a teenager growing up in late 80s and early 90s Latvia, I was overwhelmed by the impact that economic forces can have on our lives. As I remember it, first there were long lines of people waiting for hours in front of stores to buy their daily necessities. Then life savings of a whole generation were wiped out by prices that seemed to never stop rising. A year later, I deposited all my financial wealth (around $100) in a bank and doubled it, in real terms, in a six-month time. I was lucky! Those who made similar deposits half a year later lost everything. Yes, life in Sweden is boring indeed in comparison.

For my decision to pursue Ph.D. studies I have to thank everyone who contributed to the establishment of the Stockholm School of Economics in Riga. Morten Hansen convinced me that Economics has some important things to say about the life around us. Anders Paalzow encouraged me to apply to the Ph.D. program at the Stockholm School of Economics and has helped me throughout my graduate studies. This dissertation has benefited greatly from the help provided by my Ph.D. advisor Professor Lars Ljungqvist. His courses in Macroeconomics and guidance in research have been invaluable. Each visit that Kristian and I paid to Lars's office led us into yet uncharted waters of economic theory. Whenever we were stuck or thought that the paper was completed, Lars pointed out a way to improvement. Thank you, Lars, for pushing me to work hard.

In one way or another, all of the essays in this dissertation were inspired by the work of Professor Timothy J. Kehoe. I have received help from Tim in all aspects of academic work - from model solving to preparation for presentations to even a private dinner with Nobel-prize winners. Tim, your enduring enthusiasm and encouragement have made my dissertation research so much more fun.

I also want to thank Martin Floden and David Domeij who were always willing to listen and provide advice on any problem that I encountered in my research.

Without doubt, the person with whom I spent most time while working on this dissertation is Kristian Jönsson. Chronologically, the first two papers of the dissertation were written together with Kristian and my later work, Essays I and IV, builds on the insights and ideas that I gained while working with Kristian. Our collaboration has been more fruitful than I could ever imagine and I can only hope that more co-authored papers will follow.

Throughout the Ph.D. studies fellow students made my Ph.D. life more enjoyable. Among others, I want to thank Magnus Anderson, Giovanni Favara, Therese Lindahl and Alberto Naranjo for fun during the coursework years and beyond. Late nights at the Holländargatan office would not have been the same without Andriy Bodnaruk and Per
Östberg. Lunches with Max Elger or Anete Pajuste were always a break to look forward to. Sergey Stepanov was a great officemate to have during the stressful 'jobmarket' period. Belgian beers are the best in the world! Magnus Lomakka, Alexander Matros and Elena Paltseva helped me avoid the overregulated Stockholm's housing market. Thank you guys!

Many warm thanks to all the staff at the Stockholm Institute of Transition Economics, who generously hosted me during the last two years of my Ph.D. studies. Director of the SITE, Erik Berglöf, has always been ready to listen and offer advice in any area of academic life. Also, I would like to thank the administrative staff at the Department of Economics, especially, Ritva Kiviharju and Pirjo Furtenbach, for their help and assistance.

Last but not least, thanks to my parents, Astrida and Andris, and my partner, Chiaki, for their patience and support throughout my graduate studies.

Stockholm, April 2005
Rudolfs Berns
Introduction and Summary

The four essays included in this dissertation are in the field of open economy Macroeconomics. Essays I, II and IV deal with a work-horse model in this field – a two-sector small open economy growth model with traded and nontraded goods.

Writing down such a model requires an assumption about the role of traded and nontraded goods in domestic consumption and investments. While several empirical studies have looked at the consumption side, a systematic examination of the role of traded and nontraded goods in investments is missing.

Essay I aims to fill this gap. Drawing on extensive empirical evidence, we show that aggregate investment expenditure shares on traded and nontraded goods are very similar in rich and poor countries. Furthermore, the two expenditure shares have remained close to constant over time, with the average nontraded expenditure share varying between 0.54-0.60 over the 1960-2002 period. Combined with the fact that the relative price of nontraded goods correlates positively with income and exhibits large differences across space and time, our findings suggest that investment can be modeled using the Cobb-Douglas aggregator.

The results of this essay offer a new restriction for the two-sector growth model, which can alter the conclusions drawn from the model. To demonstrate this, we apply the new restriction to a study by Hsieh and Klenow (2003), which argues that differences in relative productivity between traded and nontraded sectors, i.e., the Balassa-Samuelson effect, is the main cause of higher PPP-adjusted investment rates in rich countries. With the restriction imposed on the model, no more than 25 percent of the differences in PPP-adjusted investment rates between rich and poor counties can be attributed to the Balassa-Samuelson effect.

In Essays II and IV the same two-sector growth model is put to the test using the recent economic developments in countries of Eastern and Central Europe.

Essay II investigates whether the two-sector growth model can explain the magnitudes and the timing of the trade flows in the Baltic countries. The model is calibrated for each of the three countries, which we simulate as small closed economies that suddenly open up to international trade and capital flows. The results show that the model can account for the observed magnitudes of the trade deficits in the 1995-2004 period. Introducing a real interest rate risk premium in the model increases its explanatory power. According to the model, trade balances will turn positive in the Baltic states around 2010.

Essay IV starts by summarizing empirical regularities for the key aggregate real sector variables in the eight countries that joined the EU in May 2004. It is shown that, following the reforms in the early 1990s, real sector developments in all eight
countries exhibit remarkable similarities. Interestingly, this is the case despite the fact that different reform policies were pursued in several dimensions (e.g., privatization, nominal exchange rate).

Next, we show that a calibrated two-sector small open economy growth model can account for most of the real sector adjustments in early post-reform years. Empirical studies have found rapid traded sector productivity growth in Central and Eastern European countries over the last decade. When traded sector productivity growth is added to the model, it captures the development in all key real sector variables during the post-reform period.

Finally, Essay III contributes to the study of financial crises in emerging markets. In contrast to the other essays, this paper develops a highly stylized theoretical model that allows us to study analytically government response to financial crises.

In particular, Essay III develops a framework for analyzing optimal government bailout policy in a dynamic stochastic general equilibrium model where financial crises are exogenous. Important elements of the model are that private borrowers internalize only part of the social cost of foreign borrowing in the emerging market and that the private sector is illiquid in the event of a crisis. The distinguishing feature of our paper is that it addresses the optimal bailout policy in an environment where there are both costs and benefits of bailouts, and where bailout guarantees potentially distort investment decisions in the private sector.

We show that it is always optimal to commit to a bailout policy that only partially protects investment against inefficient liquidation, both in a centralized economy and a market economy. Due to overinvestment in the market economy, the government’s optimal level of bailout guarantees is lower than in the social optimum. Further, we show that, in contrast to a social planner, the government in the market economy should optimally bail out a smaller fraction of private investments when the probability of a crisis is higher.

References

Aggregate Investment Expenditures on Traded and Nontraded Goods*

Abstract

This paper shows that aggregate investment expenditure shares on traded and nontraded goods are very similar in rich and poor countries. Furthermore, the two expenditure shares have remained close to constant over time, with the average nontraded expenditure share varying between 0.54-0.60 over the 1960-2002 period. Combined with the fact that the relative price of nontraded goods correlates positively with income and exhibits large differences across space and time, our findings suggest that investment can be modeled using the Cobb-Douglas aggregator. The results of this paper offer a new restriction for the two-sector growth model. We apply the restriction to a study by Hsieh and Klenow (2003), which argues that differences in relative productivity between traded and nontraded sectors, i.e., the Balassa-Samuelson effect, is the main cause of higher PPP-adjusted investment rates in rich countries. With the restriction imposed on the model, only around 25 percent of the differences in PPP-adjusted investment rates between rich and poor counties can be attributed to the Balassa-Samuelson effect.

JEL classification: F41; O41; E22

Keywords: Investment; nontraded and traded goods; capital formation

*I am grateful to Lars Ljungqvist, Timothy J. Kehoe, David Domeij, Martin Flodén and Jesper Lindé for comments and helpful advice. I have also benefited from discussions with seminar participants at the Federal Reserve Bank of Minneapolis and Stockholm School of Economics. Financial support from Jan Wallander and Tom Hedelius Foundation is gratefully acknowledged.
1 Introduction

Models with traded and nontraded goods are widely used in macroeconomics. A common practice in the literature is to assume that only traded goods can be transformed into investment goods, although an assumption that only nontraded or both traded and nontraded goods are used in the capital formation process has also been used.\(^1\) Model results are sensitive to the assumption used.

This paper provides a systematic empirical examination of the role played by traded and nontraded goods in the capital accumulation process. We find that around 60 percent of aggregate investment expenditures are spend on nontraded goods. Aggregate investment expenditure shares on traded and nontraded goods are very similar in rich and poor countries around the world. Moreover, the two investment expenditure shares have remained close to constant over the last 50 years.

To reach such conclusions, this paper examines extensive empirical evidence – up to 115 countries for cross-section data and up to 53 years for annual time-series data. The results suggest no significant systematic differences in investment expenditure shares between countries with widely different income levels. The correlation between the investment expenditure share on nontraded goods and per capita income is between -0.30 and 0.30. We also find no significant differences in investment expenditure shares between different regions of the world, such as Africa, South-East Asia, Europe or Latin America.

Nontraded expenditure shares in most of the sample countries show no noticeable time trends during the second half of the 20th century. For the OECD countries, a pooled linear time trend in the nontraded goods' expenditure share has a 95 percent confidence interval of \((-0.015, -0.010)\) per decade. Cross-section averages are also close to trendless. Over the 1960-2002 period, the average nontraded expenditure share has decreased from 0.60 to around 0.57.

One of the most consistent related empirical findings in the macroeconomic literature is that the relative price of nontraded goods in terms of traded goods exhibits a strong positive correlation with income in cross-section as well as time-series data.\(^2\) Price data for traded and nontraded goods in investments offers no exception to this empirical regularity. In rich countries, such as the U.S., the relative price of nontraded goods in investments is 3-4 times higher than in poor countries, such as Kenya, Morocco and Egypt. Similarly, the relative price of nontraded goods in investments has doubled in

\(^1\)For examples of models with only traded goods in investments see Rebelo and Vegh (1995), Obstfeld and Rogoff (1996), Mendoza and Uribe (2000), Uribe (2002). The assumption of only nontraded goods in investments is used, for example, in van Wincoop (1993). For a model with both traded and nontraded goods in investments see, for example, Stockman and Tesar (1995), Luxton and Pesenti (2003).

\(^2\)See, among others, Balassa (1964), Samuelson (1964), Kravis et al. (1982) and De Gregorio et al. (1994).
OECD countries over the last 30 years.\textsuperscript{3} Furthermore, there is evidence that the variation in relative prices in cross-section and time-series data would be even larger after properly adjusting for improvements in quality.\textsuperscript{4}

Combined with the large variation in relative prices, our results suggest that at the level of aggregate economy investment process can be modeled using a unitary elasticity of substitution between traded and nontraded goods, i.e., the Cobb-Douglas case. Importantly, our findings are based entirely on current price data and are therefore immune to problems associated with the measurement of changes in relative prices for the two investment components.

The results of this paper are applicable not only to small open economy models with traded and nontraded goods, but also to closed economy models differentiating between equipment (or durable goods) and structures (or plants) in investments. This is the case since, as shown in the paper, 90 percent of the aggregate investment expenditures are spent on acquiring output from only two sectors of economic activity – equipment from the manufacturing sector and structures from the construction sector. The former is a traded and the latter a nontraded good.

To our knowledge, no previous research has extensively examined the question addressed in this paper. De Long and Summers (1991) and, more recently, Burstein et al. (2004) point out that investments have a very significant nontradable component. Drawing on evidence from 19 medium and high income countries, Burstein et al. (2004) also report a strong negative correlation (−0.69) between investment expenditures on nontraded goods and real per capita income. The considerably larger dataset of our paper does not support this finding. For the particular country-year observations, used by Burstein et al. (2004), our data also exhibit a negative correlation between the nontraded expenditure share and real per capita income. However, when the whole dataset is considered, the correlation is small and positive.

Our results agree with findings in Whelan (2003), who argues that the investment expenditure share on equipment in the U.S. National Income and Products Accounts data exhibits no significant trend over the past 50 years. He finds that over 1960-1999, durable goods accounted for 47 percent of the investment expenditures in the U.S.

The findings of this paper fit well with several already established empirical regularities in the growth literature. First, it has repeatedly been reported that investment rates, calculated in domestic prices, have little correlation with real per capita income.\textsuperscript{5} Eaton and Kortum (2001) find that the same is true for equipment investment rates, calculated

\textsuperscript{3}Data from 1996 benchmark for Penn World Tables 6.1 (see Heston et al. (2002)) and OECD detailed national accounts (see OECD (2004)).

\textsuperscript{4}See Gordon (1990) and Navaretti et al. (2000).

in domestic prices. Combined with either of the two findings, our results would imply the other finding. Second, combined with the higher relative price of nontraded goods in rich countries, the empirical results of our paper imply that equipment intensity of investments should increase with income. De Long and Summers (1991, 1993) find this to be the case.

Our results provide empirical support for two-sector growth models in which aggregate investment expenditure shares on traded and nontraded goods (or equipment and structures) are non-zero and constant over time. There are, in fact, several models in the literature that satisfy this restriction, although the empirical motivation behind the modeling choice has been missing.7

In the second part of the paper, we set up a two-sector small open economy growth model with traded and nontraded goods in investments to address one of the unsettled questions in the growth literature - what causes the large differences in international price investment rates between rich and poor countries? Among other explanations, Hsieh and Klenow (2003) have identified the Balassa-Samuelson effect, i.e. differences in relative productivity between traded and nontraded sectors across countries, as a potential source of differences in investment rates. Using the two-sector growth model we show that, when the composition of traded and nontraded goods in investments is correctly accounted for, only around 25 percent of the differences in international price investment rates between rich and poor countries can be attributed to differences in relative productivity between traded and nontraded sectors. The driving force behind this result is the empirical finding that the composition of investments and consumption between traded and nontraded goods is much more similar than what is commonly assumed in the literature.

The structure of the rest of the paper is as follows. In Section 2, we examine how much of the aggregate investment expenditures are spent on the output of different sectors of economic activity. This section also presents the data sources and discusses several data related issues. Section 3 presents empirical findings about the nontraded expenditure shares in both time-series and cross-section data. Section 4 presents a small open economy two-sector growth model with traded and nontraded goods in consumption and investments. The model is solved both analytically and numerically and its implications for investment rate differences between rich and poor countries are examined. Section 5 concludes.

6In the rest of this paper, investment rates, calculated in domestic prices, will be called domestic price investment rates, while investment rates, calculated in common prices for all countries, will be called international price investment rates.

7See, for example, Brock and Turnovsky (1994), Fernandez de Cordoba and Kehoe (2000) for open economy models and Greenwood et al. (1997) and Whelan (2003) for closed economy models that comply with this empirical regularity.
2 The data

2.1 Structure of aggregate investment expenditures

We start by looking at the distribution of investment expenditures between the output of different sectors of economic activity. The most appropriate data source for this purpose is input-output tables and we use data from the OECD input-output database (see OECD (2000a, 2000b)).

Table 1 presents investment spending for 10 OECD countries during 1970-1990. The expenditure pattern reveals that around 90 percent of the investment expenditures are spent on the output of two sectors of economic activity: manufacturing and construction. Manufacturing goods in investments, e.g. machinery and transportation equipment, are traded goods, while the output of the construction sector, e.g. residential and nonresidential buildings, is nontraded. Measures of tradedness of sectoral output usually put these two sectors at the opposite extremes of the spectrum. The weight of manufacturing and construction in investment expenditures in Table 1 is stable across time and sample countries, varying between 0.85-0.95.

From the remaining 10 percent of aggregate investment expenditures, 4/5 are spent on the output of two other sectors: retail/wholesale trade and real estate/business services sectors, both of which are nontraded services. This leaves two percent of the investment expenditures, which are spent on the output of other sectors, such as financial intermediation, agriculture, transport and communications.

The structure of investment expenditures in Table 1 is very similar to that reported in Burstein et al. (2004). Their sample refers to the 1990-1998 period and includes 18 observations from input-output tables for OECD countries as well as Argentina and Chile. Burstein et al. (2004) find that the construction sector accounts for 51 percent of the investment expenditures and distribution and real estate services for 8 percent.

While input-output data on investment expenditures might be sufficient to draw conclusions about the relative importance of traded and nontraded goods in aggregate investments, the coverage is clearly too limited to say anything convincing about the other questions we set out to answer in this paper. An alternative data source is detailed gross fixed capital formation (GFCF) data from national accounts (NA). This data offer a considerably larger sample for our investigation. However, they also incorrectly assign some of the investment expenditures on nontraded goods as expenditures on traded goods. Investment expenditures on the output of manufacturing and construction sectors in the NA data are reported separately, so that 90 percent of the investment expenditures

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8See e.g. De Grigorio et al. (1994).
9The Netherlands stand out from the rest of the sample, with weights for manufacturing and construction varying within the 0.83-0.86 range.
expenditures can be correctly accounted for as traded or nontraded. At the same time, retail/wholesale trade and real estate/business services, both of which are nontraded, are not accounted for separately. Hence, such expenditures are assigned to expenditures on either construction or manufacturing output.

Ignoring the 2 percent of investment expenditures spent on output of other traded and nontraded sectors, we conclude that NA data can account for investment expenditures on nontraded goods with an error in the range of −0.08 to 0.00. The maximum error would apply if all retail/wholesale trade and real estate/business services were assigned to the output from the manufacturing sector. If, on the other hand, these services are assigned to the expenditures on the output of the construction sector, NA data would contain no error. In this case, traded and nontraded expenditures are correctly accounted for.

Clearly, the actual size of the error is somewhere in between these two extremes. Comparing investment expenditure data from input-output tables and NA, an estimate of the size of the error can be obtained. When data in Table 1 are compared with their counterpart from NA, NA data are found to underestimate the share of investment expenditures on nontraded goods by 0.040-0.059. The size of the error appears to be stable during the 30 year period for which input-output tables are available.\(^{10}\)

2.2 Data sources

In view of the considerably larger coverage of the NA data and the small size of the error, the rest of the paper builds on evidence from the detailed GFCF data of NA. Three distinct datasets are used:

1. Annual GFCF data from the United Nations (UN) detailed NA statistics. This dataset covers the 1950-1997 period. The number of countries included in the sample gradually increases from 9 in 1950 to 30 in 1960, 71 in 1970, 80 in 1980 and thereafter gradually decreases to 74 in 1990 and 21 in 1997. In total, there are 2515 observations. In this dataset, GFCF data are divided into (i) residential buildings, (ii) non-residential buildings, (iii) other construction and land development and (iv) other. For the purpose of our investigation, we define residential, non-residential buildings, other construction and land development as nontraded investment goods and ‘other’ products as traded investment goods.

2. NA data for 1970, 1975, 1980, 1985 and 1996 benchmarks in Penn World Tables (PWT). Details of these data are available in Summers et al. (1995) and Heston et al.\(^{10}\) Details of the estimation of the error are presented in Appendix A. This Appendix also considers the role of traded intermediate inputs in the production of structures and the role of nontraded intermediate inputs in the production of equipment.
al. (2002). This dataset is further complemented with data for 1987 from Nehru-Dhareshwar (1993). The sample size for different years gradually increases from 16 countries in 1970 to 34 in 1975, 60 in 1980, 65 in 1985, 42 in 1987 and 115 in 1996. In 1996, PWT benchmark GFCF data are divided into (i) construction and (ii) machinery and equipment. In this case, we define construction as nontraded input and machinery and equipment as traded input. The same division is also available for the 1987 data. Benchmark data for 1970, 1975, 1980 and 1985 report up to 20 subcategories of GFCF, which we divide into traded and nontraded sectors by defining all equipment and machinery related subcategories as traded and all construction related subcategories as nontraded.

3. OECD annual detailed NA data, which contain GFCF data for a period from 1970-1995 until 2002 depending on a country. Detailed investment data from 1970 are available for 9 countries. For 12 additional countries, data become available starting with some year between 1970 and 1995. For three of the sample countries, data for 2002 were not available. Disaggregation of GFCF data from OECD detailed NA distinguishes between six types of investment inputs: (i) products of agriculture, forestry, fishing and aquaculture, (ii) metal products and machinery, (iii) transport equipment, (iv) dwellings, (v) other buildings or structures and (iv) other products. For our purpose, we define (i)-(iii) as traded inputs and (iv)-(v) as nontraded.

The treatment of ‘other products’ requires a more careful consideration. The main components of this subgroup of investment expenditures are intangible fixed assets (e.g., mineral exploration, computer software, entertainment, literary or artistic originals) and costs associated with the transfer of ownership of non-produced assets. Although most of the items in the subgroup are nontraded, some types of computer software, for example, should be treated as traded services. Unfortunately, no further breakdown of the ‘other products’ category is available. For the purpose of our investigation, we therefore exclude ‘other products’ from GFCF data. On average, this amounts to excluding 3 percent of the GFCF in 1970 and 10 percent in 2002.

Although all three datasets use NA statistics, there are good reasons for examining each of them separately. The UN dataset contains the largest number of countries and covers the whole post WWII period. Data for this dataset are collected using standardized NA statistics reports provided to the UN statistics office by the national statistical offices of its member states.

11 Also includes New Zealand with data coverage starting from 1971.
The benchmark data for PWT offer the largest cross-section comparison of 115 countries for 1996. GFCF data in PWT are more detailed than in the UN dataset and compiled as part of a worldwide IPC project. Data from Nehru and Dhareshwar (1993) should, in principle, be treated as a separate cross-section dataset for 1987, compiled by the authors using various sources (see Nehru and Dhareshwar (1993) for details).

The distinguishing feature of the OECD dataset is that its data are compiled using SNA 93 definitions. This is the reason why the GFCF subgroup 'other products' in the OECD dataset is not available as a separate subgroup in the other datasets. In addition, the OECD dataset is the only one containing GFCF data for the 1998-2002 period.

3 Empirical evidence on investment expenditure shares

This section first presents empirical evidence from time-series data and then considers the evidence from cross-section comparisons. At the end of the section, we discuss the compatibility of our findings with several already established empirical regularities in the growth literature.

3.1 Time-series data

Time series results are based on annual investment expenditure data from the OECD NA and the UN NA. Starting with the OECD dataset, Table 2 summarizes investment expenditure shares on nontraded goods for twenty-one OECD countries. All country-year observations of this variable are between 0.40-0.76. The dashed line in Figure 1 depicts the average yearly expenditure share on nontraded goods in the OECD data for the nine countries with full 1970-2002 coverage. Between 1970 and 2002, the average expenditure share decreased by a mere 0.01.

Figure 2 depicts the annual time series data for the six largest economies in the OECD sample. We see that in each country, the nontraded expenditure share is quite stable over time and differences across countries are small but persistent. For two of the countries in Figure 2, the US and France, there is a clear time trend in the expenditure shares, although its slope is small.

Data for the six largest economies are representative of the rest of the sample countries. Panel 1 in Table 4 shows results of a simple linear time trend regression for sample countries with at least 30 years of data. Time trends in Table 4 are expressed as a change in aggregate investment expenditures on nontraded goods over a decade. For five countries out of nine, the time trends are significantly different from zero at a 5 percent level.

These countries are: Denmark, Finland, Germany, Italy, the Netherlands, United States, Norway, United Kingdom and also New Zealand with 1971-2001 coverage.
confidence level. At the same time, with the exception of Denmark, the point estimate of the time trends in all countries is between -0.03 to 0.03 per decade. Panel 1 in Table 5 shows results for a pooled regression containing the same nine countries and a panel regression with country dummies. In either case, the results suggest that there is a small, negative and significant time trend in the investment expenditure data.

Between some of the countries in the OECD dataset, there are significant differences in investment expenditures on traded and nontraded goods. From Table 1, the highest average nontraded expenditure share for a country (Canada 0.689) is 0.226 higher than the lowest average expenditure share (Sweden 0.463). The pattern of high and low expenditure shares shows persistence over time. To measure this persistence, we divide the OECD dataset into three equal eleven-year periods and calculate the correlation of nontraded expenditure shares between any two periods. Between 1970-80 and 1981-91, the expenditure share correlation is 0.59. For 1970-80 and 1992-2002, the correlation is 0.56. Between 1981-91 and 1992-2002, the correlation is 0.81.

Data from the UN NA provide further support for the observations made with the OECD data (see Table 3). The UN dataset includes at least one observation for 113 countries and the range of nontraded expenditure shares is generally wider. However, 95 percent of all country-year observations for nontraded expenditure shares are in the 0.33-0.79 range and 90 percent are in the 0.39-0.75 range.

The sample average nontraded expenditure share in the UN NA data, also depicted in Figure 1, is stable over time. While the share decreases by 0.08 from 0.68 to 0.60 during the first 10 years of the sample (1950-1959), the share fluctuates within the 0.54-0.60 range with only a slight downward trend during the subsequent 37 years.

Panels 2 and 3 in Table 4 present time trend regressions for OECD and non-OECD countries. With few exceptions, the results for both sets of countries are very similar to what we observed in Panel 1 of Table 4. This is further confirmed by the results in Panel 2 of Table 5. Point estimates for time trends in OECD countries in Table 5 range between -0.012 to -0.014 per decade. As can be expected, non-OECD countries exhibit more variation in the time trends. Also, in non-OECD countries, time trends in pooled and panel regressions of Table 5 are larger than in OECD countries, ranging between -0.016 to -0.020 per decade.

Average nontraded expenditure shares across countries in the UN data range from 0.34 for Saint Kitts and Nevis to 0.97 for Kyrgyzstan. Large differences in nontraded expenditure shares are present not only at the extremes. Thus, in the sample on 113 countries, the 10th smallest average nontraded expenditure share is 0.429 (Equatorial Guinea), while the 10th largest is 0.719 (Iceland). Table 6 shows the persistent pattern

\[13\] At one extreme, in Kyrgyzstan the nontraded expenditure share is 0.99 in 1996 and, at the other extreme, in Tanzania the share is 0.20 in 1989.
of high and low nontraded expenditures over time in the UN dataset divided into five periods: 1950-59, 1960-69, 1970-79, 1980-89 and 1990-97. Correlations of the expenditure shares between any two subsequent decades are in the 0.64-0.86 range, with a smaller, but still positive, correlation between any other two decades.

To summarize the empirical evidence from time series data, several points need to be stressed. First, both traded and nontraded goods are important ingredients in investments. Furthermore, aggregate investment expenditures on nontraded goods often exceed the expenditures on traded goods.

Second, at a yearly frequency, nontraded expenditure shares of individual countries show little variation and no notable time trends during the second half of the 20th century. As a result, sample averages also exhibit no economically significant time trend. A simple linear trend for the average nontraded expenditure share in the OECD and UN detailed NA data suggests that over the 1960-2002 period (43 years), the share has decreased from 0.60 to around 0.57. This finding is particularly remarkable, given the large changes in relative prices of traded and nontraded goods in investments since 1960s.

Third, there are sizable and persistent differences in expenditure shares between some of the sample countries.

### 3.2 Cross-section data

Equally interesting is the cross-section evidence about differences in nontraded expenditure shares across different country characteristics, most importantly the level of income. Table 7 presents the cross-section results from the UN dataset for each year between 1950 and 1997. The mean of the sample, presented in Figure 1, was already discussed with the time series evidence. The fourth column of Table 7 shows the correlation between the nontraded expenditure share and PPP adjusted income per capita across countries. In all the sample years, the correlation is within the -0.31 to 0.32 range. Furthermore, with the exception of the six years 1950-53 and 1995-1996, the correlation is within the -0.03 to 0.32 range. Thus, in the UN dataset, there is a small and positive correlation between expenditure shares and per capita income in all but a few sample years. The average correlation across 1950-97 is 0.10.

Cross section results from the PWT dataset, presented in Table 8, show a very similar picture. For all six sample years, the correlation is positive and in five cases out of six, the correlation is between 0.04 and 0.31. To illustrate the correlation between income and expenditure shares, Figure 3 plots the two data series for the largest cross-section

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14Several measures of economic activity were considered, including real GDP per capita in constant international prices, GDP per capita in current prices and real GDP per worker in constant international prices. The correlations between investment expenditure share and different measures of income are very similar.
sample from the PWT dataset. Figures 4-7 present the same data from the UN dataset for the years 1960, 1970, 1980 and 1990.

Next, we use the largest PWT benchmark dataset for 1996 to investigate the differences in the nontraded expenditure shares across different regions of the world. Table 9 shows that, once more, there is very little variation. The average coefficients for eight different country groups range between 0.51 and 0.66.

The only notable exception in the PWT 1996 benchmark dataset is Africa, where the coefficient is much lower than in other regions. For 1996, the nontraded expenditure share in each of the 22 African countries is below the sample average of 0.51. To find out more about African countries, Table 9 also includes the average coefficients for Africa in 1985 and 1980 PWT benchmark datasets. The 1996 results for Africa appear to be an exception. Since Africa represents a sizable country group, this can explain why the average coefficient in the whole PWT 1996 benchmark dataset (see Table 8) is lower than in previous years. The last column of Table 9 reports correlations with income for each of the country groups. For five groups out of eight, the correlation is in the -0.02 to 0.32 range.

Table 10 presents the UN data separately for four country groups: Africa, Europe, Latin America and South East Asia. Years before 1960 have been excluded from the table, since the number of countries did not exceed two in any of the groups. With few exceptions, the average nontraded expenditure share in any of the groups does not deviate from the total sample average by more than 0.05. This result is illustrated in Figure 8. Note that, in contrast to PWT 1996 benchmark data, expenditure shares in African countries during 1990-95 are only slightly below the sample average and for the sample of three African countries in 1996, it is above the sample average.

Table 11 summarizes the cross-section results for OECD countries in the OECD dataset. The average expenditure share for the sample of twenty-one developed countries is very similar to the average numbers in the UN and PWT datasets. During the 1970-1990 period, the correlation between income and nontraded expenditure shares in the OECD country group is systematically higher than the correlation observed for the whole sample in the UN data. This finding is confirmed with the correlation coefficients for European countries in Table 10. During the 1990s, the correlation is close to the total sample correlation in the UN dataset.

The cross-section results are not affected, if the differences in the size of population across countries are taken into account. The average correlation between the size of the population and the expenditure shares in the UN dataset is 0.01, with correlations for different years varying in the -0.20 to 0.10 range. One observation that does stand out

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15 The two exceptions to this rule are Latin America in the 1960s and Africa in the 1990s. In both cases, the number of countries in the regional group was less than seven.
in all cross-section comparisons is that countries with lower per capita income exhibit
more variation in nontraded expenditure shares (e.g. see Figures 3-7). The same is also
true for the time series data (see Table 4).

Overall, cross-section evidence indicates that nontraded expenditure shares increase
systematically with the level of per capita income. However, the magnitude of the
increase is small. For example, the linear trend fitted into Figures 3-7 suggests that a
country with a per capita income half of the US level has a nontraded expenditure share
which is 0.01-0.06 lower than in the US. These figures are representative of the whole
cross-sectional evidence. Importantly, there are no notable differences in expenditure
shares across different regions of the world. As with the time-series evidence, this result
is particularly remarkable given the large differences in relative prices of traded and
nontraded goods in investments between poor and rich countries.

Our cross-section results differ from findings in Burstein et al. (2004), who in a sample
of 19 countries find a significant negative correlation between the investment expenditure
share on nontraded goods and real per capita income. To reconcile the results of the two
studies, Table 12 presents the results of Burstein et al. (2004) and replicates their study
using the data of our paper. Columns 1-5 of the table present the results of Burstein
et al. (2004). The fourth column presents the share of construction sector output in
investment expenditures. The fifth column presents the same share for all nontraded
sectors, defined in Burstein et al. (2004) as construction, retail/wholesale trade and
real estate/business services. All expenditure data, except for Brazil, are obtained from
input-output tables. Notice that the data for each country refer to some year over the
1990-1999 period, presented in the second column.

The last three columns of the table present comparable data from each of our datasets.
In the case of the UN data, the comparison is restricted by the fact that for most
countries, the data series end in 1996-97 and therefore six of the observations are missing.
For the OECD data, the comparison is restricted by the fact that our dataset only covers
selected OECD countries and the Burstein et al. (2004) sample includes several non-
OECD countries. Consequently, six observations are also missing. In the case of the
PWT data, we are restricted to using 1996 data for each country.

Burstein et al. (2004) find that construction expenditures and per capita income have
a correlation coefficient of -0.69, while for all nontraded expenditures, this coefficient is
-0.64. The correlation coefficients in the three comparable samples from our datasets are
also negative, but smaller, ranging from -0.01 to -0.29.\footnote{Data used in this paper also offers an alternative estimate of correlation, based on input-output
table data. Using such data for 10 OECD countries over 1970-1990 period (see Table 1 and OECD
(2000a)) we find that the correlation between the investment expenditure share on nontraded goods and
real per capita income is -0.11.}

What explains the large differences in correlation between real income per capita and
investment expenditure shares in our paper and Burstein et al. (2004)? The negative correlation coefficients at the bottom of the last three columns of Table 9 indicate that, at least partly, the differences are due to the particular years from which the Burstein et al. (2004) sample is selected. For nine countries out of nineteen, the data are for the 1995-96 period. Cross-section results in Table 7 show that for these two particular years, the UN data also exhibit negative correlations between per capita income and expenditure shares (-0.15 in 1995 and -0.23 in 1996). However, these two years are very clear outliers when compared to the whole 1954-1997 period.17

The remaining differences are likely to stem from the limited sample size in the Burstein et al. (2004) study. Note from Table 10 that for subgroups of countries in the UN dataset, it is not uncommon to find correlations with per capita income that differ significantly from the correlation in the aggregate sample. For example, in 1981 the expenditure shares-income correlation for eleven South East Asian countries is -0.42. In the same year we find a correlation of -0.36 for sixteen African countries. At the same time, the average correlation for the whole UN sample for the same year is -0.01. Significant deviations in correlation coefficients can also be found for Europe and Latin America.

3.3 Compatibility with existing empirical regularities

Our empirical findings fit well with the body of already established empirical regularities, which provides an additional reliability check for our results.

First, consider the empirical fact that the relative price of nontraded goods increases with the level of income. Combined with our findings about investment expenditures, this implies that, as per capita income increases, investments become more intensive in traded goods or equipment. In a series of papers, Summers and De Long (1991, 1993) conclude this to be the case in the data. They find a strong positive correlation between equipment intensity of investments and economic growth.

Second, Eaton and Kortum (2001) note that domestic price investments in equipment, as a share of GDP, do not vary systematically with the level of income. Together with our findings, this implies that aggregate domestic price investment rates also should not vary systematically with income. Parente and Prescott (2000) find that this indeed is the case for a wide set of countries over the 1960-2000 period. The same empirical fact is also stressed by Hsieh and Klenow (2003) and Restuccia and Urrutia (2001). Note that findings in Burstein et al. (2004) imply that either the domestic price investment

17In the PWT 1996 benchmark data, the correlation between per capita income and expenditure shares is 0.12. However, as already noted, 1996 data for African countries in this dataset appear to contain an error. If the African countries are excluded, the PWT 1996 benchmark data also exhibit a small negative correlation between income and expenditure shares.
rates are decreasing with income or domestic price investment rates in equipment are increasing with income and thus, contradict previous findings in the literature.

4 A theoretical implication: Can the Balassa-Samuelson effect account for investment rate differences between rich and poor countries?

One of the most consistent empirical growth facts is that international price investment rates in rich countries are 2-3 times higher than in poor countries. In this section, we look at the implications of our empirical findings for the theoretical literature that investigates sources of the significant difference in investment rates.18

To provide a convincing explanation for the differences in investment rates, a theoretical model needs to satisfy two closely related empirical regularities. First, the relative price of nontraded goods is increasing with income and second, domestic price investment rates do not correlate with income. Restuccia and Urrutia (2001) show that, among other possible explanations such as distortionary policies in poor countries, differences in international price investment rates can be the result of differences in relative productivity in the production of investment and consumption goods. This finding is taken one step further by Hsieh and Klenow (2003). The authors argue that differences in the relative price of nontraded goods across income are driven by differences in the price of nontraded, rather than traded, goods. Consequently, they use a small open economy two-sector growth model and show that only productivity differences in the production of consumption and investment goods can account for the differences in international price investment rates.

These findings beg for a question: what stands behind the differences in relative productivity between sectors producing investment and consumption goods? Hsieh and Klenow (2003) suggest the Balassa-Samuelson effect to be the prime candidate for explaining such differences. Our empirical findings, however, show that in rich as well as poor countries, the investment expenditures on nontraded goods are at least as large as the expenditures on traded goods. Thus, the often used notion that investment goods are traded while consumption goods are nontraded contradicts the empirical evidence.

In this section, we investigate to what extent the differences in investment rates between rich and poor countries can be generated with the two-sector small open economy growth model, when nontraded and traded goods in investments and consumption are correctly accounted for. This is equivalent to asking to what extent the required produc-

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18 Ultimately, the goal of this literature is to explain income differences across countries, but for the purpose of this paper, the attention is restricted to explaining differences in investment rates.
tivity differences in production of investment and consumption goods can be assigned to
differences in the traded-nontraded nature of sectoral output.

4.1 Theoretical framework

We start by presenting a simple two-sector small open economy growth model, which
is sufficiently general to accommodate most of the formulations that have been used in
the literature. Importantly, the model setup allows for traded and nontraded goods to
be used in both investments and consumption. To keep the model simple and focus on
the main task, it is formulated in a deterministic environment. Moreover, we ignore any
labor-leisure considerations.

The representative consumer in the model solves

$$\max_{\{c_{Tt}, c_{Nt}, k_{Tt+1}, k_{Nt+1}, l_{Tt}, l_{Nt}, b_{t+1}\}} \sum_{t=0}^{\infty} \beta^t u(F_C(c_{Tt}, c_{Nt})),$$

subject to the following per-period budget constraint

$$c_{Tt} + p_{Nt} c_{Nt} + q_{t+1} F_I(x_{Tt}, x_{Nt}) + b_{t+1} \leq (1 + \gamma_i) b_t + p_{Nt} F_N(k_{Nt}, l_{Nt}) + F_T(k_{Tt}, l_{Tt}).$$

Here, $\beta$ is the subjective discount rate; $c_{Tt}$ and $c_{Nt}$ represent traded and nontraded
components of consumption, which through the function $F_C(c_{Tt}, c_{Nt})$ are aggregated
into consumption goods; the total inelastic labor supply in the economy is normalized
to unity so that in every period, $l_{Tt} + l_{Nt} = 1$; $k_{Tt}$ and $k_{Nt}$ are capital stocks in traded
and nontraded sectors, which together with labor input produce sectoral output with
$F_j(k_{jt}, l_{jt}), j \in \{T, N\}$; $F_I(x_{Tt}, x_{Nt})$ represents new investments, which can be purchased
at a price $q_{t+1}$; $b_t$ is outstanding foreign assets; and $\gamma_i$ is the interest rate charged on
foreign assets. The price of the traded good is used as the numeraire.

The resource constraints for traded and nontraded sectors of the economy are

$$c_{Nt} + x_{Nt} \leq F_N(k_{Nt}, l_{Nt})$$

$$c_{Tt} + x_{Tt} + b_{t+1} - b_t (1 + \gamma_i) \leq F_T(k_{Tt}, l_{Tt}).$$

The output in each sector can be used either for consumption, $c_j$, or investment, $x_j$,
purposes. In the traded sector, the difference between domestic absorption and output
is equal to the trade balance.

Capital in this economy is accumulated according to

$$k_{Tt+1} + k_{Nt+1} = (1 - \delta) (k_{Tt} + k_{Nt}) + F_I(x_{Tt}, x_{Nt}),$$

17
where $\delta$ is the depreciation rate and in each period, $F_I(x_T, x_N)$ is acquired from the investment production sector.

Producers of investment goods solve

$$
\max_{\{x_T, x_N\}} q_{t+1} F_I(x_T, x_N) - x_T - p_N x_N,
$$

so that new investment goods in the economy are potentially produced using the output of both traded and nontraded sectors.

In the framework of this model, the setup with traded investment goods and nontraded consumption goods corresponds to assuming that $F_C(c_T, c_N) = c_N$ and $F_I(x_T, x_N) = x_T$. Hsieh and Klenow (2003) show that under such assumptions, a relatively higher productivity in the investment sector (relative to the consumption sector) in rich countries leads to (i) higher relative prices of nontraded goods in rich countries and (ii) higher international price investment rates in rich countries, while domestic price investment rates are the same in rich and poor countries. All three of these model predictions find strong empirical support.

The spirit of our investigation is to examine whether these three empirically relevant results can be generated in a model where productivity differences are due to traded relative to nontraded sectors of economic activity. Our empirical results suggest that this is not identical to assigning productivity differences to investment and consumption sectors. We examine both qualitative and quantitative predictions of the model.

### 4.2 Analytical solution

It is instructive to start the investigation by considering the analytical solution of the two-sector growth model presented in Section 4.1. Motivated by earlier empirical findings, we assume that traded and nontraded goods are aggregated into investments using

$$
F_I(x_T, x_N) = G x_T^\gamma x_N^{1-\gamma}.
$$

(1)

In the model, this imposes constant investment expenditure shares on traded and nontraded goods. The production function in traded and nontraded sectors is assumed to be

$$
F_j(k_j, l_j) = A_j k_j^{a_j} l_j^{1-a_j} \text{ for } j \in \{T, N\}.
$$

Traded and nontraded goods are aggregated in consumption goods through

$$
F_C(c_T, c_N) = c_T^{c_T} c_N^{1-c_T},
$$

(2)
so that consumption expenditures on traded and nontraded goods are also constant. The assumed functional form for the consumption aggregator is chosen because of its analytical convenience. It will be relaxed in the latter part of this section.

Outcomes of the model are evaluated by comparing solutions for model economies with differing relative productivities in traded and nontraded production sectors, in particular

\[
\left( \frac{A_T}{A_N} \right)^{rich \ country} > \left( \frac{A_T}{A_N} \right)^{poor \ country}.
\]

In all other respects, model economies are identical. To avoid an additional layer of complexity, we assume that all model economies are in a steady state with a zero external asset position, i.e., \( b = 0 \). Each country is a small open economy and takes the world interest rate as given.

The analytical solution of the model's steady state is presented in Appendix B. Here, we present only the part of the solution that is relevant for our discussion. The expression for the domestic price steady state investment rate in the model is

\[
\frac{I}{Y} = \frac{x_T + p_N x_N}{x_T + c_T + p_N (c_N + x_N)} = \frac{a \delta}{r + \delta}.
\]

(3)

The investment rate is positively related to the capital income share and negatively related to the return on capital. This result is the same as in the model with fully traded investments and nontraded consumption. Since the investment rate in (3) does not depend on productivity levels in the two sectors, all countries exhibit the same constant domestic price investment rates. The investment expenditure share on nontraded goods in the model is also the same in all countries and equal to

\[
\frac{p_N x_N}{x_T + p_N x_N} = (1 - \gamma) .
\]

This result follows directly from the functional form imposed in (1).

The relative price of nontraded goods in terms of traded goods, \( p_N \), in the model satisfies

\[
p_N = \frac{A_T}{A_N}.
\]

(4)

Model economies exhibiting a higher relative productivity in the traded sector will also exhibit a higher relative price of nontraded goods. This result is also the same as that in the model with fully traded investments and nontraded consumption.

With the relative price of nontraded goods varying across countries, model outcomes expressed in common prices will differ from outcomes expressed in domestic prices. To compare model outcomes expressed in terms of common prices across countries, the relative price of nontraded goods is kept fixed at \( p_N^{PPP} \) and the effect of productivity
changes on steady state quantities is examined.

Since investment expenditure shares on traded and nontraded goods are constant, changes in the relative price of nontraded goods imply that the model economy with higher relative productivity in the traded sector exhibits higher equipment intensity in investments. This is in line with the empirical evidence presented in De Long and Summers (1991, 1993).

The international price investment rate in the model can be expressed as

$$I^{PPP} = \frac{I_{PPP}}{Y^{PPP}} = \frac{x_T + p_N^{PPP} x_N}{x_T + c_T + p_N^{PPP} (c_N + x_N)},$$

$$I^{PPP} = \frac{\Delta T / \Delta N}{1 - \gamma \left(1 - \frac{\Delta T / \Delta N}{\Delta T / \Delta N}\right)},$$

where $\Delta T / \Delta N = p_N^{PPP}$ denotes the sectoral productivity ratio in the base country. Equation (5) shows that in terms of a common international price, the investment rate is affected by the deviation of the sectoral productivity ratio from the same ratio in the base country. If $\Delta T / \Delta N = \Delta T / \Delta N$, then (5) reduces to (3). It can further be shown that

$$\frac{\partial I^{PPP}}{\partial \Delta T / \Delta N} = (\gamma - \varepsilon) \frac{\Delta T / \Delta N}{\left[1 - \gamma \left(1 - \frac{\Delta T / \Delta N}{\Delta T / \Delta N}\right) \right]^2}.$$

According to (6), model economies with a higher relative productivity in the traded sector exhibit higher international price investment rates if $\gamma > \varepsilon$, and vice versa if $\gamma < \varepsilon$. The intuition behind this result is simple. In the model, both investment and consumption expenditure shares on traded and nontraded goods are constant across countries. When traded goods play a more important role in investments than consumption, i.e. $\gamma > \varepsilon$, and the relative price is fixed at $p_N^{PPP}$, higher relative productivity in traded sector increases the weight of investments in output at the expense of consumption. As a result, in term of a common price, higher relative productivity in the traded sector leads to a higher investment rate.

We conclude that subject to the condition that $\gamma > \varepsilon$, the model with traded and nontraded goods in both consumption and investments delivers qualitatively the same results as the more restrictive version of the model with only traded goods in investments and only nontraded goods in consumption.
4.3 Quantitative results

Are the investment rate differences in the model quantitatively important, when compared to the data? To answer this question, we compare the differences in international investment rates in the data with the differences that can be generated in a parametrized two-sector model.

We start by summarizing the empirical evidence. The best available data comparing international investment rates across countries are from the PWT dataset. For illustrative purposes, Table 13 presents the relevant data from the PWT 1996 benchmark, with countries grouped according to their real GDP per worker relative to the US. In line with earlier empirical findings, domestic investment rates do not vary systematically with income, while international investment rates in rich countries are 2-3 times higher than in poor countries. A similar magnitude of differences in international investment rates has been found by other studies (see Hsieh and Klenow (2003)).

The last two rows in Table 13 compare prices of traded and nontraded goods across income levels. Traded goods prices are represented by the price of machinery and equipment, while nontraded goods prices are represented by the prices of structures. As can be expected, the relative price of nontraded goods in terms of traded goods increases with income. Further, as already pointed out by Hsieh and Klenow (2003), the price of traded goods does not correlate with income. Hence, differences in the relative price are driven by differences in the price of nontraded goods between rich and poor countries.

The magnitude of price differences exhibits a substantial variation depending on the subset of goods and services considered, as well as the year of the benchmark data. However, most of the estimates can be put in the boundaries of 3-8 times higher relative prices of nontraded goods in the rich countries. Given the uncertainty surrounding the magnitude of differences in the relative price, a wide range of price differences will be considered.

Turning to the model, first recall that the only source of heterogeneity in model outcomes is the difference in relative productivity across model economies. To compare model outcomes with the data, we use equation (4) to generate the observed differences in the relative price of nontraded goods between rich and poor countries. The performance of the model is then evaluated by comparing differences in international investment rates in the model and the data.

To parametrize the model, we set the capital income share, \( \alpha \), equal to 1/3. This is a standard value in the literature. Gollin (2002) finds no correlation between capital

\[19\] For example, Hsieh and Klenow (2003) measure the price of nontraded goods using a subset of consumed services. Their estimated price elasticity with respect to income in the PWT 1980 and 1985 benchmarks suggests the price of nontraded goods in rich countries to be around 4 times higher than in poor countries. In the 1996 benchmark, the estimated difference is twice as large.
income shares and the level of income. There is also evidence of capital income shares being very similar in highly aggregated sectors of economic activity, such as the traded and nontraded (see Parente and Prescott (2000)). The discount rate is set at $\beta = 0.964$ and the depreciation rate at $\delta = 0.073$. These two values are chosen so that the domestic price investment rate in model economies is the same as in Table 13, i.e. 0.22, and the capital output ratio is equal to 3.0.

As a benchmark for further discussion, we first consider the model specification with fully traded investments and nontraded consumption, which corresponds to assuming that $\varepsilon = 0$ in equation (2) and $\gamma = 1$ in equation (1). The results of the benchmark parametrization are summarized with the solid line in Figure 9. In this figure, the x-axis represents the relative price of nontraded goods in the poor model economy as a fraction of the relative price in the rich model economy. The Y-axis represents the international price investment rate in the poor model economy, with the rich model economy taken as the base country. Thus, on both axes, the value of 1 corresponds to the rich model economy. According to the data, the empirically relevant range on the x-axis is between 0.125-0.33 and on the y-axis, it is between 0.33-0.5. The magnitude of differences in the international price investment rates observed in the data can be rather closely matched with the benchmark model specification.

In the second model specification, motivated by the empirical results of this paper, we set the investment expenditure share on nontraded goods, $\gamma$, in equation (1) equal to 0.40. For aggregation of consumption in equation (2), we set $\varepsilon = 0.25$. This particular parameter value is taken from Burstein et al. (2004), who estimate the consumption expenditure share on traded goods in medium and high income countries to be $1/4$ of the aggregate consumption expenditures. Note that the parameter values for $\varepsilon$ and $\gamma$ imply that consumption is more intensive in nontraded goods than investments, and therefore from (6), we know that the model’s international price investment rate will increase with the level of income.

The corresponding solution in Figure 9 shows that with this empirically motivated parametrization, the model can only account for 15-30 percent of the differences in international price investment rates between rich and poor countries. Note that this conclusion does not depend on the magnitude of differences in the relative price of nontraded goods.

Differences in outcomes of the two model parametrizations can be better understood

---

20We found the same average expenditure share also in the OECD input-output tables for 1990.
by considering the relevant ratio from the model’s analytical solution

\[
\frac{(I/Y)^{PPP}_{poor}}{(I/Y)^{PPP}_{rich}} = \frac{\left(1 - \frac{\Delta x}{\Delta x_{AN}}\right)^{-1} - \gamma}{\left(1 - \frac{\Delta x}{\Delta x_{AN}}\right)^{-1} - \left[\gamma \frac{I}{Y} + \varepsilon \left(1 - \frac{1}{Y}\right)\right]}.
\]

(7)

The ratio in (7) is obtained from (5), where we have substituted in the expression for domestic price investment rate from (3). As in Figure 9, the rich model economy is taken as the base country, so that \(\frac{\Delta x}{\Delta x_{AN}} < 1\).

Compare the second term in the numerator and denominator of equation (7): \(\gamma\) and \(\gamma \frac{I}{Y} + \varepsilon \left(1 - \frac{1}{Y}\right)\). The latter term is a weighted average of investment and consumption expenditure shares on traded goods, weighted by investment and consumption rates correspondingly. First, note that for the ratio in (7) to be less than unity, we need \(\varepsilon < \gamma\). Second, ceteris paribus, the ratio is smaller the larger is \(\gamma\) and the smaller is \(\varepsilon\). Hence, the ratio is smaller the larger is the difference \(\gamma - \varepsilon\).

The benchmark parametrization can therefore be interpreted as the extreme case, which allows for maximum differences in expenditure shares and, consequently, maximum differences in international price investment rates. Intuitively, it is then clear that if the model solution with the most favorable values of \(\gamma\) and \(\varepsilon\) closely match the differences in investment rates, only a fraction of the investment rate differences can be accounted for under the more realistic parametrization.

We should also note the limited effect of differences in sectoral productivities on the international price investment rates. In the extreme case with \(\frac{\Delta x}{\Delta x_{AN}} \to 0\), the investment rate ratio in (7) can be written as

\[
\frac{(I/Y)^{PPP}_{poor}}{(I/Y)^{PPP}_{rich}} = \frac{1 - \gamma}{1 - \left[\gamma \frac{I}{Y} + \varepsilon \left(1 - \frac{1}{Y}\right)\right]}.
\]

(8)

Thus, although larger variation in sectoral productivity ratios does increase the differences in international price investment rates, asymptotically its effect is limited to (8).

### 4.4 Sensitivity analysis of numerical results

How sensitive are the results in Figure 9 to the assumed values of \(\beta\), \(\delta\) and \(\alpha\)? Equation (7) together with equation (3) show that the discount factor, depreciation rate and capital income share only affect the international price investment rate through their effect on weights, \(I/Y\) and \(1 - I/Y\), for the two expenditure shares. Thus, as long as the model is restricted to exhibiting a reasonable domestic price investment rate, which for our parametrization is 0.22, the results in Figure 9 are not sensitive to values of \(\beta\), \(\delta\) and \(\alpha\). Furthermore, since there is substantial empirical evidence that domestic price
investment rates do not correlate with income, any correlation between parameters $\beta$, $\delta$, $\alpha$ and income should not affect the results in Figure 9.

The extensive empirical evidence presented in this paper suggests that around 60 percent of the investment expenditures are spent on nontraded goods, and that this share does not vary systematically with the level of income. However, the available evidence for consumption expenditures is more scarce. To deal with this shortcoming, Figure 9 also depicts the solution of model parametrization with $\gamma = 0.40$ and only nontraded goods in consumption, i.e. $\varepsilon = 0$. In this case, the model accounts for 40-60 percent of the investment rate differences. This parametrization provides the upper bound for the investment rate differences for which the model can potentially account, give that $\gamma = 0.40$.

We also consider an alternative aggregation function for consumption goods. Stockman and Tesar (1995) report the elasticity of substitution between traded and nontraded goods in consumption to be 0.44 rather than unitary, so that instead of (2), consumption is aggregated through

$$F_C(c_T, c_N) = \left( \mu c_T^{\theta-1} + (1 - \mu) c_N^{\theta-1} \right)^{\frac{\theta}{\theta-1}},$$

where $\theta = 0.44$ and $\mu$ is a weight parameter. With less than unitary elasticity of substitution between traded and nontraded goods in consumption, the expenditure share on nontraded goods will be higher for model economies with higher relative prices of nontraded goods, i.e. the rich model economy. This is the case since with $\theta < 1$, the price increase is not fully offset by the decrease in quantity and, consequently, the expenditure share increases.

The result that the consumption expenditure share on nontraded goods is higher in countries with higher income levels agrees with the often reported observation (see e.g. Kravis (1982), p. 194) that the share of nontraded sector output in GDP is higher in OECD countries than in less developed countries. In this case, weight parameter $\mu$ is set so that in the rich model economy, the consumption expenditure share on nontraded goods is 0.25, as reported in Burstein et al. (2004). With this model specification, the difference in the nontraded expenditure share between consumption and investments,

\[\text{To make this connection, we (i) use the empirical result of our paper concerning constant investment expenditure shares on traded and nontraded goods and (ii) assume that the trade balance across countries does not vary systematically with the income level. In this case, all variation in nontraded sector output to GDP across countries is absorbed by consumption expenditures.}\]

\[\text{We do not report the value of } \mu \text{ since in the CES setting, it has no economic meaning. As in the case of unitary elasticity of substitution, with the CES functional form for consumption aggregation, the results in Figure 9 only depend on the productivity ratios } \frac{A_T}{A_N}, \frac{A_T}{A_N}. \text{ The results are independent of the level of productivity in traded and nontraded sectors, } A_T \text{ and } A_N. \text{ A change in the level of the productivity ratio, } A_T/A_N, \text{ requires a change in } \mu, \text{ but does not otherwise affect the results. See Appendix B.3 for details.}\]
i.e. $\gamma - \varepsilon$, in the poor model economy is, in fact, smaller than in the case with a Cobb-Douglas aggregator. Thus, not surprisingly, the *international price* investment rate in the poor model economy is higher than in any of the earlier model solutions.

For the sake of completeness, we also consider elasticities reported by two other empirical studies. Mendoza (1995) finds that in OECD countries, $\theta_{\text{rich}} = 0.74$, while Ostry and Reinhart (1992) find that for some regions of less developed countries, $\theta_{\text{poor}} = 1.3$. With such a model specification, we allow the elasticity of substitution between traded and nontraded goods in consumption to differ between rich and poor model economies. As with the previous model specification, the weight $\mu$ is set to match consumption expenditure shares in the rich model economy. To avoid an assumption about the exact relationship between the intratemporal elasticity of substitution and income, results from this parametrization are not depicted in Figure 9. Comparing only a rich and a poor model economy, we find that in this case, the model can account for 30-50 percent of the investment rate differences. Note that under no CES parametrization can the model explain more than in the case of $\gamma = 0.40$ and $\varepsilon = 0$.

We conclude that the generalization of a growth model with traded investment goods and nontraded consumption goods to a case with traded and nontraded goods in both consumption and investments leads to no qualitative differences in model outcomes, as long as the traded good expenditure share in investments exceeds the traded good expenditure share in consumption. Empirically, this appears to be a reasonable restriction for the more general model. At the same time, for quantitative results, the generalization considerably decreases the model's ability to account for differences in international price investment rates between developed economies and less developed countries. With reasonable parameter values, the model can only account for around 10-40 percent of the interest rate differences, depending on the assumed parameter values.

Our results suggest that the relative productivity differences between traded and nontraded goods cannot be the main cause for the differences in *international price* investment rates between rich and poor countries. The driving force behind this result is the empirical finding that nontraded goods play a dominant role in both consumption and investments.

5 Concluding remarks

Setting up a two-sector open economy growth model requires an assumption about the role of traded and nontraded goods in the capital accumulation process. A common practice in the literature is to assume that only traded or only nontraded goods can be transformed into investments. In a survey of the topic, Turnovsky (1997) concludes that 'no one assumption has gained a uniform acceptance', since these assumptions are...
driven by mere convenience considerations rather than empirical facts. Furthermore, model results are often sensitive to the assumption used.

Although there is some variation across countries, we find that, on average, expenditures on nontraded and traded goods account for 60 and 40 percent of all investment expenditures, respectively. Furthermore, the investment expenditure shares on traded and nontraded goods have been close to constant over the last 50 years and exhibit a small positive correlation with the level of income. These results are particularly remarkable, given the large variation in relative prices across both time and income levels.

Our empirical results indicate that model outcomes that are more in line with the data can be obtained with relatively little additional complexity. There are, in fact, several models in the literature that satisfy our empirical restriction, although the empirical motivation for the particular modeling choice has been missing. In this paper, we have concentrated on the traded-nontraded nature of sectoral output; however, our results are also applicable to models distinguishing between equipment and structures in investments.

With our empirical restriction imposed on a two-sector small open economy growth model, only around 25 percent of the differences in international price investment rates between rich and poor countries can be attributed to differences in relative productivity between traded and nontraded sectors, i.e., the Balassa-Samuelson effect. Thus, this effect is not the main cause for the differences in international price investment rates.

Our empirical results would also affect the transition dynamics in a two-sector model. As Turnovsky (1997), Fernandez de Cordoba and Kehoe (2000) and, more recently, Burstein et al. (2004) have pointed out, an investment process with traded and nontraded goods in a two-sector open economy model can have the same effect as the standard investment adjustment costs and thus help generate more plausible investment dynamics. We leave the study of such effects to future research.
References


A Data issues

A.1 Estimates of the bias, due to investment expenditures on ‘retail/wholesale trade’ and ‘real estate/business services’

A problem accompanying the use of the more widely available national accounts is that the detailed fixed capital formation data cannot be directly mapped into investment expenditures on traded and nontraded goods. In national accounts, all investment expenditures are divided into expenditures on producer durables (e.g. machinery, equipment) and structures (e.g. manufacturing buildings, residential buildings). Expenditures on output of nontraded sectors, other than construction, are bundled together with either expenditures on construction or producer durables and can therefore lead to an underestimation of the expenditure share of nontraded goods. In practice, around 98 percent of the investment expenditures are accounted for if we only add two other nontraded sectors: retail/wholesale and real estate/business services.

To estimate the size of the investment expenditures, which from a ‘traded-nontraded output’ perspective are incorrectly booked in the NA GFCF data, we consider 42 input-output tables for ten OECD countries. These tables cover the period 1970-1990 (see OECD (2000a) for details). Data from input-output tables are compared with NA data for investment expenditures on producer durables and structures. Such comparative data are presented in Table A1.

In Table A1, we should find that the weight for investment expenditures on nontraded goods from input-output data always exceeds the weight obtained from NA data. The size of the difference shows the bias in the NA data for a particular country and a particular year. In Table A1, the expected sign of the difference between weights in input-output and NA data is, in fact, not satisfied for three countries out of ten (Canada, France and Germany). This is probably due to poor compatibility of data. In particular, the much greater detail of the input-output tables often means that it is not fully compatible with data gathered according to NA definitions (see OECD (2000a, 2000b) for a more detailed discussion).

Subject to such compatibility problems, we compare the average differences for the ten sample countries, presented in the last row of Table A1. In this case, the sign of the difference is as expected and the size suggests that NA data underestimate the expenditure weight of nontraded goods by 0.040-0.059. There is no table time trend in the size of the bias.

A similar estimate of the bias is obtained by comparing input-output table data in Burstein et al. (2004) with the corresponding weights in NA data. The results suggest a bias of 0.042 (see Table A2).
A.2 Traded and nontraded intermediate inputs in the production of structures and equipment

Although models with traded and nontraded goods do not usually model intermediate production sectors, in some cases it might be of interest to know the size of the intermediate input of traded goods in the production of nontraded goods for investments and vice versa. The nontraded sector, in particular construction, uses a large amount of intermediate traded inputs and producers of investment goods in the traded sector use nontraded intermediate inputs, such as distribution services. The actual size of these intermediate 'cross inputs' cannot be precisely estimated from the input-output tables, since these do not differentiate between traded and nontraded intermediate inputs in sectoral production for investment and consumption purposes.

To obtain an estimate of the size of these 'cross effects', we calculate the fraction of traded intermediate inputs in the gross output of construction sector. The same fraction is also calculated for a subset of manufacturing sectors which constitutes a majority of traded investments. We do not consider this fraction for all traded and nontraded sectors, since for sectors that were omitted, most of the final use is consumption, not investments. It is likely that intermediate inputs are not equally important for these two components of final demand. The fractions we obtain, expressed as 'intermediate input/gross output' are similar across OECD countries (see Table A3). The average size of traded intermediate input in construction is 31 percent of the gross output. The intermediate input of nontraded goods for the selected subset of the manufacturing sector is 17 percent of gross output.

These estimates suggest that in a model with intermediate traded and nontraded inputs, the weight of aggregate investment expenditures on nontraded goods should be lower than in a model without intermediate inputs. In particular, if the estimated investment expenditure share in Section 3 (adjusted for the bias discussed in A.1) is 0.60, then in a model with intermediate traded and nontraded goods, the same share is 0.48, obtained as $0.60 \times (1 - 0.31) + 0.40 \times 0.17 = 0.48$. 

31
<table>
<thead>
<tr>
<th>Country</th>
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<th>Early-'80s</th>
<th>Mid-'80s</th>
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<td>0.101</td>
<td>0.089</td>
<td></td>
</tr>
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<td>USA</td>
<td>input-output data</td>
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<td>0.606</td>
<td>0.623</td>
<td>0.609</td>
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</tr>
<tr>
<td></td>
<td>NA data</td>
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<td>0.580</td>
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<td>0.550</td>
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</tr>
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<td>0.063</td>
<td>0.059</td>
<td>0.073</td>
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<td>input-output</td>
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<td>0.620</td>
<td>0.583</td>
<td>0.592</td>
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Data sources: For input-output table data, see OECD (2000a), for national accounts data, see OECD (2004). The exact years of comparison are reported in Table 1.
Table A2: Comparison of investment expenditures on nontraded goods in Burstein et al. (2004) and national accounts

<table>
<thead>
<tr>
<th>Country</th>
<th>Burstein et al. (2004)</th>
<th>NA data*</th>
<th>Difference</th>
</tr>
</thead>
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<tr>
<td>Korea</td>
<td>0.601</td>
<td>0.666</td>
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</tr>
<tr>
<td>Mexico</td>
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<td>Australia</td>
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<td>Canada</td>
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<td>-0.053</td>
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<tr>
<td>Chile</td>
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<tr>
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<td>Finland</td>
<td>0.564</td>
<td>0.524</td>
<td>0.040</td>
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<tr>
<td>France</td>
<td>0.562</td>
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<tr>
<td>Germany</td>
<td>0.546</td>
<td>0.640</td>
<td>-0.094</td>
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<tr>
<td>Greece</td>
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<td>0.602</td>
<td>0.109</td>
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<td>Italy</td>
<td>0.586</td>
<td>0.498</td>
<td>0.088</td>
</tr>
<tr>
<td>Japan</td>
<td>0.653</td>
<td>0.552</td>
<td>0.101</td>
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<td>Norway</td>
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<tr>
<td>US</td>
<td>0.527</td>
<td>0.470</td>
<td>0.057</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>0.587</strong></td>
<td><strong>0.545</strong></td>
<td><strong>0.042</strong></td>
</tr>
</tbody>
</table>

* OECD data complemented with UN data for Chile, Australia, Mexico and Korea.

Table A3: Intermediate 'cross inputs' in traded and nontraded investment goods, as a fraction of gross output

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
<th>Nontraded into traded</th>
<th>Traded into nontraded</th>
</tr>
</thead>
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<tr>
<td>Australia</td>
<td>1989</td>
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<td>0.35</td>
</tr>
<tr>
<td>Canada</td>
<td>1990</td>
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<td>0.30</td>
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<tr>
<td>Denmark</td>
<td>1990</td>
<td>0.15</td>
<td>0.30</td>
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<tr>
<td>France</td>
<td>1990</td>
<td>0.23</td>
<td>0.29</td>
</tr>
<tr>
<td>Germany</td>
<td>1990</td>
<td>0.20</td>
<td>0.33</td>
</tr>
<tr>
<td>Italy</td>
<td>1985</td>
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<td>0.34</td>
</tr>
<tr>
<td>Japan</td>
<td>1990</td>
<td>0.19</td>
<td>0.33</td>
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<tr>
<td>Netherlands</td>
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<td>UK</td>
<td>1990</td>
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<tr>
<td>US</td>
<td>1990</td>
<td>0.16</td>
<td>0.31</td>
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<tr>
<td><strong>Average</strong></td>
<td></td>
<td>0.17</td>
<td>0.31</td>
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</table>

Data source: OECD (2000a).
B Model with traded and nontraded goods in consumption and investments

B.1 Steady-state solution of the model

The steady-state solution of the model presented can be characterized by the following system of ten equations and ten unknowns

\[
\begin{align*}
1 - \frac{e}{e_N} - p_N &= 0 \\
q(1 - r)Gx_T^{-1}x_N^{-\gamma} - p_N &= 0 \\
qGx_T^{-1}x_N^{-\gamma} - 1 &= 0 \\
p_N\alpha A_N k_N^{\alpha-1}l_N^{(1-\alpha)} - q(r + \delta) &= 0 \\
\alpha A_T k_T^{\alpha-1}l_T^{(1-\alpha)} - q(r + \delta) &= 0 \\
Gx_T^{-1}x_N^{-\gamma} - \delta(k_T + k_N) &= 0 \\
A_T k_T^{\alpha-1}l_T^{(1-\alpha)} - c_T - x_T &= 0 \\
A_N k_N^{\alpha-1}l_N^{(1-\alpha)} - c_N - x_N &= 0 \\
p_N A_N k_N^{\alpha-1}l_N^{(1-\alpha)} - A_T k_T^{\alpha-1}l_T^{(1-\alpha)} &= 0 \\
L - l_T - l_N &= 0.
\end{align*}
\]  

\( (9) \)

Note that in the steady state, foreign asset position, \( b \), is treated as exogenous and is set equal to zero. \( L \) denotes the inelastic aggregate labor supply in the economy. To solve the system, we use equations 2, 3, 4, 5 and 9 in (9) to solve for

\[
\begin{align*}
\frac{x_T}{x_N} &= \frac{A_T}{A_N} \left( 1 - \gamma \right), \\
p_N &= \frac{A_T}{A_N}, \\
q &= \left( \frac{A_T}{A_N} \right)^{1-\gamma}, \\
k_T &= \frac{k_N}{l_T} = \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \left( \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right)^{1-\alpha},
\end{align*}
\]

where, without loss of generality, we have set \( G = \gamma (1 - \gamma)^{1-\gamma} \).

Next, substituting the expressions in (10) back into the remaining equations in (9), we solve for other variables of interest. First, from equation 6 in (9), we can directly solve for

\[
x_N = A_N (1 - \gamma) L - \frac{\delta \alpha}{r + \delta} \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha},
\]
which combined with equation 1 in (10) implies that

\[ x_T = A_T \gamma L \frac{\delta \alpha}{r + \delta} \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha}. \]

Equations 1, 7, 8 and 10 in (9) are then used to solve for

\[ l_N = L - L \left( \gamma \frac{\delta \alpha}{r + \delta} + \varepsilon \left[ 1 - \frac{\delta \alpha}{r + \delta} \right] \right), \]
\[ l_T = L \left( \frac{\delta \alpha}{r + \delta} + \varepsilon \left[ 1 - \frac{\delta \alpha}{r + \delta} \right] \right), \]
\[ c_T = A_T L \varepsilon \left( 1 - \frac{\delta \alpha}{r + \delta} \right) \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha}, \]
\[ c_N = A_N L (1 - \varepsilon) \left( 1 - \frac{\delta \alpha}{r + \delta} \right) \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha}, \]

and substituting expressions for \( l_N \) and \( l_T \) into (10), we obtain

\[ k_N = L \left( 1 - \left( \gamma \frac{\delta \alpha}{r + \delta} + \varepsilon \left[ 1 - \frac{\delta \alpha}{r + \delta} \right] \right) \right) \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha}, \]
\[ k_T = L \left( \gamma \frac{\delta \alpha}{r + \delta} + \varepsilon \left[ 1 - \frac{\delta \alpha}{r + \delta} \right] \right) \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha}. \]

Finally, we solve for the steady-state values of output and investments. Total output can be expressed as

\[ Y = x_T + c_T + p_N c_N + p_N x_N, \]
\[ Y = A_T L \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha}. \]

Expressions for total investments are

\[ I = x_T + p_N x_N, \]
\[ I = A_T L \frac{\delta \alpha}{r + \delta} \left[ \frac{\alpha}{r + \delta} A_T^\gamma A_N^{1-\gamma} \right]^{1-\alpha}. \]

Thus, we have that in the steady state of the model, the investment rate is

\[ \frac{I}{Y} = \frac{\delta \alpha}{r + \delta}. \]
and the investment expenditure shares on nontraded goods are

\[ \frac{p_N x_N}{I} = (1 - \gamma). \]

It is also of interest to note here that in the steady state of the model, total output is positively related to the sectoral productivity parameters

\[ \frac{\partial Y}{\partial A_T} = \frac{1 - \alpha (1 - \gamma)}{1 - \alpha} \frac{Y}{A_T} > 0, \]
\[ \frac{\partial Y}{\partial A_N} = \frac{\alpha (1 - \gamma)}{1 - \alpha} \frac{Y}{A_N} > 0. \]

## B.2 PPP comparisons for countries with different relative sectoral productivity, \( \frac{\tilde{A}_T}{\tilde{A}_N} \)

For PPP adjusted comparisons of model outcomes, we keep prices fixed at \( p_N^{PPP} = \tilde{A}_T / \tilde{A}_N \) and thus, consider the effect of productivity changes on quantities only. The expression for PPP adjusted investments is

\[
I^{PPP} = x_T + p_N^{PPP} x_N,
\]
\[
I^{PPP} = \left( A_T \gamma + \frac{\tilde{A}_T}{\tilde{A}_N} A_N (1 - \gamma) \right) L \frac{\delta \alpha}{r + \delta} \left[ \frac{\alpha}{r + \delta} A_T A_N^{1 - \gamma} \right]^{\delta - \alpha}.
\]

The ratio \( \frac{p_N^{PPP} x_N}{I^{PPP}} \), which represents PPP adjusted expenditure share on nontraded goods, is

\[
\frac{p_N^{PPP} x_N}{I^{PPP}} = \left( \frac{\tilde{A}_T}{\tilde{A}_N} A_N \frac{\gamma}{A_T (1 - \gamma) + 1} \right)^{-1}.
\]

We are interested in the sign of

\[
\frac{\partial p_N^{PPP} x_N}{\partial A_N} = - \frac{\tilde{A}_N \gamma}{\tilde{A}_T (1 - \gamma)} \left( \frac{\tilde{A}_T \tilde{A}_N \gamma}{\tilde{A}_T (1 - \gamma) + 1} \right)^2,
\]

which is negative.
The expression for PPP adjusted output is

\[ Y^{PPP} = x_T + c_T + p^{PPP}_N c_N + p^{PPP}_N x_N, \]

\[ Y^{PPP} = \left( \frac{\delta \alpha}{r + \delta} \left( A_T \gamma + \frac{\tilde{A}_T}{A_N} A_N (1 - \gamma) \right) + \left( 1 - \frac{\delta \alpha}{r + \delta} \right) \left( A_T \varepsilon + \frac{\tilde{A}_T}{A_N} A_N (1 - \varepsilon) \right) \right) \]

\[ \ast L \left[ \frac{\alpha}{r + \delta} A_T^2 A_N^{1-\gamma} \right] \frac{1}{1-a}. \]

We are interested in the sign of the derivative of the PPP adjusted output with respect to sectoral productivity

\[ \frac{\partial Y^{PPP}}{\partial A_T} = 1 - \alpha (1 - \gamma) \Psi_1 A_T^{\frac{1-a}{1-a}} A_N^{\alpha(1-\alpha)} + \frac{\gamma \alpha}{1 - \alpha} \Psi_2 A_T^{\frac{\alpha-a+\alpha}{1-a}} A_N^{\frac{1-a}{1-a}} > 0 \]

and

\[ \frac{\partial Y^{PPP}}{\partial A_N} = \alpha (1 - \gamma) \Psi_1 A_T^{\frac{1-a+\alpha}{1-a}} A_N^{\frac{\alpha-a+\alpha}{1-a}} + 1 - \frac{\alpha \gamma}{1 - \alpha} \Psi_2 A_T^{\frac{\alpha-a-a}{1-a}} A_N^{\frac{1-a}{1-a}} > 0, \]

where

\[ \Psi_1 = \left( \frac{\gamma \delta \alpha}{r + \delta} + \varepsilon \left( 1 - \frac{\delta \alpha}{r + \delta} \right) \right) \left( \frac{\alpha}{r + \delta} \right) \frac{1}{1-a} L > 0, \]

\[ \Psi_2 = \left( (1 - \gamma) \frac{\delta \alpha}{r + \delta} + (1 - \varepsilon) \left( 1 - \frac{\delta \alpha}{r + \delta} \right) \right) \left( \frac{\alpha}{r + \delta} \right)^{\frac{1}{1-a}} \frac{\tilde{A}_T}{A_N} > 0. \]

PPP adjusted output is positively related to changes in either of the productivity parameters. With respect to changes in relative productivity, \( A_T/A_N \), there is no clear relation, since it depends on the sign of the change in the level of \( A_T \) and \( A_N \). For example, if only \( A_N \) or only \( A_T \) increases, then output will increase, but relative productivity move in opposite directions in the two scenarios.

The PPP adjusted investment ratio can be expressed as

\[ I^{PPP} = \frac{\frac{\alpha \delta}{r + \delta} \left[ 1 - \gamma \left( 1 - \frac{4x}{\tilde{A}_N} \right) \right]}{1 - \left[ \gamma \frac{\alpha \delta}{r + \delta} + \varepsilon \left( 1 - \frac{\alpha \delta}{r + \delta} \right) \right] \left( 1 - \frac{4x}{\tilde{A}_N} \right)}. \]

We are interested in the sign of

\[ \frac{\partial I^{PPP}}{\partial A_T} = \frac{(\gamma - \varepsilon) \frac{\delta \alpha}{r + \delta} \left( 1 - \frac{\delta \alpha}{r + \delta} \right) \frac{\tilde{A}_T}{A_N}}{\left[ 1 - \left[ \gamma \frac{\alpha \delta}{r + \delta} + \varepsilon \left( 1 - \frac{\alpha \delta}{r + \delta} \right) \right] \left( 1 - \frac{4x}{\tilde{A}_N} \right) \right]^2}, \]

which is positive if \( \gamma > \varepsilon \) and negative if \( \gamma < \varepsilon \).
B.3 CES aggregation in consumption

This is a simple extension of the model’s steady state solution. Instead of the unitary elasticity of substitution for traded and nontraded goods in consumption, we now allow for a more general functional form

\[ F_C(c_{Tt}, c_{Nt}) = \left( \mu c_{Tt}^{\frac{\theta}{\theta - 1}} + (1 - \mu) c_{Nt}^{\frac{\theta}{\theta - 1}} \right)^{\frac{\theta}{\theta - 1}}, \]

where \( \theta \) represents the intratemporal elasticity of substitution and \( \mu \) is a weight parameter. In this case, all steady state solutions above are still valid, subject to the following substitution

\[ \varepsilon = \left( \frac{A_T}{A_N} \right)^{1-\theta} \left( \frac{\mu}{1 - \mu} \right)^{\theta} + 1 \right)^{-1}. \]
Table 1: Investment expenditures on the output of different sectors of economic activity, as a fraction of total expenditures

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Table 2: Investment expenditures on nontraded goods, as a fraction of total expenditures (OECD data, 1970-2002)

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Table 3: Investment expenditures on nontraded goods, as a fraction of total expenditures (UN data, 1950-1997)

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Data source: UN (2001a, b).
Table 4: Time trends in investment expenditures on nontraded goods for sample countries with at least 30 years of data*

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<td>-0.01</td>
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<td>0.003</td>
<td>-6.93</td>
<td>-0.05</td>
<td>-0.03</td>
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<td>1963-1997</td>
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<td>-6.95</td>
<td>-0.08</td>
<td>-0.04</td>
</tr>
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<td>Syrian Arab Republic</td>
<td>1963-1997</td>
<td>35</td>
<td>-0.003</td>
<td>0.017</td>
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<td>-0.07</td>
<td>0.06</td>
</tr>
<tr>
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<td>37</td>
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<td>0.007</td>
<td>-0.71</td>
<td>-0.03</td>
<td>0.02</td>
</tr>
<tr>
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<td>1960-1999</td>
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<td>0.061</td>
<td>0.030</td>
<td>1.43</td>
<td>-0.03</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Data sources: OECD (2004), UN (2001a, b).

* The time trend reports the estimate of $10^6 \beta$ from the regression: $Y_t = \alpha + \beta t + \epsilon_t$, where $t$ denotes years. The test statistic is a t-statistic corresponding to Newey-West corrected standard error and tests $\beta = 0$. Note that the slope of expenditure shares is multiplied by 10 and should therefore be interpreted as a change in expenditure share over a decade. The N-W standard error and 95% bounds are also multiplied by 10.
Table 5: Pooled time trends for sample countries with at least 30 years of data*

<table>
<thead>
<tr>
<th>Type of regression</th>
<th>Sample</th>
<th># of obs.</th>
<th>Time trend, per decade</th>
<th>Standard error</th>
<th>t-statistic</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
</tr>
</thead>
<tbody>
<tr>
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<td></td>
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<tr>
<td>Pooled OLS</td>
<td>OECD countries</td>
<td>295</td>
<td>-0.013</td>
<td>0.004</td>
<td>-3.60</td>
<td>-0.021</td>
<td>-0.006</td>
</tr>
<tr>
<td>Panel with country dummies</td>
<td>OECD countries</td>
<td>295</td>
<td>-0.013</td>
<td>0.002</td>
<td>-6.04</td>
<td>-0.018</td>
<td>-0.009</td>
</tr>
<tr>
<td>Panel 2: UN data</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pooled OLS</td>
<td>all countries</td>
<td>1335</td>
<td>-0.014</td>
<td>0.002</td>
<td>-6.65</td>
<td>-0.019</td>
<td>-0.010</td>
</tr>
<tr>
<td></td>
<td>OECD countries</td>
<td>610</td>
<td>-0.014</td>
<td>0.002</td>
<td>-6.26</td>
<td>-0.019</td>
<td>-0.010</td>
</tr>
<tr>
<td></td>
<td>Non-OECD countries</td>
<td>725</td>
<td>-0.016</td>
<td>0.003</td>
<td>-4.65</td>
<td>-0.023</td>
<td>-0.009</td>
</tr>
<tr>
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<td>all countries</td>
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<td>0.002</td>
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<td>-0.020</td>
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<td>0.003</td>
<td>-7.96</td>
<td>-0.025</td>
<td>-0.015</td>
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</table>


* See notes to Table 4. In case of country dummies, the time trend reports the estimate of $10^*\beta$ from the regression: $Y_t = a + \beta t + d_i + \epsilon$, where $d_i$ is a country dummy.

Table 6: Correlation between nontraded expenditure shares

<table>
<thead>
<tr>
<th></th>
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</thead>
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Data sources: UN (2001a, b).
Table 7: Cross-section comparison of investment expenditures on nontraded goods (UN data)

<table>
<thead>
<tr>
<th>Year</th>
<th># of countries included</th>
<th>Mean</th>
<th>Corr with real income per capita</th>
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<tbody>
<tr>
<td>1950</td>
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<td>0.63</td>
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<td>0.63</td>
<td>0.15</td>
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<td>1957</td>
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<td>0.14</td>
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<tr>
<td>1958</td>
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<td>0.62</td>
<td>0.10</td>
</tr>
<tr>
<td>1959</td>
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<td>0.04</td>
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<td>1960</td>
<td>30</td>
<td>0.60</td>
<td>0.07</td>
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<tr>
<td>1961</td>
<td>31</td>
<td>0.60</td>
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<td>0.59</td>
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<td>0.59</td>
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<td>1983</td>
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<td>0.60</td>
<td>0.01</td>
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<td>0.52</td>
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</table>

Data sources: UN (2001a, b).
Table 8: Cross-section comparison of investment expenditures on nontraded goods (PWT benchmark data)

<table>
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<tr>
<th>Data set</th>
<th># of countries included</th>
<th>Mean</th>
<th>Correlation with real income per capita</th>
</tr>
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<tbody>
<tr>
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<td>115</td>
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</tr>
<tr>
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<td>0.03</td>
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<tr>
<td>- only A</td>
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<td>0.10</td>
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<td>Nehru-Dhareshwar dataset, 1987</td>
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<td>PWT 1985 benchmark</td>
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<td>0.56</td>
<td>0.04</td>
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<td>PWT 1980 benchmark</td>
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<td>0.58</td>
<td>0.31</td>
</tr>
<tr>
<td>PWT 1975 benchmark</td>
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<td>0.57</td>
<td>0.53</td>
</tr>
<tr>
<td>PWT 1970 benchmark</td>
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<td>0.13</td>
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</table>

* A, B, C and D refer to data quality, with A representing the highest and D the lowest quality. See Penn World Table 6.1 benchmark for details.

Table 9: Investment expenditure share on nontraded goods by region, (PWT 1996 benchmark data)

<table>
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<tr>
<th>Region</th>
<th># of countries included</th>
<th>Mean</th>
<th>Correlation with real income per capita</th>
</tr>
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<tbody>
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<td>- Africa, PWT 1985</td>
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<td>0.29</td>
</tr>
<tr>
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<td>0.54</td>
</tr>
<tr>
<td>Asia</td>
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<tr>
<td>Oceania</td>
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<td>0.51</td>
<td>0.12</td>
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<tr>
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<tr>
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<td>-0.26</td>
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<tr>
<td>Middle East</td>
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<td>0.57</td>
</tr>
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</table>

* Also includes Japan, Australia and New Zealand.
<table>
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<th>Year</th>
<th># of countries included</th>
<th>Mean of countries included</th>
<th>Corr. with real GDP per capita</th>
<th># of countries included</th>
<th>Mean of countries included</th>
<th>Corr. with real GDP per capita</th>
<th># of countries included</th>
<th>Mean of countries included</th>
<th>Corr. with real GDP per capita</th>
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<tr>
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<td>-0.06</td>
<td>10</td>
<td>0.60</td>
<td>-0.24</td>
<td>4</td>
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<td>0.45</td>
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Data sources: UN (2001a, b).
Table 11: Investment expenditures on nontraded goods in OECD countries (OECD data)

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<th>Year</th>
<th># of countries included</th>
<th>Mean</th>
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### Table 12: Comparison of investment expenditures on nontraded goods with estimates in Burstein et al. (2004)

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<th>Year</th>
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<th>Burstein et al. (2003), all nontraded</th>
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<th>OECD data</th>
<th>PWT 1996 benchmark data</th>
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### Table 13: Investment rates and prices in the PWT 1996 benchmark data

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<th>10%-15%</th>
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Data sources: Heston et al. (2002).

* Antigua & Barbuda, Bahamas, Barbados, Belize, Bermuda, Dominica, Grenada, Jamaica, St. Kitts & Nevis, St. Lucia, St. Vincent & Grenadines, Trinidad & Tobago were excluded from the calculation of the price of nontraded goods, pn, since each of these countries was an outlier with respect to the rest of the sample. The average value of pn for these small Caribbean countries was 3.74.
Figure 1: Investment expenditure share on nontraded goods, cross-section averages

OECD data

UN data

Figure 2: Investment expenditure share on nontraded goods in selected countries (OECD data)
Figure 3: Investment expenditure share on nontraded goods (1996 PWT benchmark data)

Figure 4: Investment expenditure share on nontraded goods (UN data, 1990)
Figure 5: Investment expenditure share on nontraded goods
(UN data, 1980)

Figure 6: Investment expenditure share on nontraded goods
(UN data, 1970)
Figure 7: Investment expenditure share on nontraded goods (UN data, 1960)

Figure 8: Investment expenditure share on nontraded goods for selected regions (UN data)
Figure 9: Variation in *international price* investment rates under different model specifications
ESSAY II
Trade Deficits in the Baltic States: How Long Will the Party Last?*

with Kristian Jönsson

Abstract

Since their opening up to international capital markets, the economies of Estonia, Latvia and Lithuania have experienced large and persistent capital inflows and trade deficits. This paper investigates whether a calibrated two-sector neoclassical growth model can explain the magnitudes and the timing of the trade flows in the Baltic countries. The model is calibrated for each of the three countries, which we simulate as small closed economies that suddenly open up to international trade and capital flows. The results show that the model can account for the observed magnitudes of the trade deficits in the 1995-2001 period. Introducing a real interest rate risk premium in the model increases its explanatory power. The model indicates that trade balances will turn positive in the Baltic states around 2010.

JEL classification: F41; C68

Keywords: Baltic states; international factor movements; non-traded goods; adjustment costs; dynamic general equilibrium

*We are grateful to Lars Ljungqvist, Timothy J. Kehoe, Martin Flodén, Caroline Betts, Gonzalo Fernandez de Cordoba, David Domeij and two anonymous referees for helpful comments and suggestions. We have also benefited from discussions with seminar participants at the Stockholm School of Economics, the 2003 BeMAD conference in Sevilla, Spain, the SED 2003 meeting in Paris, France and the EEA Congress in Stockholm 2003. Financial support from Jan Wallander's and Tom Hedelius' Foundation and from CentrA is gratefully acknowledged.
1 Introduction

As the transition in Estonia, Latvia and Lithuania enters its second decade with trade deficits and capital inflows that show no signs of reversal, the general public and the Baltic politicians in particular are increasingly concerned about the consequences of the large deficits. Most economists approach the issue using the neoclassical framework and make the point that external deficits in poor countries are not a problem, but rather a sign of healthy development, as long as the foreign capital is wisely invested in the local economy. However, an elementary ingredient in the neoclassical message is that the developing country will, sooner or later, have to start repaying its foreign creditors.

Is there really no reason to worry about the size of the trade deficits in the Baltic states, as long as ten years after liberalization? The aim of this paper is to give a quantitative answer to that question. Calibrating and simulating a two-sector neoclassical growth model for each of the Baltic states, we investigate whether the trade deficits implied by the theory are in line with the magnitudes observed in the data. In simulations of the Baltic countries as initially closed economies that suddenly open up to trade, we pinpoint the predicted timing of capital flow reversals in the model.

The type of model we employ is sometimes referred to as "the dependent economy model" (Thornovsky (1997)). It is a standard two-sector model of a small open economy with a traded good, a non-traded good, labor, capital and an investment good that augments the capital stock. Traded and non-traded goods are either consumed or used as inputs into the investment sector, in which case we can consider them as equipment and structures. Previous literature includes many applications of the model: Fernandez de Cordoba and Kehoe (2000) apply the model to study the Spanish economy after its entry into the European Community in 1986. Slightly different versions of the same model have been used to study the consequences of exchange-rate based stabilization programs in countries such as Portugal (Rebelo (1993)) and Argentina (Burstein et al. (2003)).

In this paper, we use the same basic model as in Fernandez de Cordoba and Kehoe (2000), where the authors point to the importance of incorporating frictions in factor mobility for the two-sector growth model to explain data on capital flows and real exchange rates. Our paper builds on this finding and contributes to the development of the dependent economy model in two ways. Firstly, we specify adjustment costs in a way that enables us to calibrate the factor frictions used in the analysis. Relating the magnitude of frictions in the model to what we observe in the data is a prerequisite for taking the quantitative implications of the model simulations seriously. We calibrate the adjustment parameters to observations other than those that we want to explain. Fernandez de Cordoba and Kehoe (2000) do not do this. Secondly, we do modelling and
data work to study the effects of incorporating a calibrated interest rate premium in our simulations for the Baltic countries.

The sudden change of the economic system in the Baltic states after their independence in 1991 and an almost immediate economic liberalization make the countries well-suited as test cases for the model. Estonia, Latvia and Lithuania were completely closed off from the West before 1991 and upon opening, they were much poorer than their Western neighbors. The three countries are small and have become very open; the population ranges from 1.4 million in Estonia to 3.7 million in Lithuania, while exports plus imports amount to more than 110 percent of GDP in all three countries.

In Section 2, we identify the years when trade and capital flows were liberalized in each of the Baltic countries. These years will be used as the first open periods in our simulations. Section 3 looks at data for the Baltic countries and identifies important macroeconomic developments that have been associated with the trade deficits in the decade after liberalization. Data is presented for the trade balances, real GDP growth rates, the sectoral composition of GDP and the real exchange rates.

Sections 4, 5 and 6 present the model, its calibration, and the results of our basic simulations. The model is found to capture the main dynamics of trade balances and output, but the initial responses to the shock of liberalization are larger in the model than what we observe in the Baltics. Furthermore, the real exchange rate dynamics of the model do not show any of the persistence found in the data. Both of these problems are in the next section addressed with an extension of the model.

In Section 7, we augment the model to account for financial frictions by introducing and calibrating an interest rate risk premium on foreign loans to each of the Baltic states. The model dynamics for the trade balances, the real exchange rates and the sectoral composition of GDP now more closely capture the variation in the data. The trade deficits in the model are in line with what we observe in the data, and the predicted year of capital flow reversal is around 2010 for all three countries. The date of reversal is robust to varying the initial capital stocks used in the simulations. If the neoclassical model is an appropriate framework for analyzing the Baltic countries, our results indicate that the current trade deficits should not be a reason to worry.

Section 8 concludes and gives suggestions for future research.

2 Dating the Economic Liberalization in the Baltic Countries

In this paper, the Baltic states will be modeled as initially closed economies that suddenly open up to trade with the rest of the world. A time period in the model will represent one
year. Although extraordinarily rapid, the economic liberalization was a gradual process that took more than a year. It is therefore not possible to identify exactly one year in which it all happened. To make our computational experiment valid, we identify the first year for which it can be said that the Baltic economies where sufficiently integrated in the world economy, sufficiently driven by market forces, and had sufficiently well working currency arrangements for our model of the small open economy to make sense.

In their quest to achieve social stability and economic growth, the Baltic states rather closely followed the recommendations of the “Washington consensus,” which advocated a rapid shift from a planned economy to an open market system. With some minor exceptions, Estonia opted for a complete liberalization of import and export flows by 1993, thereby becoming one of the most open countries in the world. Latvia and Lithuania also liberalized their trade flows in 1993, but retained import duties of 15 percent or less on most products, as well as export duties on some products. Capital flows were liberalized by 1993 in Latvia and Lithuania and by 1994 in Estonia.

To appropriately choose the first open years in our simulations, the degree to which economic outcomes were market determined in the years following the independence from the Soviet Union should also be considered. A relatively large private sector with competing firms is important for a successful application of the model, since our model assumes perfect competition. Most prices were liberalized and a process of rapid privatization was begun in the Baltics already in 1992. Privatization was less rapid in Latvia, which is seen in Table 1, where the share of the private sector in GDP is taken as a proxy for the progress of privatization. Table 1 also reveals that the private sector did not produce half of GDP or more in any of the three countries until 1994.

The existence of a credible national currency is of importance because a liberalization of capital flows is incomplete without a reasonably functioning foreign-exchange market. All three countries substituted away from the Russian rouble in 1992, with Estonia implementing a currency board in mid-1992. In the same year, Latvia and Lithuania introduced transitional currencies that were allowed to float. In 1993, Latvia adopted a permanent currency, which was pegged to the SDR at the beginning of 1994. The Lithuanian permanent national currency was not issued until the end of 1994, when a currency board was established.

A weighted assessment of these elements of liberalization leads us to treat 1994 as the first open year for Estonia, since most of the liberalization had been completed by that year. For Latvia and Lithuania, we choose 1995 as the year of opening, motivated by the slower pace of reforms in those countries. Privatization was less rapid in Latvia, and Lithuania was slower in implementing an exchange-rate based stabilization program and introducing a credible national currency. Current account data lends support to these choices of opening years. According to the World Development Indicators database,
the current account turned negative in Estonia in 1994 and in Latvia in 1995. For Lithuania, the current account, as a percentage of GDP, was close to zero in 1993 and 1994, to become significantly negative in 1995.

3 Effects of the Economic Liberalization

All three Baltic countries have been running substantial trade deficits since the economic liberalization.¹ Net trade in goods and services as a percentage of nominal GDP is presented in Figure 1, which shows steady trade deficits of around 10 percent of GDP since the liberalization.² The contraction of the deficits during the 1999-2000 period was a result of the Russian crisis in 1998-1999.

The completion of liberalization coincided with the time when economic growth returned to the Baltic states, following a period of contraction immediately after the independence. During the 1995-2003 period, real economic activity expanded with yearly average growth rates of 5.7 percent in Estonia and 5.3 percent in Latvia and Lithuania. Figure 2 shows annual real GDP growth rates in the three countries after the opening.

In the model which we subsequently develop, the GDP share of traded output and the real exchange rate will be closely associated with trade flows. Next, we therefore examine the development of these variables in data for the Baltic states.

A shift in economic activity from the traded to the non-traded sectors is associated with the large trade deficits in the Baltic countries. Defining manufacturing, agriculture, mining and transportation as the traded sector and other industries as non-traded, Figure 3 shows the reduction of the traded sector as a share of GDP to vary from 7 percentage points in Estonia to 14 percentage points in Latvia. The shift mainly consists of a contraction in manufacturing and agriculture and an expansion of the wholesale/retail trade, the real estate and the construction industries. In Estonia and Lithuania, after contracting to around 40 percent of GDP, economic activity shifted back towards the traded sector in the period 2000-2004.

Along with sustained trade deficits, the Baltic states have also experienced marked real exchange rate appreciations. Figure 4 presents the development of the log of the bilateral real exchange rate with Germany for each of the Baltic countries after the liberalization. We choose to present the real exchange rate with Germany, since it is the largest trading partner for Latvia and Lithuania and the third largest for Estonia. Germany is also the largest economy in the EU, which accounts for more than half of the total trade in all three Baltic states. Nominal exchange rates and Consumer Price

¹Before the collapse of the USSR, the Baltic republics were net exporters.
²For each country, data series end with the latest annual data available, which is 2003 for Latvia and 2004 for Estonia and Lithuania.
Indices from the IFS are used to construct the series labeled \(rer\) in Figure 4. In the model that we develop in section 4, there is only one traded good and no nominal variables. Therefore, we can only hope to account for the part of the real exchange rate fluctuations which is due to changes in the relative price of non-tradable to tradable goods in each country. Assuming that Purchasing Power Parity holds for goods in the traded sector, we use the same decomposition as in Betts and Kehoe (2001) to express the real exchange rate in terms of its traded and non-traded components:

\[
RER_t = RER_{Tt} RER_{Nt},
\]

where

\[
RER_{Tt} = S_t \frac{P^G_t}{P^C_t} \quad \text{and} \quad RER_{Nt} = \frac{P^G_t}{P^C_t} \frac{P^C_t}{P^G_t},
\]

Here \(S_t\) stands for the nominal exchange rate expressed in units of Baltic currencies per DM, \(P^G_t\) is a price index for Germany, \(P^C_t, C \in \{\text{Est, Lat, Lit}\}\) is a price index for each of the Baltic states and \(P^C_t\) is a price index for tradable goods.

In (1), \(RER_{Tt}\) captures price changes of traded goods whereas \(RER_{Nt}\) captures relative price changes of non-traded goods. Expressing (1) in log form we have:

\[
\log r_{er_t} = \log r_{er_{Tt}} + \log r_{er_{Nt}}.
\]

The assumption of Purchasing Power Parity in our model implies that \(rer_{Tt} = 0, \forall t\) and that fluctuations in the real exchange rate can only be caused by movements in the relative price of non-tradables across countries. Since we cannot account for more than \(rer_N\) with our model in section 4, we plot \(rer_N\) together with the log of the real exchange rate in Figure 4. When constructing price indices for traded goods \((P^G_t, P^G_{Tt})\), we use Producer Price Indices for the manufacturing sector in each country.\(^3\)

In line with the existing empirical evidence for other countries, we find most of the real exchange rate movements in the Baltic states to be explained by changes in the relative prices of traded goods.\(^4\) Relative movements of non-traded prices are, however, also important and account for 43 percent of the movement in the real exchange rate between 1994 and 2004 in Latvia. The same figures for Estonia and Lithuania are 25 percent and 14 percent, respectively. Figure 4 reveals a co-movement between \(rer\) and \(rer_N\). During the 1995-2000 period there is a clear trend of sustained appreciation present in both the real exchange rate and its non-traded component for all three countries. Therefore, we can hope for the model to account for a significant part of the observed real exchange

\(^3\)For a more detailed discussion of the suitability of PPI as a measure of price changes for traded goods, see Engel (1999) and Betts and Kehoe (2004a).

\(^4\)For evidence on other countries, see Engel (1999), Chari et al. (2002), Betts and Kehoe (2004b), and Burstein et al. (2003).
rate fluctuations, although the Purchasing Power Parity assumption considerably limits its explanatory power.

4 The Model

Each Baltic country is modeled as a small open economy with a representative consumer. There are five goods in any period: a traded good, a non-traded good, capital, labor and an investment good augmenting the capital stock in the subsequent period.

The representative consumer maximizes the sum of discounted utility from the consumption of traded and non-traded goods. Taking prices as given, the consumer solves the following problem:

$$\max_{\{c_{Tt}, c_{Nt}, k_{t+1}, b_{t+1}\}} \sum_{t=0}^{\infty} \beta^t \left[ \frac{c_T^\delta - 1}{\sigma} \right],$$

(3)

where

$$c_t = [\varepsilon c_T^\delta + (1 - \varepsilon) c_N^\delta]^{1/\delta},$$

(4)

subject to

$$c_{Tt} + p_{Nt} c_{Nt} + q_{t+1} k_{t+1} + b_{t+1} \leq w_t L + (1 + r_t) b_t + v_t k_t, \forall t$$

(5)

$$c_{Tt}, c_{Nt} \geq 0, \forall t$$

$$b_{t+1} + q_{t+1} k_{t+1} \geq -A, \forall t$$

$$k_0, b_0 \text{ given.}$$

Here, $c_{Tt}$ is consumption of the traded good, which is numeraire in the model; $c_{Nt}$ is consumption of the non-traded good; $p_{Nt}$ is the relative price of the non-traded good; $k_{t+1}$ is investment in the domestic capital stock, purchased at the relative price of capital $q_{t+1}$; $b_{t+1}$ is investment in a bond denominated in units of traded goods and earning the interest $r_{t+1}$; $L$ is the endowment of labor, inelastically supplied at wage $w_t$; and $v_t k_t$ is income from selling capital at the relative price $v_t$ to firms producing traded or non-traded goods.

Note that $q_t$ is the price at which the consumer acquires capital for period $t$ (the transaction takes place at the end of period $t - 1$), whereas $v_t$ is the price at which the consumer sells capital in period $t$ to firms producing traded or non-traded goods.

The specified utility function exhibits a constant intertemporal elasticity of substitution, $1/(1 - \sigma)$, and a constant intratemporal elasticity of substitution between traded and nontraded goods in consumption, $1/(1 - \eta)$. $\varepsilon$ is a preference parameter and $\beta$ is a subjective discount rate.

If $b_{t+1}$ is negative, the economy is borrowing from the rest of the world. Ponzi schemes
are ruled out by assuming that consumer’s assets, \( b_{t+1} + q_{t+1}k_{t+1} \), in any period cannot be smaller than \(-A\), for \( A \) sufficiently large.

The first-order conditions for the consumer maximization problem are:

\[
\begin{align*}
\ u_{CT}(c_t) - \theta_t &= 0, \quad (6) \\
\ u_{CN}(c_t) - \theta_t\pi N_t &= 0, \quad (7) \\
\ \theta_{t+1}\beta(1 + r_{t+1}) - \theta_t &= 0, \quad (8) \\
\ \theta_{t+1}\beta v_{t+1} - \theta_t q_{t+1} &= 0, \quad (9)
\end{align*}
\]

where \( \theta_t \) is a Lagrange multiplier for the consumer budget constraint, \( u(c_t) = (c_t^\sigma - 1)/\sigma \), and where \( u_{CT}(c_t) \) denotes the marginal utility from consumption of traded goods in period \( t \).

The model allows for different specifications of interest rate determination. If the economy is closed in period \( t \), there can be no foreign borrowing or lending, \( b_{t+1} = 0 \), and the return on investment is endogenously determined in the model. If the economy is open, the interest rate is equal to an exogenously given international rate, \( r_{t+1} = r^*_{t+1} \) and \( b_{t+1} \) is endogenously determined.

A condition of no arbitrage between investments in domestic capital and foreign assets requires the relationship between the prices of capital before and after production to be

\[
v_{t+1} = q_{t+1}(1 + r_{t+1}). \quad (10)
\]

In addition to being consumed, the traded and non-traded goods can be used as inputs into the investment sector. The economy’s resource constraint for non-traded goods is:

\[
c_{NT} + x_{NT} \leq F_N(k_{NT}, k_{NT-1}, l_{NT}, l_{NT-1}), \forall t \quad (11)
\]

where \( x_{NT} \) is the input of non-traded goods into the investment sector. Note that the production process for non-tradables, \( F_N(.) \), is a function of inputs of capital and labor into the non-traded sector in both the current and the previous period. Output depends on lagged production factors due to costs associated with frictions in capital and labor mobility.

The resource constraint for traded goods is more complicated, due to the possibility of trading with the rest of the world:

\[
c_{T} + x_{T} + b_{t+1} - b_t(1 + r_t) \leq F_T(k_{T}, k_{T-1}, l_{T}, l_{T-1}), \forall t \quad (12)
\]

where \( b_{t+1} - b_t(1 + r_t) \) is the trade balance.

Investment goods are produced using a Cobb-Douglas technology taking traded and
non-traded goods as inputs. The investment good augments the capital stock in the subsequent period, which gives the following law of motion for capital:

\[ k_{t+1} - (1 - \delta) k_t \leq G x_T^{-\gamma} x_N^{1-\gamma}, \forall t. \]  

(13)

Firms in the investment sector are assumed to operate under perfect competition. They choose how much of the traded and non-traded good to buy as inputs, taking prices \( p_{Nt} \) and \( q_t \) as given. In every period, firms in the investment sector maximize:

\[
\max_{\{x_T, x_N\}} q_{t+1} G x_T^{-\gamma} x_N^{1-\gamma} - x_T t - p_{Nt} x_N t.
\]  

(14)

The problem in (14) has the following first-order conditions:

\[
q_{t+1} G x_T^{-\gamma} x_N^{1-\gamma} - 1 \leq 0,
\]

(15)

\[
q_{t+1} (1 - \gamma) G x_T^{-\gamma} x_N^{1-\gamma} - p_{Nt} \leq 0.
\]

(16)

Firms producing traded or non-traded goods maximize infinite horizon profits under perfect competition. Taking prices as given (with \( p_T \) normalized to 1, since the traded good is numeraire), the firms choose how much capital and labor to buy in each period. The firms in the traded and non-traded sectors solve the following problem:

\[
\max_{\{k_{jt}, l_{jt}\}} \sum_{t=0}^{\infty} \beta^t \left[ \prod_{t=0}^{t} \frac{u_{ct}(c_{t+1})}{u_{ct}(c_t)} \right] \pi_t,
\]

(17)

where

\[
\pi_t = p_{jt} F_j (k_{jt}, k_{jt-1}, l_{jt}, l_{jt-1}) + q_{t+1} (1 - \delta) k_{jt} - w_{jt} l_{jt} - v_{jt} k_{jt},
\]

(18)

\( j \in \{T, N\} \) and \( \delta \) is a constant per-period capital depreciation rate. The production functions are assumed to have the following form:

\[
F_j (k_{jt}, k_{jt-1}, l_{jt}, l_{jt-1}) = A_j k_{jt}^{\alpha_j} l_{jt}^{1-\alpha_j} - \Phi (k_{jt}, k_{jt-1}) - \Psi (l_{jt}, l_{jt-1}),
\]

(19)

where

\[
\Phi (k_{jt}, k_{jt-1}) = \frac{\phi \zeta}{1 + \zeta} \left( \frac{k_{jt} - (1 - \delta) k_{jt-1}}{k_{jt-1}} \right)^{\frac{\phi}{1 + \zeta}}, \quad \zeta > 0, \phi \geq 0,
\]

(20)

\[
\Psi (l_{jt}, l_{jt-1}) = \psi \left( \frac{l_{jt} - l_{jt-1}}{l_{jt-1}} \right)^2 l_{jt-1}, \quad \psi \geq 0.
\]

(21)

Here, \( \Phi(\cdot) \) is a convex cost associated with investment, which we model in line with Abel and Eberly (1994) and Eberly (1997). Note that the specification in (20) implies capital frictions to be present in steady state, because the cost is associated with the transformation of investment goods rather than the adjustment of the capital stock. \( \Psi(\cdot) \)
is a quadratic cost associated with the adjustment of the labor force in a sector, in line with Sargent (1978) and Cooper and Willis (2003). The specification implies that there are costs of both hiring and firing, whenever labor movements between sectors take place. It is in the specification of the factor frictions that our model differs from the model in Fernandez de Cordoba and Kehoe (2000). The functional forms in equations (20) and (21) can readily be calibrated to the data, which is not the case for the frictions used by Fernandez de Cordoba and Kehoe.

The first-order conditions for the profit maximization problem in (17) are:

\[ \frac{\partial F_j(k_{jt}, l_{jt})}{\partial l_{jt}} + \beta \frac{u_{ct}(c_{t+1})}{u_{ct}(c_t)} \frac{\partial F_j(k_{jt}, l_{jt})}{\partial l_{jt}} - w_t \leq 0, \]
\[ \frac{\partial F_j(k_{jt}, l_{jt})}{\partial k_{jt}} + q_{t+1}(1 - \delta) - v_t + \beta \frac{u_{ct}(c_{t+1})}{u_{ct}(c_t)} \frac{\partial F_j(k_{jt}, l_{jt})}{\partial k_{jt}} \leq 0. \]

**Definition of equilibrium** An equilibrium in this model is characterized by sequences of prices \( \{\hat{P}_N, \hat{w}_t, \hat{q}_{t+1}, \hat{\nu}_t, \hat{\rho}_t\}_{t=0}^{\infty} \); consumption and assets \( \{\hat{c}_T, \hat{c}_N, \hat{k}_{t+1}, \hat{b}_{t+1}\}_{t=0}^{\infty} \); sectoral production plans \( \{\hat{k}_T, \hat{l}_T\}_{t=0}^{\infty} \) and \( \{\hat{k}_N, \hat{l}_N\}_{t=0}^{\infty} \), and inputs into the investment sector \( \{\hat{x}_T, \hat{x}_N\}_{t=0}^{\infty} \), such that:

(i) given prices \( \hat{p}_N, \hat{q}_{t+1}, \hat{\nu}_t, \hat{\rho}_t \), the representative consumer's first-order conditions in (6)-(9) are satisfied in every period.

(ii) given prices \( \{\hat{p}_N, \hat{w}_t, \hat{q}_{t+1}, \hat{\nu}_t\}_{t=0}^{\infty} \), producers in sector \( j \in \{T, N\} \) choose factor inputs \( \{\hat{k}_j, \hat{l}_j\}_{t=0}^{\infty} \) so that the first-order conditions in (22) are satisfied in every period.

(iii) given prices \( \hat{p}_N \) and \( \hat{q}_{t+1} \), the investment sector's first-order conditions in (15) and (16) are satisfied in every period.

(iv) The market clearing conditions in (11), (12) and (13) are satisfied in every period.

If the economy is closed in period \( t \), \( \hat{b}_{t+1} = 0 \). If the economy is open in period \( t \), \( \hat{b}_{t+1} = r_{t+1}^* \).

(v) Factor markets clear in every period:

\[ \hat{k}_T + \hat{k}_N = \hat{k}_t, \quad \forall t \]
\[ \hat{b}_T + \hat{b}_N = L, \quad \forall t. \]
5 Calibration

In this section, we first discuss the data used in the calibration and then present the way we calibrate the model to the Baltic countries.

5.1 Data issues

Most of the macroeconomic data we need for this paper was readily available at the statistical offices in the Baltic states. The only exceptions, which we now discuss in more detail, were data on capital stocks and input-output tables.

Capital stock estimates Unfortunately, there are no official estimates on capital stocks available for the Baltic countries. Furthermore, since the time series of National Accounts data for the Baltic states are very short, we cannot estimate the capital stock using the perpetual inventory method. Instead, we estimate the capital stock by assuming the total capital stock to be the sum of fixed tangible assets of all enterprises in the economy, and the total stock of residential housing. A detailed explanation of this method is presented in Appendix A. Dividing these estimates with the output for the same year, we obtain capital-output ratios of 1.41 for Estonia, 1.40 for Latvia and 1.33 for Lithuania.

We have confidence in our estimates for two reasons. First, using a different methodology, Hazans (1999) arrives at a similar estimate for the part of the capital stock excluding residential housing for Latvia. Second, the size of our estimates for residential housing stocks relative to real GDP per capita is broadly in line with the averages for countries with similar income levels in PWT 5.6.5

Input-output tables Our calibration of the model to the Baltic economies relies on input-output tables. Given the amount of detailed data required, it should not be surprising that input-output matrices were not constructed for the early years of transition in the Baltic states. We base our calibration on the first official input-output tables for 1997 for Latvia and Estonia and the 1998 experimental input-output table for Lithuania.

We aggregate the input-output tables into two-sector input-output tables, which requires that we classify each sector of the economy as traded or non-traded. In deciding whether an industry is traded, we use a classification that has empirical foundations in De Gregorio et al. (1994), and that is commonly used in the literature (see for instance Stockman and Tesar (1995)). The classification is summarized in Table 2. In the context of the model, the traded sector should include services and goods that can be immediately traded when the borders open up. Furthermore, the sector should consist of products.

---

that are fairly homogenous across countries. Defined this way, the traded sector can be expected to satisfy the assumption of Purchasing Power Parity.

Based on Table 2, we aggregate the 57 sector input-output matrices compiled by the central statistical offices in the Baltic countries to obtain the two-sector matrices presented in Tables 3 and 4.6

5.2 Initial factors and parameter values

When calibrating the model, we use the equilibrium conditions of the model while normalizing all prices to 1 for the initial year, except the rental price of capital. As mentioned in Section 2, a time period in the model represents one year. The results of the calibration for each of the Baltic states are summarized in Table 5.

As explained above, we cannot use input-output tables for the last closed year (1993 for Estonia and 1994 for Latvia and Lithuania) in our calibration. In general, parameters derived from input-output tables for 1997 or 1998 might be more representative for the simulated time span, but caution is called for since relative price changes occur between the beginning of the simulation and the year for which parameter values are calibrated. We deal with this by constructing appropriate price indices for traded and non-traded goods. Price changes for traded goods are captured with the PPI for manufacturing, and for non-traded goods we use GDP deflators for the non-traded sector. These indices connect the normalized prices of the last closed year with prices of the year for which input-output tables are available.7

In our baseline simulations, we set \( \sigma = -1 \), implying an intertemporal elasticity of substitution in consumption equal to 0.5, which is a standard value in the literature (see, for example, Mankiw et al. (1985)). Following empirical estimates in Kravis et al. (1982) and Stockman and Tesar (1995), the intratemporal elasticity of substitution between traded and nontraded goods in consumption is also set equal to 0.5, by choosing \( \eta = -1 \). In Section 7, we perform sensitivity analysis by investigating the model dynamics under different assumptions about the consumption elasticities.

In simulating the model, we will take Germany as representing the world outside the Baltic states. The rate of depreciation, \( \delta \), is calibrated for Germany, using the law of motion for capital and the Summers et al. (1995) data on capital stocks and expenditures on gross fixed capital formation. To obtain our parameter value, we calculate a fifteen-year average for the years 1975-1989, which yields \( \delta = 0.081 \).

6The Department of Statistics to the Government of the Republic of Lithuania has not granted us permission to publish the 1998 unofficial input-output table for Lithuania.

7In theory, this should not be a problem, since we use price indices as deflators to uncover the allocations expressed in base year prices. In practice, it of course introduces an additional source of measurement errors.
An assumption on which we will base our simulations is that the German economy has reached its steady state. The discount factor, \( \beta \), is therefore calibrated for Germany, using the average real return on German government bonds over the 1981-2001 period. The measured annual real interest rate is \( r^* = 0.0419 \), which implies that \( \beta = 1/(1+r^*) = 0.9597 \).

To calibrate the remaining preference parameter, \( \varepsilon \), the consumption entries by sector in the input-output tables need to be adjusted with price indices. Using the first-order conditions for the consumer’s problem in (6) and (7), we obtain:

\[
\varepsilon = \frac{(c_{N97}/c_{T97})^{\sigma-1}}{(p_{N97}/p_{T97})^\sigma + (c_{N97}/c_{T97})^{\sigma-1}},
\]

where \( c_{T97} \) and \( c_{N97} \) are consumption of traded and non-traded goods in current prices, which can be obtained directly from the input-output table.\(^8\)

In order to calibrate the parameters of the production function for the investment sector, \( \gamma \) and \( G \), we use estimates from the literature. Burstein et al. (2004) report that in OECD countries, 41 percent of aggregate investment expenditures are spent on the output of the traded sector. Empirical work by Berns (2004), on a larger sample of countries, reports a very similar expenditure share on traded goods and shows that this share does not vary systematically with the level of income. Based on this evidence, we set \( \gamma = 0.41 \) for each of the Baltic states. Using the first order conditions in (15) and (16), the value of \( G \) is then obtained as

\[
G = \frac{1}{\gamma(1-\gamma)^{1-\gamma}},
\]

Eberly (1997) has estimated the convex component of capital frictions of the same form that we specified in (20). Looking at annual data for the OECD countries between 1981-1994, she finds that \( \zeta \) ranges from 0.65 in Sweden to 1.95 in France. For the Baltic states, we have adopted the convexity parameter that she estimated for the US, \( \zeta = 1.22 \). Our choice is motivated by the observation that the Baltic states in the 1990’s were closer to the US, with very liberal capital regulations, more bankruptcies and higher volatility of the capital stock at the firm level than in Western Europe. Unfortunately, Eberly cannot simultaneously identify the level parameter, \( \phi \), and the convexity parameter. In our baseline simulations we set \( \phi = 1 \), resulting in steady state investment costs of 1.4 percent of GDP in Estonia, 1.6 percent in Latvia and 1.9 percent in Lithuania. In Section 7, as a robustness check, we also report the model dynamics for the case of larger investment costs (\( \phi = 2 \)), and for the case with no investment costs (\( \phi = 0 \)). Since Eberly (1997) does not estimate sector specific adjustment cost parameters, we

\(^8\)In the case of Lithuania, the time subscript in equation (24) is 1998.
map her estimate into our two sector framework by assuming that the adjustment costs parameters are the same in both sectors.

Next, we calibrate the production functions for traded and non-traded goods. Output figures for each sector in the last year before liberalization, \(y_{T0}\) and \(y_{N0}\), were obtained from National Accounts data. Normalizing the total output in each country to 100, the values of sectoral outputs are presented in the second and third rows of Table 5.

To obtain values for \(k_{T0}, k_{N0}, l_{T0}, l_{N0}, \alpha_T, \alpha_N, A_T\) and \(A_N\), we solve a system of eight equations provided by the equilibrium conditions of the model for the autarky steady state. The equations are presented in detail in Appendix B and the resulting values for initial factor endowments, income shares and productivity levels are reported in Table 5.

The calibrated income shares are broadly in line with the empirical findings in Gollin (2002), where it is argued that capital income shares in most countries around the world are in the 0.20-0.35 range. In all three Baltic states, there are no notable differences in the income shares across the traded and nontraded sectors. This finding is in line with Parente and Prescott (2000), who note that highly aggregated sectors of economic activity exhibit similar income shares.

Finally, we calibrate \(\psi\) so that sectoral job creation in the model never exceeds the highest rates of sectoral net job creation observed in the data. For the period from the first open year until 2003, data on employment by economic activity is available at the national statistical offices. After aggregating this data into sectors, we find that the largest observed annual net job creation rates were 6.4 percent in Estonia, 5.1 percent in Latvia and 2.9 percent in Lithuania. In all three countries, the maximum increase took place in the non-traded sector. The high sectoral adjustment capacities we find in the data are in line with Haltiwanger and Vodopivec (2002), who study job flows in Estonia and reveal a very high degree of flexibility in the labor market of that economy.

6 Numerical Experiments

In this section, we simulate the model introduced and calibrated in the previous sections. Each Baltic country is modeled as an initially closed economy that opens up in the first year after the economic liberalization (1994 for Estonia and 1995 for Latvia as well as Lithuania). Figure 5 presents the simulated time paths of the trade balance, the annual growth rate of real GDP, the GDP share of traded output and the logarithm of the real exchange rate for the three model economies. To contrast the model results with the data, we have included the corresponding Baltic data in the graphs. Note that the relevant data series for the real exchange rate is \(rer_N\) and not \(rer\).

When presenting the model outcomes for the trade balance and the traded share
of GDP, we express the series in terms of same period tradable goods, since the data series are in current prices. To match the National Accounts data on real GDP growth, which is in constant prices of 2000, we compute GDP in constant prices, by keeping the relative price of nontraded goods fixed at the level of the year 2000. We construct the non-traded component of the real exchange rate in the model as the inverse of a constant consumption basket price index with base year 2000, since CPI and PPI with base year 2000 were used when calculating the real exchange rates in the data.

After the economic liberalization, the capital-poor model economies borrow heavily from abroad, as revealed by the large trade deficits in Figures 5a-5c. Naturally, this implies that in steady state, the economies will have to run permanent trade surpluses. In essence, the large net inflows of traded goods are a result of consumption smoothing by consumers. After the shock of liberalization, borrowing allows consumers to transfer the higher levels of future consumption into the early stage of transition. Although the model does capture the main dynamics of the trade balance, in the initial post-liberalization years trade deficits in the model exceed those observed in the data for all three countries.

The model growth rates of real GDP capture the trends observed in the data, as shown in Figures 5d-5f. The initial contraction of real GDP in the model is a result of costly factor reallocation, as a response to liberalization. For Latvia and Lithuania, we do not observe such effects in the data. After the initial adjustment, however, GDP in the model expands at a rate similar to the data. In line with the data, traded output as a fraction of GDP decreases after liberalization. However, this process exhibits more persistence in the data than in the model, which is seen in Figures 5g-5i. Since consumers in the model can only borrow traded goods, the shock of liberalization makes the non-traded goods relatively scarce. As specified in (13), the investment sector requires both traded and non-traded goods as inputs for augmenting the capital stock. While traded goods can be borrowed, non-traded goods must be produced at home. Thus, non-traded goods become a bottleneck for development in the model. The optimal response of the Baltic model economies is to initially import traded goods and specialize in the production of non-traded goods at home.\textsuperscript{9}

In terms of the real exchange rate, Figures 5j-5l show that the model dynamics imply a sharp appreciation in the first open year. The intuition for the marked appreciation in the model follows from our discussion of traded output: the scarcity of the non-traded good results in a sudden substantial increase in its relative price. Similar to the sectoral dynamics of output, the model predicts too strong an appreciation of the real exchange rate in the first year after liberalization and fails to capture the persistence in the data.

\textsuperscript{9}If the model had no frictions in factor markets, the optimal solution would be for all three countries to completely specialize in producing non-traded goods in the first open period.
7 Interest Rate Risk Premium

After the opening of their economies, the Baltic states faced considerably higher real interest rates than Germany, which is something that has so far not been accounted for in our model. Interest rate differentials can slow down capital flows in the model and cause persistence in the movements of the real exchange rate and the sectoral composition of output. We pursue a simple way of investigating such dynamic effects by introducing real interest rate risk premia on foreign loans in the model, which we calibrate to the risk premia that can be observed in data for the Baltic countries.

It is common in the literature on business cycles in small open economies to model the risk premium as a function of aggregate debt, in line with Benigno (2001) and Schmitt-Grohé and Uribe (2003). A look at the risk premia and the debt levels in the Baltic countries, however, reveals that the interest risk premia in the Baltic countries mainly have been determined by factors other than the debt level. Table 6 reveals that the ratio of total external debt to GNI has increased dramatically in all three countries, while a first glance at Table 7 tells us that the risk premia at the same time fell substantially. 10 Subsequently, we will define the risk premia and explain the calculations behind Table 7.

We believe that institutional factors explain the falling risk premia in the Baltics. The Institutional Investor ratings, which Reinhart et al. (2003) use as a component in evaluating debt intolerance, have been constantly improving for the Baltic countries since 1994 (Institutional Investor, March 2004). A theoretical foundation for the effects of institutions on the risk premium has been provided by Eaton et al. (1986), who point to the importance of the possibility of enforcing contracts when extending international credit to developing countries. Hutchison (2002) has provided empirical evidence that countries with better institutions and regulatory environments run lower risks of banking crises. Using the World Bank Governance Indicators provided by Kaufmann et al. (2003), one finds that the Baltic countries, between 1996 and 2002, gradually approached the institutional quality of Germany when it comes to political stability, control of corruption, democracy, rule of law and regulatory quality.

Given that the standard growth framework does not lend itself readily to the modelling of changing institutional factors, we chose to introduce the empirically observed interest rate premium exogenously in the model.

The real interest rate risk premium $\rho^C_t$ for country $C \in \{\text{Est, Lat, Lit}\}$ in period $t$ is defined as:

$$r_t^C = (1 + \rho^C_t) (1 + r_t^*) - 1 , \quad (26)$$

10 Our definition of total debt is the same as in Reinhart et al. (2003), and includes both private and public external debt. The data in Table 6 is taken from the Global Development Finance database.
where $1 + \gamma_C^t$ is the gross interest rate faced by consumers in country $C$ on foreign loans to be repaid in period $t$, and where $\gamma_I^t$ is the international real interest rate.

Taking Germany and the U.S. as representing the rest of the world, the risk premium is calibrated as:

$$\rho_C^t = \frac{\gamma_C^t - \gamma_W^t}{1 + \gamma_W^t}. \quad (27)$$

Here, $\gamma_C^t$ is the annualized average real interest rate charged on 6-12 month DM denominated loans to the private sector in Estonia or on 6-12 month US dollar denominated loans to the private sector in Latvia and Lithuania; and $\gamma_W^t$ is the real interest rate on loans to enterprises for up to twelve months in Germany (for Estonia) or the real prime loan rate in the U.S. (for Latvia and Lithuania). After 1998, interest rate data for Estonia refers to 6-12 month Euro denominated loans and is compared to the real interest rate on loans to enterprises in the Euro Area. Yearly CPI inflation rates in Germany or the Euro Area (for Estonia) or the U.S. (for Latvia and Lithuania) were used to calculate real interest rates.

There are several reasons for considering DM denominated loans in Estonia and US dollar denominated loans in Latvia and Lithuania. Lending rates are appropriate, since it is the private sector that has incurred most of the debt in the Baltic countries: In the period 1997-2003, private debt as a percentage of total debt averaged 86 percent in Estonia, 61 percent in Latvia and 44 percent in Lithuania.\(^{11}\) We want to avoid any local currency risk considerations to be reflected in the measured risk premium, which is why foreign currency loans must be considered. It is also the case that most of the lending to the private sector in the Baltic states during the 1990's was denominated in foreign currencies. In Estonia, the majority of the foreign currency loans were DM and after 1998 Euro denominated, while in Latvia and Lithuania almost all such loans were denominated in US dollars.\(^{12}\) Although theoretically, it would be better to calculate the risk premium in DM (or Euro) denominated loans for all three countries, the market for such loans was very thin in Latvia and Lithuania in the 1990's. By calculating the risk premium using US dollar interest rates, we implicitly assume that, for the sake of our simulations, differences in the U.S. and German real interest rates can be ignored.

The interest rate data for the Baltic countries was taken from the web sites of the national central banks.\(^{13}\) Interest rate data for the U.S., Germany and the Euro Area is

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\(^{11}\)It would probably be ideal to calculate the country interest rates as a weighted average of interest rates on loans and government bonds, especially in Lithuania. However, we have not been able to obtain data on foreign currency denominated public debt issuance for the early years of transition.

\(^{12}\)These differences in denomination is a result of the exchange-rate arrangements. The Estonian Kroon was fixed to DM, the Lithuanian Litas was fixed to the US dollar and the Latvian Lats was pegged to the SDR, which in the 1990's was dominated by the US dollar.

from the IMF International Financial Statistics. The risk premia we arrived at through these calculations are shown in Table 7 and the resulting interest rates in the model are depicted in Figure 6.

Since a non-negligible real interest rate risk premium is still present in 2003, we must take a stand in our simulations about the future size of the premium. In our baseline simulations, we assume that after 2003, the risk premium in the three Baltic states will decrease linearly, reaching zero in 2005. This is based on the assumption that a financial crisis does not occur in the Baltic countries or that the country risk does not increase relative to Germany in the years to come. We believe that this is the most likely scenario. With the accession to the EU, the Institutional Investor ratings of the three Baltic countries increased substantially in September 2004 (Institutional Investor, September 2004), which according to Reinhart et al. (2003) would imply that the countries can sustain higher debt levels without increasing the risk of a crisis. With the participation in the ERM and the likely adoption of the Euro in 2007/2008, Estonia, Latvia and Lithuania will have to comply with the requirements of the Stability and Growth Pact, which will strengthen fiscal discipline and help to avoid surging public debt. When simulating the model, we perform sensitivity analysis with respect to our assumption about the future interest rates, and in the next section, we further discuss the possibility of a financial crisis in the Baltic countries.

With a country-specific interest rate risk premium, the problem of the representative consumer in country $C$ now reads:

$$\max_{\{c_{\tau t}, c_{NNt}, k_{\tau +1}, b_{\tau +1}\}} \sum_{\tau=0}^{\infty} \beta^{\tau} \left[ \frac{c_{\tau t}^2 - 1}{\sigma} \right],$$

where

$$c_t = [c_{\tau t}^N + (1 - \varepsilon) c_{NNt}^N]^\frac{1}{2},$$

subject to

$$c_{\tau t} + p_{\tau t} c_{NNt} + q_{\tau +1} k_{\tau +1} + b_{\tau +1}^f - b_{\tau +1}^l - \nu_t k_t \leq w_t L + (1 + r^*) b_t^f - (1 + r^C) b_t^l + \nu_t k_t, \forall t$$

(30)

$$c_{\tau t}, c_{NNt}, b_t^f, b_t^l \geq 0, \forall t$$

(31)

$$b_{\tau +1} + q_{\tau +1} k_{\tau +1} \geq -A, \forall t$$

(32)

$$k_0, b_0 \text{ given.}$$

We differentiate between foreign assets and foreign liabilities and allow for different interest rates on foreign savings and borrowings; $b_{\tau +1}^f$ is a foreign asset denominated in units of traded goods earning the world interest rate, $r^*$; and $b_{\tau +1}^l$ is a foreign liability denominated in traded goods with a country specific borrowing cost, $r^C_{\tau +1}$. Based on
equation (26), \( r_{t+1}^C = (1 + r^*) (1 + \rho_{t+1}^C) - 1 \) is the real interest rate at which consumers can borrow in period \( t \), and \( \rho_{t+1}^C \) is the risk premium for country \( C \) in period \( t \).

Note that, when the risk premium is zero, this model reduces to the model in Section 4, with \( b_{t+1} = b_{t+1}^C - b_{t+1}^f \). Further note that in the presence of a risk premium, at least one of the negativity constraints on savings or borrowings will always bind. Although it would be more satisfactory to obtain the risk premium as an endogenous outcome of the model, the current setup provides a simple way of evaluating the effects of such a premium. The rest of the model is the same as in Section 4.

In our simulations, we again assume the rest of the world to be in steady state, so that \( r^* = \beta^{-1} - 1 \). The dynamics of the model with the interest rate risk premium are presented in Figure 7.\(^{14}\) The higher interest rates slow down the capital inflows and thus, the initial adjustments in all of the graphs are more gradual. Since the cost of borrowing from abroad now varies between periods in a realistic manner, the model accounts for more of the variations in the data. In the simulations for Latvia, the measured interest rate premium is such that the negativity constraints on savings and borrowings both bind in the first year after liberalization. Foreign borrowing is therefore postponed for a period.

For Lithuania, the model captures the overall trade balance dynamics, although the size of the deficits in the model is still larger than in the data. Part of the discrepancy between the model and the data in Figures 7a-7c is likely to be a consequence of the Russian crisis of 1998-99, which we have not modelled. As shown in Figure 2, Latvia was the country least affected by the crisis while Lithuania was most severely hit.

Figures 7d-7f show the initial contraction of GDP in the model to be smaller and more in line with the data when an interest rate risk premium is introduced. The simulated GDP growth rates still capture the trends of the data, but the rates of expansion are slightly lower than in the model without the risk premium.

An interesting result is that the model with a risk premium can generate a more gradual decrease in the relative size of the traded sector, and some sustained appreciation in the real exchange rate. In terms of sectoral adjustment, the model dynamics in Figures 7g-7i are now more similar to the gradual shift towards the non-traded sector that we observe in the Baltics. The overall magnitude of the shift is, however, still larger in the model economies than in the data.

The real exchange rate appreciation in the model now lasts for three periods in Lithuania and for two periods in Estonia and Latvia (see Figures 7j-7l). Furthermore, the overall size of the appreciation for Latvia and Lithuania is very close to what we

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\(^{14}\)In the simulations shown in Figure 7, \( \psi \) has been recalibrated to match the observed maximum net job creation rates: \( \psi^{Est} = 1.095 \), \( \psi^{Lat} = 16.30 \) and \( \psi^{Lit} = 29.83 \). The relative magnitudes of these parameters reflect country differences in the observed degree of labor market flexibility. The values of \( \psi \) are lower than in Section 5, since the interest rate premium constitutes an additional friction.
observe in the data. For Estonia, the introduction of the risk premium results in the model real exchange rate not moving enough, however.

**Sensitivity analysis** Tables 8-10 summarize the dynamics of the model with interest rate premia, under different initial capital stocks and parameter values that deviate from the baseline calibration. In producing each line of the tables, the other parameters of the model were recalibrated when required.

The estimates of the initial capital-output ratios in the Baltic countries are crucial for the outcome of our simulations, since in the model trade deficits are a consequence of the Baltic economies being capital poor when liberalization occurs. In Tables 8-10, we see that changes in the initial capital stocks have a considerable effect on the size of the trade deficits that the model economies experience during the first decade after liberalization. For instance, a twenty-percent decrease in the initial capital stock decreases the Estonian minimum trade balance by about three percentage points of GDP in the peak year, while a twenty-percent increase in the capital stock increases the minimum trade balance by three percentage points. At the same time, the year in which capital flows are reversed is rather insensitive to varying the initial capital stocks. The first year of trade surplus only changes by a year up or down when varying the initial capital stocks for the three countries.

Tables 8-10 further reveal that the consumption elasticities do not matter very much for the years of trade flow reversals predicted by the model. The magnitudes of the trade deficits are, however, sensitive to the elasticity of intertemporal substitution. For a lower value of the intertemporal elasticity, the model economies display larger trade deficits than in the baseline simulations.

The sensitivity analysis shows that the parameters governing the factor frictions are important for the dynamics in the model. Switching off the investment friction, or dramatically changing its convexity properties, affects the years of trade flow reversals in the model. Similarly, switching off the labor friction produces much larger trade deficits and earlier reversals than in the baseline simulations. This should not be surprising, given that Fernandez de Cordoba and Kehoe (2000) demonstrated the importance of including factor frictions in the two-sector model, in order for it to match the data at all.

Given the variation in the capital share parameters that we calibrate for the Baltic countries, it is of interest to note that the dates of trade flow reversals, for all three countries, are insensitive to setting both $\alpha_T$ and $\alpha_N$ to $1/3$.

In each table, the last line shows that the model dynamics do not change much if we assume that the interest rate differential with Germany disappears by 2008, instead of 2005.
8 Concluding Remarks

The results of the simulations in this paper show that a calibrated two-sector growth model can account for much of the trade deficits in the Baltic states during the last decade. The model predicts that the current deficits will be reversed into trade surpluses in 2009 for Estonia, in 2011 for Lithuania and in 2013 for Latvia. The predicted years of trade flow reversals have in the simulations proven robust to considerable changes in the initial capital inherited from the Soviet Union. There is reason to have confidence in the results of the neoclassical model, since the implications of the model for real GDP growth, the sectoral composition of GDP and the real exchange rate are in line with the data for the Baltic countries.

The analysis has shown that the reversal of trade flows will have far reaching effects on the Baltic economies. The current boom in the service and real estate sectors will, according to the model, come to an end as capital and labor will have to be shifted into the traded sector to produce export goods. A high degree of flexibility in the labor market therefore seems imperative for the economies to successfully accommodate the pressures for sectoral readjustment in the future. Politicians and the general public in the Baltics should bear in mind that a serious transfer problem, with drastically reduced imports as a result, might arise if the factors of production cannot easily be moved into the export sector.

One important aspect which we have not modelled in this paper is the possibility of a financial crisis in the Baltic countries. Although we believe that the most likely future scenario is one without sudden stops in the Baltic countries, there is still a risk of future crises. As many emerging markets have experienced in the last decade, financial crises tend to be associated with sudden interruptions of capital flows and sharp increases in the trade balance. Although our model cannot account for reversals of trade flows due to financial crises, we believe that the model says something about the long run dynamics of capital flows in the Baltic countries. In the event of a crisis in the next years, we would likely see trade surpluses before the reversal dates predicted by the model. However, we believe that a sudden stop would only cause a temporary reversal of capital flows in the Baltic countries. These small countries are still much poorer than their fellow members in the EU, and they will offer attractive investment opportunities to foreigners for a long time. We conjecture that the forces of economic transition would be sufficiently strong to produce trade deficits again in the Baltic countries, soon after the crisis. In the event of a sudden stop, we could therefore expect trade surpluses for a sustained period of time to arise later than predicted by our analysis.

The prospects of productivity growth in the Baltic states have also been omitted in our quantitative exercise. Productivity is likely to increase as the Baltic states catch
up with the EU economies. In the model, this would increase the steady-state levels of capital and consumption, thereby inducing larger trade deficits. The Balassa-Samuelson effect of higher relative productivity growth in the traded sector, would in our model increase the relative price of non-traded goods and lead to a more sustained appreciation of the real exchange rate. Bajona and Chu (2004) emphasize that it is also important to model productivity differences between private and state owned firms.

Our analysis has furthermore not taken into account that economic trends in countries that open up to trade can depend on changes in government policies and on tax changes in particular. As indicated in Conesa and Kehoe (2003), taking capital taxation into account would slow down capital flows in the model, reduce the investment demand for non-traded goods, and thereby reduce the initial appreciation of the real exchange rate.

The introduction of an interest rate risk premium is found to improve the model's explanatory power. An interesting extension of the present work would therefore be to endogenize financial market frictions, which could be done by incorporating explicit financial contracts in the model. The introduction of uncertainty and volatility of interest rates in the model could have the effect to slow down capital flows during the transition due to precautionary savings. With stochastic fluctuations around an eventual steady state, the countries might again run trade deficits, depending on the type of shocks that they face. We think that extensions in this direction would be very fruitful. Solving for stochastic transition paths lies beyond the scope of this paper, but it is an extension that we hope to pursue in future research. Another improvement would be to explore ways of relaxing the assumption of purchasing power parity for traded goods, since that would allow the model to account for a larger part of the observed real exchange rate movements.
References


A  Estimates of the capital stocks

In this appendix, we describe the methodology used for estimating the capital stocks in the Baltic states. The final estimates are obtained as a sum of the value of fixed tangible assets and the value of residential housing in each of the countries.

Data on fixed tangible assets is provided by the national statistical offices in each of the countries. It is obtained from the balance sheets of all larger companies (more than 100 employees) and a representative sample from small enterprises. For Lithuania, the earliest measurement of fixed tangible assets that we have obtained was for the end of 1995. To obtain the same figure for 1994, we subtract gross fixed capital formation for 1995 ($GFCF_{95}$) and add consumption of fixed capital for 1995 ($CFC_{95}$) to the fixed tangible assets in 1995 and then deflate the resulting figure with the GDP deflator for 1995. The nominal value of the stocks of fixed tangible assets that we obtain are 1772.6 million lats for Latvia in 1994, 21115.4 million krooni for Estonia in 1993 and 13506.9 million litas for Lithuania in 1994.

To our knowledge, there is no reliable data available for the stock of residential housing in the Baltic states. To obtain an estimate of the residential capital, we therefore look at comparable data for other countries. The country which is closest to the Baltic states in its economic conditions and for which residential housing stock data is available in the PWT 5.6 data set is Poland. To estimate the residential housing stock for the Baltic states using Polish data, we assume that in each of the Baltic countries, the real value of residential capital per capita in the last closed year was the same as the real value of residential capital per capita in Poland in 1990. More formally,

$$\frac{\text{real rescap}_C}{n_i^C} = \frac{\text{real rescap}_{\text{Pol}}}{n_{90}^\text{Pol}},$$  

(A.1)

where $C \in \{\text{Est}, \text{Lat}, \text{Lit}\}$, $i$ is the last closed year (1993 for Estonia and 1994 for Latvia and Lithuania), $\text{real rescap}$ is the real value of the residential capital stock and $n$ is population. Such an assumption is quite reasonable, since before the collapse of socialism, the level of economic development in Poland and the Baltic states was similar and, by 1994, the progress of transition in the Baltics was at a level comparable to Poland’s progress by 1990.

According to the data in PWT 5.6, the Polish stock of residential housing in 1990 was at a level of 47 per cent of real GDP. Next, we use PWT 6.1 (see Heston et al. (2002)), which is the first version of the Penn World Tables to include real GDP data for the Baltic states, but it does not yet include data on residential capital stocks for any country. Using PWT 6.1, we translate the value of Polish residential housing into comparable figures for the Baltic states. This is done by first noting that in PWT 6.1,
the Polish ratio of residential housing stock to real GDP in 1990 should be the same as in PWT 5.6, since the different “international dollars” in which values are measured in PWT 5.6 and PWT 6.1 cancel out in a ratio. Thus, we get that the real residential capital per capita for Poland in 1990 was 3121.8 “1996 international dollars.” Using our assumption in equation (A.1), the Polish per capita value of the residential housing is applied to each of the Baltic states through the following formula:

$$\text{nominal rescap}_i^C = \frac{\text{nominal GDP}_i^C \cdot \text{real rescap}^{Pol}_{90}}{\text{real GDP}_i^C \cdot n_{90}^{Pol}} n_i^C,$$  \hspace{1cm} (A.2)

where the notation is the same as in equation (A.1). \(\text{real GDP}_i^C\) is measured in 1996 international dollars and \(\text{nominal GDP}_i^C\) is measured in year \(i\) local currency of country \(C\). The resulting value for the \(\text{nominal rescap}_i^C\) is measured in the same (nominal) units as tangible fixed assets. Using this procedure, we get that the residential capital stock was 1087.0 million lats for Latvia in 1994, 9666.8 million krooni for Estonia in 1993 and 7836.5 million litas for Lithuania in 1994.

Adding up fixed tangible assets and residential housing stock and dividing the sum by nominal GDP, we obtain the following capital to output ratios:

$$\frac{k_{Est}^{93}}{y_{93}^{Est}} = 1.410, \quad \frac{k_{Lat}^{94}}{y_{94}^{Lat}} = 1.399, \quad \frac{k_{Lit}^{94}}{y_{94}^{Lat}} = 1.334.$$  \hspace{1cm} (A.3)

### B Calibration of production functions

First, note that output in sector \(j\), where \(j = \{T, N\}\), in the last year before liberalization is:

$$y_{j0} = A_j k_{j0}^{\alpha_j} l_{j0}^{1-\alpha_j} - \frac{\varphi \zeta}{1 + \varsigma} \delta^{\frac{1+\varsigma}{\varsigma}} k_{j0},$$  \hspace{1cm} (B.1)

where the last term is the cost associated with the transformation of investment goods into capital. Next, we use the fact that capital in each sector in equilibrium must earn its marginal product, which implies that

$$y_{j0} X_j = (\alpha_j A_j k_{j0}^{\alpha_j} l_{j0}^{1-\alpha_j} + Z) k_{j0},$$  \hspace{1cm} (B.2)

where \(Z = \beta \delta^{\frac{\varsigma}{\varsigma-1}} \left(1 - \frac{1}{\beta} - \frac{\varsigma}{1+\varsigma} \delta\right)\) is once more a term stemming from investment transformation costs and where \(X_j\) denotes the income share of capital and is obtained from
the aggregated input-output tables using the following formula:\textsuperscript{15}

\[
X_j = \frac{os_{j,97}}{os_{j,97} + w_l_{j,97} + mix_{j,97}}.
\]  

(B.3)

Here, \(os\) is the operating surplus (i.e. the operating surplus of incorporated enterprises), \(w_l\) is remuneration of employees and \(mix\) stands for mixed income (i.e. the operating surplus of private unincorporated enterprises). We include all mixed income in labor income, which has been proposed by Gollin (2002) as one way of getting the income shares right. This is a sensible adjustment for self-employment, since household enterprises in the Baltic countries are labor intensive. Unfortunately, we only have data on the division between mixed income and operating surplus for Latvia. Since the three Baltic economies are very similar in structure, we assume the relative size of these subcategories of business profit to be the same for all three countries. In the case of Lithuania, the time subscript in (B.3) refers to 1998.

Equilibrium conditions also require that the returns to capital and labor are the same in both sectors, which implies that:

\[
\alpha_T A_T k_T^{\alpha_T-1} l_T^{1-\alpha_T} = \alpha_N A_N k_N^{\alpha_N-1} l_N^{1-\alpha_N},
\]

\[
(1 - \alpha_j) A_j k_0^{\alpha_j} l_0^{1-\alpha_j} = 1, \quad j = \{T, N\},
\]

where in the last equality, we used the fact that initial wages have been normalized to 1. Finally, we can use the market clearing condition for capital:

\[
k_0 = k_{T0} + k_{N0}.
\]

(B.6)

The eight equations in (B.1)-(B.2) and (B.4)-(B.6) are used together to obtain values for \(k_{T0}, k_{N0}, l_{T0}, l_{N0}, \alpha_T, \alpha_N, A_T\) and \(A_N\).

\textsuperscript{15}Note that since capital frictions are present in the steady state in the model, the capital income share in a sector differs from \(\alpha_j\).
Table 1: The size of the private sector in the Baltic states, percent of GDP

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<td>60</td>
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</table>

Source: EBRD Transition reports, 1995-2000

Table 2: The division of industries into traded and non-traded sectors

<table>
<thead>
<tr>
<th>Traded industries</th>
<th>Non-traded industries</th>
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</thead>
<tbody>
<tr>
<td>Agriculture</td>
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<td>Fish</td>
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</tr>
<tr>
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<tr>
<td>Manufacturing</td>
<td>Hotel services</td>
</tr>
<tr>
<td>Transport/Communications</td>
<td>Finance</td>
</tr>
<tr>
<td></td>
<td>Real estate/renting</td>
</tr>
<tr>
<td></td>
<td>Public administration</td>
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<td>Education</td>
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<td></td>
<td>Health</td>
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<td></td>
<td>Other community services</td>
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</table>
Table 3: Aggregated input-output matrix for Latvia, 1997

(Million Lats)

<table>
<thead>
<tr>
<th>EXPENDITURES</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>1+2+3</th>
<th>C+G</th>
<th>I</th>
<th>X</th>
<th>C+G+I+X</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
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<td></td>
<td></td>
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<td>76.4</td>
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<td>2812.3</td>
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<td></td>
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<tr>
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<td>75.1</td>
<td>19.7</td>
<td>260.5</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>S T</td>
<td>324.0</td>
<td>78.9</td>
<td>25.8</td>
<td>428.6</td>
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<tr>
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<td>3275.5</td>
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<tr>
<td>M</td>
<td>1794.0</td>
<td>123.7</td>
<td>29.6</td>
<td>1947.3</td>
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<td>511.5</td>
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<td>746.3</td>
<td>1664.1</td>
<td>5222.7</td>
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</tr>
</tbody>
</table>

Source: derived from Central Statistical Bureau of Latvia (2001)

1. Traded sectors (agriculture, fishing, mining, manufacturing, transport).
2. Non-traded sectors (except services not for sale).
3. Services not for sale (public admin., defense, other community services).
   *wl.* Remuneration of employees.
   *rk.* Net business income, of which
   *os.* Operating surplus (incorporated enterprises).
   *mix.* Mixed income (unincorporated enterprises).
   *T.* Net indirect taxes and transfers including value added tax.
   *M.* Imports.
   *C+G.* Private consumption plus government consumption.
   *I.* Investment
   *X.* Exports
Table 4: Aggregated input-output matrix for Estonia, 1997
(Billion Kroons)

EXPENDITURES

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
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<th>1+2+3</th>
<th>C+G</th>
<th>I</th>
<th>X</th>
<th>C+G+I</th>
<th>TOTAL</th>
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<td>R</td>
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<td>0.5</td>
<td>1.3</td>
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<td>0.0</td>
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<td>11.5</td>
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<tr>
<td>C</td>
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<td>33.7</td>
<td>4.2</td>
<td>92.2</td>
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<td>19.6</td>
<td>50.2</td>
<td>122.2</td>
<td>214.4</td>
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</tbody>
</table>

| 1+2+3 | 54.2 | 33.7 | 4.2 | 92.2   | 52.4 | 19.6 | 50.2 | 122.2 | 214.4 |
| E     | 13.7 | 15.7 | 4.2 | 33.6   | 33.6 | 21.1 | 16.5 | 16.5  | 4.6   |
| I     | 10.2 | 9.9  | 1.0 | 21.1   | 21.1 | 16.5 | 16.5 | 16.5  | 4.6   |
| P     | 7.0  | 8.7  | 0.8 | 16.5   | 16.5 | 16.5 | 16.5 | 16.5  | 4.6   |
| T     | 3.2  | 1.2  | 0.2 | 4.6    | 4.6  | 4.6  | 4.6  | 4.6   | 4.6   |
| S     | 5.5  | 3.6  | 0.9 | 9.9    | 9.9  | 9.9  | 9.9  | 9.9   | 9.9   |
| M     | 53.1 | 3.3  | 1.2 | 57.7   | 57.7 | 57.7 | 57.7 | 57.7  | 57.7  |
| TOTAL | 136.7 | 66.2 | 11.5 | 214.4  | 52.4 | 19.6 | 50.2 | 122.2 | 214.4 |


1. Traded sectors (agriculture, fishing, mining, manufacturing, transport).
2. Non-traded sectors (except services not for sale).
3. Services not for sale (public adm., defense, other community services).

wl. Remuneration of employees.

rk. Net business income, of which

os. Operating surplus (incorporated enterprises).

mix. Mixed income (unincorporated enterprises).

U. Net indirect taxes and transfers including value added tax.

M. Imports.

C+G. Private consumption plus government consumption.

I. Investment

X. Exports

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Table 5: Calibration of the model for the Baltic countries

<table>
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<th>Estonia</th>
<th>Lithuania</th>
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<tbody>
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<td>100.00</td>
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<tr>
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<tr>
<td>$L$</td>
<td>63.35</td>
<td>67.52</td>
<td>57.65</td>
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<td>$l_{TO}$</td>
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<td>1.9677</td>
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<tr>
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Table 6: Total external debt in the Baltic countries, percent of GNI

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<td>82</td>
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<tr>
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<td>22</td>
<td>45</td>
<td>47</td>
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<td>63</td>
<td>64</td>
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<td>47</td>
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<td>47</td>
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</table>

Source: Global Development Finance database

Table 7: Real interest rate risk premia in the Baltic countries

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<th></th>
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<td>$\rho^{Est}$</td>
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<td>0.018</td>
<td>0.047</td>
<td>0.024</td>
<td>0.011</td>
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<td>$\rho^{Lat}$</td>
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<td>0.136</td>
<td>0.051</td>
<td>0.032</td>
<td>0.039</td>
<td>0.018</td>
<td>0.021</td>
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<td>$\rho^{Lit}$</td>
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<td>0.023</td>
<td>0.037</td>
<td>0.013</td>
<td>0.012</td>
<td>0.013</td>
<td>0.007</td>
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Source: Authors' calculations
Table 8: Sensitivity analysis of the model with interest rate risk premia, Estonia

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<th>Deviation from baseline calibration</th>
<th>Min. trade balance</th>
<th>Year of reversal</th>
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<tr>
<td>None</td>
<td>-9.9</td>
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<tr>
<td>0.8k₀</td>
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<td>1996</td>
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<tr>
<td>1.2k₀</td>
<td>-6.7</td>
<td>2001</td>
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<tr>
<td>1/(1 - η) = 0.8</td>
<td>-9.2</td>
<td>1997</td>
</tr>
<tr>
<td>1/(1 - η) = 0.2</td>
<td>-11.7</td>
<td>1996</td>
</tr>
<tr>
<td>1/(1 - σ) = 0.8</td>
<td>-7.9</td>
<td>1996</td>
</tr>
<tr>
<td>1/(1 - σ) = 0.2</td>
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<td>1997</td>
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<tr>
<td>φ = 0</td>
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<td>1996</td>
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<tr>
<td>φ = 2</td>
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<td>1997</td>
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<td>ζ = 0.65</td>
<td>-11.2</td>
<td>1996</td>
</tr>
<tr>
<td>ζ = 1.95</td>
<td>-9.7</td>
<td>1997</td>
</tr>
<tr>
<td>ψ = 0</td>
<td>-13.4</td>
<td>1996</td>
</tr>
<tr>
<td>αₜ = αₙ = 1/3</td>
<td>-10.6</td>
<td>1997</td>
</tr>
<tr>
<td>1 + rₜ = 1/β, t ≥ 2008</td>
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<td>1996</td>
</tr>
</tbody>
</table>

Table 9: Sensitivity analysis of the model with interest rate risk premia, Latvia

<table>
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<tr>
<th>Deviation from baseline calibration</th>
<th>Min. trade balance</th>
<th>Year of reversal</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>-9.9</td>
<td>2003</td>
</tr>
<tr>
<td>0.8k₀</td>
<td>-12.7</td>
<td>2000</td>
</tr>
<tr>
<td>1.2k₀</td>
<td>-8.1</td>
<td>2003</td>
</tr>
<tr>
<td>1/(1 - η) = 0.8</td>
<td>-10.5</td>
<td>2000</td>
</tr>
<tr>
<td>1/(1 - η) = 0.2</td>
<td>-9.6</td>
<td>2003</td>
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<tr>
<td>1/(1 - σ) = 0.8</td>
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<td>1/(1 - σ) = 0.2</td>
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<td>2000</td>
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<tr>
<td>φ = 0</td>
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<tr>
<td>ψ = 0</td>
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<td>1998</td>
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<tr>
<td>αₜ = αₙ = 1/3</td>
<td>-7.2</td>
<td>2003</td>
</tr>
<tr>
<td>1 + rₜ = 1/β, t ≥ 2008</td>
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<td>2003</td>
</tr>
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</table>
Table 10: Sensitivity analysis of the model with interest rate risk premia, Lithuania

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<th>Year of reversal</th>
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<td>% of GDP</td>
<td>year</td>
</tr>
<tr>
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<tr>
<td>0.8k₀</td>
<td>-21.9</td>
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<tr>
<td>1.2k₀</td>
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<td>2000</td>
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<td>1998</td>
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<td>1/(1 - λ) = 0.2</td>
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<tr>
<td>1/(1 - σ) = 0.8</td>
<td>-15.7</td>
<td>1998</td>
</tr>
<tr>
<td>1/(1 - σ) = 0.2</td>
<td>-21.8</td>
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<td>1997</td>
</tr>
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<td>ζ = 1.95</td>
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<td>2000</td>
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<tr>
<td>ψ = 0</td>
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<td>1997</td>
</tr>
<tr>
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<td>2000</td>
</tr>
<tr>
<td>1 + r_t = 1/β, t ≥ 2008</td>
<td>-18.1</td>
<td>1998</td>
</tr>
</tbody>
</table>
Figure 4: Real exchange rates in the Baltic states

Estonia

Latvia

Lithuania
Figure 5: The basic model

(a) Trade balance, Estonia
(b) Trade balance, Latvia
(c) Trade balance, Lithuania
(d) Output growth, Estonia
(e) Output growth, Latvia
(f) Output growth, Lithuania
(g) Traded sector, Estonia
(h) Traded sector, Latvia
(i) Traded sector, Lithuania
(j) Real exchange rate, Estonia
(k) Real exchange rate, Latvia
(l) Real exchange rate, Lithuania

- data
- model
Figure 6: Real interest rates in the model, $r^c$

- Latvia
- Estonia
- Lithuania
- Germany
Figure 7: The model with interest rate risk premia

(a) Trade balance, Estonia
(b) Trade balance, Latvia
(c) Trade balance, Lithuania
(d) Output growth, Estonia
(e) Output growth, Latvia
(f) Output growth, Lithuania
(g) Traded sector, Estonia
(h) Traded sector, Latvia
(i) Traded sector, Lithuania
(j) Real exchange rate, Estonia
(k) Real exchange rate, Latvia
(l) Real exchange rate, Lithuania

Legend:
- data
- model
ESSAY III
Abstract

This paper develops a framework for analyzing optimal government bailout policy in a dynamic stochastic general equilibrium model where financial crises are exogenous. Important elements of the model are that private borrowers only internalize part of the social cost of foreign borrowing in the emerging market and that the private sector is illiquid in the event of a crisis. The distinguishing feature of our paper is that it addresses the optimal bailout policy in an environment where there are both costs and benefits of bailouts, and where bailout guarantees potentially distort investment decisions in the private sector. We show that it is always optimal to commit to a bailout policy that only partially protects investment against inefficient liquidation, both in a centralized economy and a market economy. Due to overinvestment in the market economy, the government’s optimal level of bailout guarantees is lower than in the social optimum. Further, we show that, in contrast to a social planner, the government in the market economy should optimally bail out a smaller fraction of private investments when the probability of a crisis is higher.

*JEL classification:* F34, F40

*Keywords:* Financial crisis; government bailout; emerging markets

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*We are grateful to Lars Ljungqvist, Timothy J. Kehoe, Martin Flodén, David Domeij, Caroline Betts and Mariassunta Giannetti for helpful comments and suggestions. We have also benefited from discussions with Philippe Aghion, Erik Berglöf, Thomas F. Cooley, Giancarlo Corsetti, Guido Friebel, Paul S. Segerstrom, Elena Paltseva, as well as seminar participants in the Economics Lunch Seminar at SSE, a research seminar at Sveriges Riksbank and the 7:th Workshop on Dynamic Macroeconomics in Vigo, Spain. Financial support from the Jan Wallander and Tom Hedelius foundation is gratefully acknowledged.
1 Introduction

A wide range of emerging market economies have experienced financial crises in recent decades. In the wake of these events, governments of such countries as Chile, Argentina, Mexico, Korea and Indonesia have spent large shares of their GDP, sometimes more than 30 percent, on saving financial systems in distress.\(^1\) In light of the large costs involved, investigating the macroeconomic role and efficiency of such rescue packages must be of prime concern. The economic profession is divided on the role of bailouts in financial crises in emerging markets. On the one hand, governments should limit the provision of guarantees to avoid distorting investment incentives in the private sector, on the other hand, they should stand ready to provide liquidity in times of crisis to minimize the negative consequences of financial panics and maturity mismatch. What advice should we give to policy makers in emerging markets? What is the optimal bailout policy in response to a financial crisis?

In this paper, we analyze optimal bailout policy under commitment in a dynamic stochastic general equilibrium model where financial crises are exogenous. Important elements of the model are that private borrowers only internalize part of the social cost of foreign borrowing in the emerging market and that the private sector is illiquid in the event of a crisis. We model the strategic interaction between the government and the private sector, assuming the government to be benevolent in the sense of maximizing consumer utility.

The distinguishing feature of our paper is that it addresses the optimal bailout policy in an environment where there are both costs and benefits of bailouts, and where bailout guarantees potentially distort investment decisions in the private sector. In the model, the cost of bailouts arises because bailouts lead to more volatile government consumption, while the benefit of bailouts is that they help avoid inefficient liquidation of investments in the private sector. The cost is aggravated by the distortion of private investment incentives which arises from bailout guarantees in the model.

To examine the optimal bailout policy, we consider a range of alternative bailout policies and construct equilibrium with commitment and a Markov structure. We show that in both a centralized economy and a market economy where the government is restricted to providing bailouts for free, it is always optimal to commit to a bailout policy that only partially protects investment against inefficient liquidation. Due to overinvestment in the decentralized economy, the government's optimal level of bailout guarantees is lower than in the social optimum. Further, we show that, in contrast to a social planner, the government in the decentralized economy should optimally bail out

\(^{1}\)See, for example, Dziobek and Pazarbasioglu (1997), Kaminsky and Reinhart (1999) and Eichen-green and Rose (1997).
a smaller fraction of private investments when the probability of a crisis increases.

Previous work on government bailouts has included some of the different elements that we merge into a unified framework in our model. Gale and Vives (2002) model a moral hazard cost of bailouts by making the private managerial effort depend on the size of bailout guarantees. Freixas (1999) pursues a cost-benefit analysis to characterize the optimal bailout policy of the Lender of Last Resort. Mundaca (2001) develops a game theoretic setting for the interaction between the government and the market to address the optimal bailout policy, whereas Schneider and Tornell (2000) investigate the effects of government bailouts on market behavior in an infinite horizon setting. The general structure of our model has been inspired by Cole and Kehoe (2000), who address the issue of optimal government debt policies and self-fulfilling debt crises.

Our paper is related to the strand of research arguing that bailout guarantees are a 'bad policy', in that the provision of these leads to distortions in investment incentives. According to the theoretical work of Corsetti et al. (1998a) and Burnside et al. (2003), bailout guarantees induce moral hazard by providing insurance against future crises to the private sector. Market participants willingly take on excessive risk, which leads to over-investment, excessive external borrowing or unhedged foreign loans. Empirical support for the 'bad policy' argument has been provided by Corsetti et al. (1998b) and Dooley and Shin (2000).

Our model also captures the arguments of the literature on maturity mismatch and financial panics, which holds a more positive view on government bailouts. The provision of emergency liquidity can help avoid inefficient liquidation of investments in times of crisis, as argued by Chang and Velasco (2001) and Allen and Gale (2000). We believe potential illiquidity to be a characteristic feature of producers in emerging markets, who are often forced to borrow abroad at short maturities. Empirical work by Radelet and Sachs (1998) and Rodrik and Velasco (1999) has found evidence supporting this view.

The next section of the paper lays out the model. In Section 3, we define an equilibrium which takes into account the strategic incentives of a government that must commit to a level of bailout guarantees in the first period of the model and adhere to this in all subsequent periods. In section 4, we analyze the market response to bailout guarantees. Section 5 presents the social planner's solution of the model and Section 6 analyzes the government’s optimal bailout policy. In Section 7, we show that the formal analysis and the policy conclusions of the paper remain unchanged if the commitment assumptions in the model are relaxed. Section 8 provides a numerical example to illustrate the model, while concluding remarks and suggestions for future research are presented in Section 9.
2 The Model

We model an emerging market as a small economy opening up to the international capital market in period $t = 0$. The economy is inhabited by a continuum of consumers and a government. The consumers receive an endowment of a consumption good in each period. Additional consumption goods can be produced with borrowed foreign capital as the only input. In the first period, the government must commit to a bailout policy, to which it must adhere in all subsequent periods.\(^2\)

2.1 The International Capital Market

A continuum of risk neutral agents act in an environment of perfect competition on the international capital market. This implies that the expected return on any one-period loan must equal $1/\beta$, where $\beta$ is the universal and subjective discount rate.

In every period, the international capital market offers one-period loans to the consumers in the emerging economy. We assume all international loans in some periods to be recalled before having reached full maturity. Define $\zeta_t$ to be an exogenous random variable realized at the beginning of each period and following the process

$$\zeta_t = \begin{cases} 
0 & \text{with prob. } (1 - \pi), \ t > 0 \\
1 & \text{with prob. } \pi 
\end{cases}$$

$$\zeta_0 = 0,$$

where $\pi \in [0, 1)$ is an exogenous parameter.

If $\zeta_t = 1$, all international loans are recalled before they have reached full maturity in period $t$, which is what we define as a financial crisis in the emerging market. Repayments of international loans are requested after full maturity if $\zeta_t = 0$. Note that a financial crisis in the model economy occurs with the exogenous probability $\pi$ in every period.

2.2 The Consumers

There is a continuum with measure one of identical and infinitely lived consumers, who consume, invest, borrow from abroad, and pay lump-sum taxes. The individual consumer’s utility function is

$$E \sum_{t=0}^{\infty} \beta^t (c_t + v(g_t)),$$

\(^2\)The formal analysis and the policy conclusions of the paper would remain unchanged if the assumption that the government must commit to its bailout policy in the first period were relaxed to allow for one-period commitment. In Section 7, we discuss the commitment assumption further.
where $c_t$ is private consumption and $g_t$ is government consumption. We assume $v$ to be twice continuously differentiable, strictly concave, monotonically increasing and that $v(0) = -\infty$.

If the probability of crisis is zero (i.e. if $\pi = 0$), the individual consumer is subject to the following budget and investment constraints

$$c_t + k_{t+1} + R_t b_t + Q_t \leq f(k_t) + b_{t+1} + \omega \quad (3)$$

$$k_{t+1} = b_{t+1} \quad (4)$$

Here, $b_{t+1}$ is a foreign loan to be repaid in period $t+1$. The investment constraint in (4) specifies that international loans can only be used to augment the capital stock, $k_{t+1}$, and that the capital used in production must be borrowed from abroad. $R_t$ is the gross interest rate on foreign loans, $Q_t$ is a lump-sum tax, and $\omega > 0$ is an endowment received in each period. We assume the production function to be of the functional form

$$f(k) = Ak^\alpha, \quad \alpha < 1. \quad (5)$$

The consumer is endowed with $k_0 = 0$ and $b_0 = 0$ in period $t = 0$. We assume that capital depreciates fully after one period.

When the probability of crisis is positive and a financial crisis occurs in period $t$, repayment of international loans must be made before production takes place. We assume that in this case, international lenders can liquidate the capital stock, $k_t$, with a linear return of $1/\beta$. This simplifying assumption implies that the interest rate on international loans in the model economy is constant and equal to the world interest rate, $R_t = 1/\beta \forall t$.\(^{3}\)

When the probability of a crisis is positive, the individual consumer’s budget constraint will depend on government policy, which is the reason why we now turn to describing the government.

### 2.3 The Government

The government is benevolent in the sense of its objective being to maximize the consumers’ utility. The government is the only strategic agent in the model, and when making its decisions, it takes into account the effects of these decisions on the level of the aggregate capital stock $K_t$, the aggregate level of international private debt $B_t$, government revenue, and the level of private consumption.

\(^{3}\)Previous versions of this paper included costs of liquidation so that the return to liquidating capital was smaller than unity. The assumption that capital can be liquidated with a return of $1/\beta$ greatly facilitates our analytical investigation, without affecting the policy conclusions of the paper.
We define a bailout policy \( x \) as the fraction of international liabilities the government provides to international lenders in the event of a crisis.

In period \( t = 0 \), the government can commit to any bailout policy \( x \in [0, 1] \), to which it must subsequently adhere forever. Choosing \( x = 0 \) corresponds to a policy of \textit{No Bailout}, which implies that the government never provides any resources for repaying international lenders in the event of a crisis. Committing to \( x = 1 \) corresponds to a policy of \textit{Full Bailout}, by which the government provides \( RB_t \) to repay international loans in a crisis.

The consumers must pay an exogenous price, \( P \geq 0 \), for the bailouts provided by the government. For a bailout policy \( x \), the government will spend \( xRB_t \) on bailouts in a financial crisis and receive \( xPB_t \) from consumers later in the same period. A price of \( P = 1/\beta \) thus implies that the consumers repay exactly what the government spends on bailouts. In the model, the price of bailouts will affect the investment decision of the individual consumer. When analyzing the government’s optimal bailout policy in Section 6, the price \( P \) will therefore play an important role for the outcomes of the model.

In the first period, the government commits to a bailout policy \( x \), and in every period, it chooses the size of the lump-sum tax, \( Q_t \geq 0 \), after observing the realization of the crisis variable, \( \zeta_t \). The timing of events in the model is such that in every period, the government must spend resources before receiving income in that period. When spending resources on government consumption and bailouts in period \( t \), the government’s budget constraint is

\[
g_t + \zeta_t xRB_t = Q_{t-1} + \zeta_{t-1} PB_{t-1},
\]

where \( g_t \geq 0 \ \forall t \). The left-hand side of equation (6) shows that resources are spent on government consumption in every period. If there is a financial crisis in the period, the government also spends resources on pursuing bailouts according to the bailout policy, \( x \). The first term on the right-hand side of equation (6) says that in every period, the lump-sum tax levied in the previous period contributes to government resources in the current period. Similarly, the second term states that any repayment of bailouts received in period \( t - 1 \) contributes to the government resources in period \( t \). Note that we have assumed that the government must run a balanced budget. The government is subject to a revenue lag, but has no other possibility of saving resources to build a buffer against future bailout costs. For expositional reasons, it is useful to define government revenues in period \( t \) as

\[
T_t = \begin{cases} 
Q_t, & \text{if } \zeta_t = 0 \\
Q_t + PB_t, & \text{if } \zeta_t = 1
\end{cases}, \quad t \geq 0.
\]

Because consumers are competitive, we need to distinguish between the individual decisions \( k_{t+1} \) and \( b_{t+1} \) and the aggregate values \( K_{t+1} \) and \( B_{t+1} \). Consumers should not
think that their individual actions affect the aggregate state in the next period, thereby affecting prices or the government's actions. In equilibrium, because all consumers are identical, \( k_{t+1} = K_{t+1} \) and \( b_{t+1} = B_{t+1} \).

Since a fraction of the individual's capital stock must sometimes be liquidated in the model, we need to enhance the notation we have used so far. Let \( k_{t+1} \) denote the consumers' choice in period \( t \) and let \( \kappa_{t+1} \) denote the part of the capital stock actually used in production in period \( t + 1 \). The law of motion for \( \kappa_{t+1} \) depends on the bailout policy in the following way:

\[
\kappa_{t+1} = \kappa(x, k_{t+1}, \zeta_{t+1}) = \begin{cases} 
  k_{t+1} & \text{if } \zeta_{t+1} = 0 \\
  xk_{t+1} & \text{if } \zeta_{t+1} = 1
\end{cases}
\]  

(8)

The first line of equation (8) simply states that if a crisis does not occur in period \( t + 1 \), there is no liquidation. The second line says that for a given bailout policy \( x \), consumers can keep \( xk_{t+1} \) in production if a crisis occurs in period \( t + 1 \).

### 2.4 The Timing

The timing of actions within period \( t = 0 \) differs from subsequent periods, since the government chooses its bailout policy only in the first period. In subsequent periods, the actions within a period depend on whether a crisis occurs; the government pursues bailouts and investments are liquidated only if a crisis occurs in that period. The timing of actions within a period is the following:

1. The variable \( \zeta_t \) is realized and the aggregate state is \( S_t = (K_t, B_t, T_{t-1}, \zeta_t) \).
2. If \( t = 0 \), the government commits to a bailout policy \( x \).

   \textbf{If a crisis does not occur}, \( \zeta_t = 0 \),

3. The government provides \( g_t \) and decides \( Q_t \).
4. Production takes place, the endowment is realized and taxes are paid.
5. Each consumer repays his international loans, amounting to \( Rb_t \).
6. Each consumer chooses \( c_t, k_{t+1} \) and \( b_{t+1} \), taking \( x, P \) and \( Q_t \) as given.

   \textbf{If a crisis occurs}, \( \zeta_t = 1 \),

3. Each consumer is asked to repay \( Rb_t \) early.
4. The government provides \( g_t \), decides \( Q_t \), and spends \( xRB_t \) on bailouts.

---

4The initial endowments are such that \( k_0 = K_0 \) and \( b_0 = B_0 \).
5. Each consumer must liquidate part of his invested capital, \((1 - x)k_t\), and use it to repay part of his international loans. Since capital can be liquidated with a return of \(1/\beta = R\), and since \(k_t = b_t\), the repayment is worth \((1 - x)Rb_t\) to the international lenders.

6. Using the part of the capital which is left in production, \(xk_t\), production takes place, the endowment is realized, taxes are paid and bailouts are repaid to the government with the amount \(Px_B_t\).

7. Each consumer chooses \(c_t, k_{t+1}\) and \(b_{t+1}\), taking \(x, P\) and \(Q_t\) as given.

An important feature of the timing is that the government in a period must spend resources on government consumption and bailouts before it receives any revenues in that period. The government carries over any revenues from one period to the next. If loans need to be repaid early, the government disposes of revenues from the previous period and can therefore bail out the consumers, who are illiquid at the beginning of each period.

3 Equilibrium in period \(t = 0\)

Within each period, the aggregate state \(S_t = (K_t, B_t, T_{t-1}, \zeta_t)\), the bailout policy \(x\), the government’s choice of \(Q_t\), the consumers’ choices \(c_t, k_{t+1}\) and \(b_{t+1}\), the interest rate on international loans \(R\) and the price of bailouts \(P\) determine the equilibrium. Since we want to analyze the government’s optimal bailout policy, we will focus on the equilibrium in period \(t = 0\), which is the only period where \(x\) is a choice variable for the government.\(^5\)

To define a recursive equilibrium, we first present the individual consumer’s problem, which takes \(x\) and \(Q_t\) as given. Next, we present the government’s problem, which takes into account that the consumer’s choices will depend on the bailout policy \(x\) and the lump-sum tax, \(Q_t\).

The solution of an agent’s maximization problem is given by the value function providing the maximum attainable value of the agent’s utility function given his state, and by policy functions providing the maximizing choices of the agent’s choice variables in the current period, given his state. In equilibrium, agents solve their own problems by correctly predicting other agents’ policies.

When an individual consumer acts, he knows the bailout policy \(x\), the size of the lump-sum tax \(Q_t\), the aggregate state \(S_t\), his individual levels of \(k_t\) and \(b_t\), the interest rate \(R\) and the price of bailouts, \(P\). To save on notation, let \(h_t = (k_t, b_t, S_t)\). The

\(^5\)In section 7, we show that the optimal bailout policy in this equilibrium is identical to the optimal policy in a model where the government in every period must commit to a bailout policy for the next period.
individual consumer's value function is defined by the following functional equation:

\[ V^C(x, h_t) = \max_{\{c_t, k_{t+1}, b_{t+1}\}} \left\{ c_t + v(g_t) + \beta E_t V^C(x, h_{t+1}) \right\} \]  

\[ s.t \quad c_t + k_{t+1} + (1 - \zeta_t) R b_t + \zeta_t P x b_t + Q_t \leq f(\kappa_t) + b_{t+1} + \omega \]

\[ k_{t+1} = b_{t+1} \]
\[ k_{t+1} \geq 0 \]
\[ \zeta_{t+1} = \begin{cases} 0 & \text{with prob. } (1 - \pi) \\ 1 & \text{with prob. } \pi \end{cases} \]
\[ Q_t = Q(x, S_t) \]
\[ K_{t+1} = K(x, S_t) \]
\[ B_{t+1} = B(x, S_t) \]
\[ \kappa_t = \kappa(x, k_t, \zeta_t) \quad \forall t \]
\[ T_t = Q_t + \zeta_t P x B_t \]
\[ x, h_t \] given,

where the functions \( Q(\cdot), K(\cdot) \) and \( B(\cdot) \) will subsequently be defined and where \( \kappa(\cdot) \) was defined in equation (8). The consumer's policy functions are \( c(x, h_t), k(x, h_t) \) and \( b(x, h_t) \).

When the government chooses its bailout policy \( x \) in period \( t = 0 \), it knows the initial aggregate state \( S_0 = (K_0, B_0, T_1, \zeta_0) \), the interest rate \( R \) and the price of bailouts \( P \). The government realizes that it can affect the consumers' decisions through its choices of \( x \) and \( Q_t \). When the government in any period chooses \( Q_t \), it also knows the bailout policy \( x \). Let \( H_t = (K_t, B_t, S_t) \). The government's value function in period \( t = 0 \) is defined by the following functional equation:

\[ V^G_0(S_0) = \max_{\{x, Q_0\}} \left\{ c(x, H_0) + v(g_0) + \beta E_0 V^G(x, S_1) \right\} \]  

\[ \text{where} \]
\[ V^G(x, S_t) = \max_{\{Q_t\}} \left\{ c(x, H_t) + v(g_t) + \beta E_t V^G(x, S_{t+1}) \right\}, \quad t > 0 \]
The government’s policy function for the lump-sum tax is $Q(x, S_t)$, and the set of optimal bailout policies is $X^*$. Having developed these concepts, we can now define an equilibrium for the first period in our model economy.

Definition of equilibrium in period $t = 0$. An equilibrium in period $t = 0$ is a list of value functions $V^C$ for individual consumers and $V^G_0$ for the government; policy functions $c(x, h_t)$, $k(x, h_t)$ and $b(x, h_t)$ for the consumers; a policy function $Q(x, S_t)$ and an optimal bailout policy $x^* \in X^*$ for the government; an interest rate $R$; a price of bailouts $P$; and laws of motion for the aggregate state variables, $K(x, S_t)$, and $B(x, S_t)$, such that the following conditions hold.

1. Given $R$, $P$, $x$ and $Q(x, S_t)$, $V^C$ is the value function for the solution to the consumer’s problem and $c(x, h_t)$, $k(x, h_t)$ and $b(x, h_t)$ are the maximizing choices.

2. Given $R$, $P$, $c(x, h_t)$, $k(x, h_t)$ and $b(x, h_t)$, $V^G_0$ is the value function for the solution to the government’s problem, and $x^*$ and $Q(x, S_t)$ are the maximizing choices.

3. $K(x, S_t) = k(x, H_t)$ and $B(x, S_t) = b(x, H_t)$.

4 The Market Response to Bailouts

To characterize the equilibrium in period $t = 0$, we start by presenting the individual consumer’s optimal behavior in response to a given bailout policy, a given lump-sum tax and a given price of bailouts. Then, we characterize the government’s optimal choice for lump-sum taxation, still for a given bailout policy.

To find the consumer’s optimal response to a given bailout policy, we can use the investment constraint in equation (4) to substitute for $b_{t+1}$ in the maximization program.
presented in (9). The fact that $f'(0) = \infty$ ensures that the non-negativity constraint on borrowed capital never binds in equilibrium. Using the consumer’s budget constraint to substitute for $c_t$, the form of the function $\kappa(.)$ and the fact that $R = 1/\beta$, we obtain the following optimality condition for the consumer’s investment decision:

$$(1 - \pi) f'(k_{t+1}) + \pi x f'(xk_{t+1}) = (1 - \pi) \frac{1}{\beta} + \pi Px. \quad (11)$$

The details of the derivation are presented in appendix A. The left-hand side of (11) contains the expected marginal return on investment, which is the weighted sum of the marginal product of borrowed capital in a period without and with a crisis, respectively. The right-hand side represents the consumer’s expected marginal cost of capital. Note that for crisis periods, the consumer need only consider the marginal return and cost of the part of the capital stock that will be left in production after government bailouts, $xk_{t+1}$.

In equation (11), we see that the optimal level of borrowed capital is independent of the bailout policy $x$, if the probability of crisis is zero. This is natural, since bailouts never occur if crises never happen. Since our interest lies in analyzing the optimal bailout policy in an environment where crises can occur, we will focus on equilibria with a positive probability of crisis in the rest of the paper.

Note that for a given $\pi > 0$, the consumer’s optimal investment decision will only depend on the bailout policy $x$, not on the individual consumer’s state $h_t$. In equilibrium, the consumer therefore makes the same investment decisions in every period. To simplify the exposition, we will henceforth denote the consumer’s policy function for borrowed capital as $k(x)$.

Since the individual consumer is risk neutral, the optimal rule for consumption is simply to consume whatever resources are left in each period, once investments, tax payments, loan repayments or bailout repayments have been made.

To find the government’s optimal lump-sum tax, $Q_t$, for a given bailout policy $x$, we first use equation (7) to recast the government’s value function (10) as a maximization problem in terms of government revenues. This can be done, since we know from equation (11) that the consumer’s choice of $k_{t+1}$ is independent of the lump-sum tax. Note also that, since $v(0) = -\infty$, the non-negativity constraint on government consumption never binds in equilibrium.

Using the fact that $k_{t+1} = K_{t+1}$ and $b_{t+1} = B_{t+1}$, the investment constraint in equation (4) further enables us to substitute for $B_{t+1}$ in the maximization program presented in equation (10). Substituting for $R = 1/\beta$, the optimality condition for
government revenues, \( T_t \), is given by

\[
(1 - \pi)\psi'(T_t) + \pi\psi\left( T_t - \frac{xk(x)}{\beta} \right) = \frac{1}{\beta}.
\]  

(12)

The details of the derivation are presented in appendix A. Note that equation (12) implies that the equilibrium level of \( T_t \) is constant in the model, since the optimal level of revenues only depends on \( x \) and the consumer's (constant) equilibrium investment decision. For simplicity, we henceforth denote the optimal level of government revenues for a given bailout policy by \( T(x) \). The optimality condition in equation (12) can be understood by remembering that government revenues can only be used for government consumption with a one-period lag. The government optimally equates the discounted expected marginal utility from public consumption tomorrow to the marginal utility from private consumption today which, due to linearity, is constant and equal to 1 (in equation (12), we have divided both sides by \( \beta \)).

Given the constant level of \( T(x) \), the optimal lump-sum tax, \( Q(x, S_t) \), can be obtained as a residual from equation (7). For a given bailout policy \( x \), the optimal tax is smaller in periods of financial crisis, since the government in such periods receives additional revenues from the repayments of bailouts.

The fact that utility is linear in private consumption implies that the optimal level of private consumption, \( c(x, H_t) \), may be negative in response to a particular bailout policy \( x \) and the associated level of government revenues. If the lump-sum tax exceeds the endowment, \( \omega \), consumption in period \( t = 0 \) will, for example, be negative. Negative consumption can be avoided in the model if the endowment in each period is sufficiently large.

5 The Social Planner Solution

Before proceeding to analyze the government's optimal bailout policy, it is instructive to consider the solution of a centralized economy where a social planner maximizes consumer utility, subject to the resource constraints of the economy. This solution will serve as a useful benchmark in interpreting the decentralized equilibrium defined in section 3.

To facilitate comparisons between the social optimum and the market economy, we assume that the social planner must also commit to a bailout policy \( x \) at the beginning of period \( t = 0 \) and adhere to it in all subsequent periods.\(^6\) Apart from choosing \( x \) in period \( t = 0 \), the social planner will act at two points in time within each period. At the beginning of a period, the social planner knows \( S_t \) and delivers \( g_t \), subject to the budget

\(^6\)The social planner's problem can be formulated without defining bailout policies or assuming commitment, as discussed in Section 7.
constraint

\[ g_t = T_{t-1} - \zeta_t x R B_t, \]  

(13)

where \( R = 1/\beta \) as in the decentralized equilibrium, and \( T_{t-1} \) is the amount of resources transferred from the consumers to the public sector in period \( t - 1 \).

Later in the period, the social planner makes decisions for \( c_t, K_{t+1}, B_{t+1} \) and \( T_t \). The value function when the social planner acts for the second time in a period is defined by the following functional equation

\[ V^{SP}(x, S_t) = \max_{\{c_t, K_{t+1}, B_{t+1}, T_t\}} \{c_t + v(g_t) + \beta E_t V^{SP}(x, S_{t+1})\} \]  

(14)

s.t \[ c_t + K_{t+1} + (1 - \zeta_t) R B_t + T_t \leq f(\kappa(x, K_t, \zeta_t)) + B_{t+1} + \omega \]

\[ g_t = T_{t-1} - \zeta_t x R B_t \]

\[ g_t \geq 0 \]

\[ K_{t+1} = B_{t+1} \]

\[ K_{t+1} \geq 0 \]

\[ \zeta_{t+1} = \begin{cases} 0 & \text{with prob. } (1 - \pi) \\ 1 & \text{with prob. } (\pi) \end{cases} \]

\[ x, S_t \text{ given}, \]  

(15)

where the function \( \kappa(.) \) was defined in equation (8). The policy functions associated with \( V^{SP} \) are \( c_{SP}(x, S_t), K_{SP}(x, S_t), B_{SP}(x, S_t) \) and \( T_{SP}(x, S_t) \).

The value function for the centralized problem in period \( t = 0 \) can now be specified as

\[ V_0^{SP}(S_0) = \max_{x \in [0,1]} \{c_{SP}(x, S_0) + v(T_{-1}) + \beta E_0 V^{SP}(x, S_1)\} \]  

(16)

\[ S_0 \text{ given}. \]

The set of optimal bailout policies is \( X_0^{SP} \).

For a given probability of crisis, \( \pi \), and a given bailout policy, \( x \), the socially optimal choices of \( c_t, K_{t+1}, B_{t+1} \) and \( T_t \) can be found by using the budget constraints for private and government consumption to substitute for \( c_t \) and \( g_t \), and the investment constraint in (15) to substitute for \( B_{t+1} \) in the maximization program in equation (14). Since \( v(0) = -\infty \) and \( f'(0) = \infty \), the non-negativity constraints will never bind at the social optimum. Substituting for \( R = 1/\beta \), the optimality conditions for \( K_{t+1} \) and \( T_t \) are,
respectively, given by

\[
(1 - \pi) f'(K_{t+1}) + \pi x f'(xK_{t+1}) = (1 - \pi) \frac{1}{\beta} + \pi \frac{x}{\beta} \left( T_t - \frac{xK_{t+1}}{\beta} \right) \tag{17}
\]

\[
(1 - \pi) \nu'(T_t) + \pi \nu' \left( T_t - \frac{xK_{t+1}}{\beta} \right) = \frac{1}{\beta}. \tag{18}
\]

A more detailed derivation is presented in appendix A. Note that the first-order conditions in (17) and (18) for a given bailout policy are independent of the aggregate state variables. For a given bailout policy, \( x \), the optimal investment and transfer decisions in the centralized economy will therefore be constant over time. To simplify the exposition, we henceforth denote the social planner's policy functions for borrowed capital and the transfer as \( K_{SP}(x) \), and \( T_{SP}(x) \).

We now proceed to analyze the optimal bailout policy in the centralized model economy. Since the investment decisions and the optimal tax are state independent for a given bailout policy, the economy can be in one of two states only after the initial period. Depending on the realization of the random variable \( \zeta_t \), the economy is either in a crisis or in a period of no crisis. The stationary nature of the equilibrium considerably simplifies the recursive value functions. Letting superscripts \( n \) and \( cr \) denote consumption in periods of no crisis and crisis, respectively, the value function of the centralized economy in period \( t = 0 \) in equation (16) can be written as

\[
V_0^{SP}(S_0) = \max_{x \in [0,1]} \left\{ c_0(x) + v(T_{-1}) + \beta E_0 V^{SP}(x, S_1) \right\} \tag{19}
\]

where

\[
E_0 V^{SP}(x, S_1) = \frac{1}{1 - \beta} \left( (1 - \pi) \left[ c^n(x) + v(g^n(x)) \right] + \pi \left[ c^{cr}(x) + v(g^{cr}(x)) \right] \right)
\]

s.t. \[
\begin{align*}
c_0(x) &= \omega - T_{SP}(x) \\
c^n(x) &= f(K_{SP}(x)) + \omega - RK_{SP}(x) - T_{SP}(x) \\
g^n(x) &= T_{SP}(x) \\
c^{cr}(x) &= f(xK_{SP}(x)) + \omega - T_{SP}(x) \\
g^{cr}(x) &= T_{SP}(x) - xRK_{SP}(x),
\end{align*}
\]

where we have used the investment constraint in equation (15) to substitute for \( B_{SP}(x) \).

In the centralized economy, we can use the Envelope Theorem to find the optimal bailout policy since the policy rules \( K_{SP}(x) \) and \( T_{SP}(x) \) attain the social optimum for any given bailout policy, \( x \). Substituting for private and government consumption in the
value function, the derivative w.r.t. $x$ of the expected utility function in equation (19) is given by

$$\frac{d}{dx} \left\{ c_0(x) + v(T_{-1}) + \beta E_0 V^{SP}(x, S_1) \right\} =$$

$$\frac{\beta}{1-\beta} \pi K^{SP}(x) \left[ f'(x K^{SP}(x)) - \frac{1}{\beta} v' \left( T^{SP}(x) - \frac{x K^{SP}(x)}{\beta} \right) \right],$$

where we have used the equilibrium value of $R = 1/\beta$.

**Proposition 1** For any positive crisis probability, the optimal bailout policy in the centralized economy lies in the interior of the policy space and only partially protects investment against liquidation. Formally, $X^{SP}_c \subset (0,1)$. Furthermore, for any positive crisis probability, the social planner’s optimal bailout policy is unique.

**Proof.** See appendix B. ■

According to Proposition 1, the optimality condition for the bailout policy in the centralized economy can be written as

$$f'(x^{SP}_c K^{SP}(x^{SP}_c)) = \frac{1}{\beta} v' \left( T^{SP}(x^{SP}_c) - \frac{x^{SP}_c K^{SP}(x^{SP}_c)}{\beta} \right),$$

where $x^{SP}_c$ is the unique optimal bailout policy, and $K^{SP}(x^{SP}_c)$ and $T^{SP}(x^{SP}_c)$ are determined by the optimality conditions for borrowed capital and the transfer in equations (17) and (18). Equation (21) tells us that the optimal bailout policy in the centralized economy must trade off the benefit of bailouts against the cost they incur. The left hand side is associated with the benefit, i.e. that bailouts help to avoid inefficient liquidation of investment in crises. The right hand side of equation (21) is associated with the cost, i.e. that bailouts cause government consumption to fluctuate, since resources that are spent on bailouts cannot be used for government consumption.

Proposition 1 tells us that at $x = 0$, the benefit of reducing inefficient liquidation outweighs the cost of increased volatility in government consumption. At $x = 1$, the volatility of government consumption should instead be reduced at the expense of some inefficient liquidation.

The model also enables us to analyze how the optimal bailout policy varies across countries with different probabilities of experiencing a crisis. The social planner’s optimality conditions in equations (17), (18) and (21) implicitly define the optimal bailout policy, $x^{SP}_c$, as a function of the crisis probability, $\pi$.

**Proposition 2** For a higher probability of crisis, the social planner should optimally
commit to bailing out a larger fraction of the borrowed capital in the economy. Formally, for any $\pi_1$ and $\pi_2$, such that $\pi_1 < \pi_2$, it is the case that $x_{sp}^*(\pi_2) > x_{sp}^*(\pi_1)$.

**Proof.** See appendix B. •

The result in proposition 2 can be understood by jointly considering the three optimality conditions in equations (17), (18) and (21). We start by noting that in the social optimum, for any probability of crisis, the social planner always chooses the same level of borrowed capital, at which the marginal product of capital in periods of no crisis is equal to the world interest rate, $1/\beta$.\(^7\) Cost-benefit considerations for capital in crisis periods can be ignored, since in the social optimum, the levels of bailouts and transfers are chosen so that the marginal product of borrowed capital always equals its marginal cost in a crisis according to equation (21).

When there is an increase in the probability of a crisis, *ceteris paribus*, the social planner will, according to equation (18), need to transfer more resources to the public sector to guard against low government consumption in crisis periods. The social planner must further trade off the benefit of bailouts against their costs according to equation (21). For a higher level of public resources in a crisis, the social planner should optimally spend more resources on both the provision of public consumption and protection against liquidation. For a higher probability of crisis, the social planner therefore transfers more to the public sector and spends more resources on bailouts.\(^8\)

### 6 The government’s optimal bailout policy

The government’s value function in period $t = 0$, given by (10), can be written on exactly the same form as the social planner’s value function in equation (19). The only differences stem from the decision rules for borrowed capital and the government revenues entering the value function

$$V_0^G(S_0) = \max_{x \in [0, 1]} \{c_0(x) + v(T-1) + \beta E_0 V^G(x, S_1)\}$$

(22)

where

$$E_0 V^G(x, S_1) = \frac{1}{1 - \beta} \left( (1 - \pi) \left[ c^p(x) + v(g^p(x)) \right] + \pi \left[ c^c(x) + v(g^c(x)) \right] \right)$$

\(^7\)This can be seen by plugging equation (21) into equation (17) and evaluating at $x_{sp}^*$.\(^8\)Note that with the level of borrowed capital being constant, equation (21) implies that a higher value of $T$ must be associated with a higher value of $x_{sp}^*$.
The optimal bailout policy can be derived from the government value function in (22). The Envelope Theorem does not hold in the decentralized economy, since the consumer's decision rule for borrowed capital, \( k(x) \), is not socially optimal. In appendix A, we show that the derivative of the government's expected utility function in (22) w.r.t. \( x \) is given by

\[
\frac{d}{dx} \{ c_0(x) + v(T_{-1}) + \beta E_0 V^G(x, S_1) \} = \frac{\beta}{1 - \beta} \pi \left( k(x) \left[ f'(xk(x)) - \frac{1}{\beta} v' \left( T(x) - \frac{xk(x)}{\beta} \right) \right] + xk'(x)D(x) \right),
\]

where we have used the equilibrium value of \( R = 1/\beta \), and \( D(x) \) is defined as

\[
D(x) = P - \frac{1}{\beta} v' \left( T(x) - \frac{xk(x)}{\beta} \right).
\]

### 6.1 Optimally priced bailouts

Comparing the optimality conditions in the decentralized economy for borrowed capital and government revenues in equations (11) and (12) with the corresponding conditions in the social planner's solution in equations (17) and (18), the only difference is one term in the condition for borrowed capital. While the price of borrowed capital actually used in production for the atomistic consumers in crisis periods is \( P \), the social planner takes into account that loans through bailouts reduce government consumption in a crisis. If the price of bailouts, \( P \), is equal to

\[
P^* = \frac{1}{\beta} v' \left( T_{SP}(x^*_{SP}) - \frac{x^*_{SP}K_{SP}(x^*_{SP})}{\beta} \right),
\]

the optimality conditions for borrowed capital in equations (11) and (17) coincide for \( x = x^*_{SP} \), which implies that \( k(x^*_{SP}) = K_{SP}(x^*_{SP}) \) and \( T(x^*_{SP}) = T_{SP}(x^*_{SP}) \). When \( P = P^* \), the derivative of the expected utility w.r.t. \( x \) therefore coincides in the decentralized and centralized economies for \( x = x^*_{SP} \), which can be seen by comparing equations (23) and (20). The government's optimal bailout policy is to set \( x = x^*_{SP} \), which enables the government to achieve the social optimum since \( P^* \) is the price of bailouts that makes the
atomistic consumers internalize the costs associated with bailouts in the social optimum.

6.2 Suboptimally priced bailouts

For any positive probability of crisis, equation (18) implies that

$$v'(T_{SP}(x) - \frac{xh_{SP}(x)}{\beta}) > \frac{1}{\beta},$$

whenever $x > 0$. Given equation (25), we can therefore conclude that $P^* > 1/\beta$ for any positive probability of crisis. The price of bailouts associated with the social optimum is thus higher for individual consumers, for a loan with a maturity of less than a period, than the one-period world interest rate.

It is interesting to analyze economies where the price of bailouts is lower than $P^*$, since the available empirical evidence suggests that governments in emerging markets actually lose resources when trying to help the financial system in a crisis (Dziobek and Pazarbasioglu (1997), Kaminsky and Reinhart (1999) and Eichengreen and Rose (1997)).

If the price of bailouts is such that $P \leq 1/\beta$, the consumers will not internalize the full social costs of using risky borrowed capital in production. For any positive level of bailout guarantees, this will lead the consumers to choose a level of borrowed capital that is too high compared to the social optimum. This is formally stated in proposition 3.9

**Proposition 3** For a given positive probability of crisis and $P \leq 1/\beta$, $k(x) \geq h_{SP}(x)$, with equality iff $x = 0$.

**Proof.** See appendix B. ■

From the atomistic consumer’s perspective, a bailout guarantee at a price lower than $1/\beta$ increases the expected return on borrowed capital, without appropriately increasing the perceived cost of taking loans. Only for $x = 0$, i.e. a policy of No Bailout, do the investment allocations in the centralized and decentralized solutions coincide. This can easily be seen by comparing the consumer’s optimality condition for borrowed capital in equation (11) with the social first-order condition in equation (17).

A consequence of the distorted investment decisions of the individual consumer is that to optimally smooth government consumption for a given bailout policy $x$, the government must set the lump-sum tax so that government revenues are higher than in the centralized solution.

---

9We omit the analysis of the cases when $P$ lies between $1/\beta$ and $P^*$, in order to focus on prices of bailouts that are empirically relevant. For $1/\beta < P < P^*$, propositions 3 and 4 do not hold, but it is the case that $k(x^*_{SP}) > h_{SP}(x^*_{SP})$ and $T(x^*_{SP}) > T_{SP}(x^*_{SP})$. 

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Proposition 4 For a given positive probability of crisis and \( P \leq 1/\beta^2 \), \( T(x) \geq T_{SP}(x) \), with equality iff \( x = 0 \).

Proof. See appendix B. ■

The extreme case of suboptimally priced bailouts is a model economy where bailouts are provided free of charge, so that their price is \( P = 0 \). In such an environment, the level of borrowed capital will be monotonically increasing in the level of bailout guarantees, since for a higher level of bailouts, the consumer can keep a larger part of his borrowed capital in production during a crisis, without having to pay for it.

Proposition 5 For a given positive probability of crisis and \( P = 0 \), the optimal level of borrowed capital, \( k(x) \), and the optimal level of government revenues, \( T(x) \), are increasing in the level of bailout guarantees. Formally, \( k'(x) > 0 \) and \( T'(x) > 0 \).

Proof. See appendix B. ■

The result concerning government revenues in proposition 5 can be understood by considering that the government needs more resources if it is to pursue a higher level of bailouts. The fact that the individual consumer takes larger loans for a higher level of bailouts further increases the need for resources in order to smooth government consumption.

When the government is restricted to providing bailouts for free, the policy considerations differ from the case when bailouts are optimally priced. Free bailouts induce consumers to choose higher levels of borrowed capital, which aggravates the social cost of providing the bailout guarantees in the first place. However, Proposition 6 states that in such an environment, the government should still provide a positive level of bailout guarantees.

Proposition 6 For any positive crisis probability and \( P = 0 \), the government should optimally choose a bailout policy in the interior of the policy space, and should thereby only partially protect private investment against liquidation. Formally, \( X^* \subset (0,1) \). Furthermore, for any positive crisis probability, the government’s optimal bailout policy is unique.

Proof. See appendix B. ■

According to Proposition 6, the government should optimally set the derivative in equation (23) equal to zero, which implies that its optimality condition for the bailout policy can be written as

\[
f'(x^*k(x^*)) = \frac{1}{\beta} v' \left( T(x^*) - \frac{x^*k(x^*)}{\beta} \right) \left[ 1 + \frac{x^*k'(x^*)}{k(x^*)} \right],
\]  

(27)
where we have substituted for $P = 0$ and $D(x)$ in equation (23) and $x^*$ is the optimal bailout policy. The right-hand side of equation (27) captures the fact that the cost of bailouts is larger in the decentralized economy with free bailouts than in the centralized economy. Compared to the optimality condition in the centralized economy in equation (21), the right-hand side of equation (27) contains an additional cost term associated with the distortion of investment decisions. In addition to reducing government consumption as in the centralized economy, bailout guarantees induce the individual consumers to choose suboptimally high levels of borrowed capital, which aggravates the volatility of government consumption in the decentralized economy. The left-hand side of equation (27) shows that when bailouts are provided for free, their social benefit is the same as in the centralized economy, i.e. bailouts help avoiding inefficient liquidation in a crisis.

Proposition 6 tells us that, as in the centralized economy, the government chooses a bailout policy in between the extremes of No Bailout and Full Bailout, to optimally weigh the benefits against the costs of bailouts. Uniqueness of the optimal bailout policy is ascertained by the fact that the benefit on the left-hand side of equation (27) is decreasing in $x$, while the cost on the right-hand side increases with the bailout policy.

In an environment where bailouts must be provided for free, the government must choose a level of bailout guarantees addressing the problem of consumers’ overinvestment. The distorted investment incentives thus imply that the government’s optimal bailout policy must deviate from the bailout policy in the social optimum.

**Proposition 7** For any positive crisis probability, the optimal level of bailout guarantees is lower in the decentralized economy with $P = 0$ than in the centralized economy. Formally, $x^* < x_{sp}$.

**Proof.** See appendix B. ■

The reason for the result in Proposition 7 is that the cost associated with bailouts is higher in the decentralized economy, whereas the benefit of bailouts is the same as in the centralized economy. The distortion leads to larger fluctuations in government consumption for a given bailout policy. Since the marginal benefit of reducing inefficient liquidation decreases with the level of bailouts, the government must choose a lower bailout policy to make the benefit equal the cost.

Just as in the centralized economy, the model enables us to analyze how the optimal bailout policy varies across countries with different probabilities of experiencing a crisis. When bailouts are provided for free, the optimality condition in equation (27) implicitly defines the optimal bailout policy, $x^*$, as a function of the crisis probability, $\pi$, since the decision rules $k(x)$ and $T(x)$ depend on $\pi$.

**Proposition 8** For a higher probability of crisis and $P = 0$, the government should
optimally commit to bailing out a smaller fraction of the borrowed capital in the economy. Formally, for any $\pi_1$ and $\pi_2$ such that $\pi_1 < \pi_2$, it is the case that $x^*(\pi_1) > x^*(\pi_2)$.

Proof. See appendix B. ■

The result in proposition 8 stands in stark contrast to the centralized economy, where a higher probability of crisis implied a higher optimal level of bailouts. When bailouts are provided for free, the consumer chooses a higher level of borrowed capital when the probability of crisis is higher, for a given bailout policy $x$. From the atomistic consumer’s perspective, a higher probability of crisis increases the expected net return to borrowed capital, since it is more likely that he gets to keep part of the return of the investment, without having to pay for it. For a given bailout policy, a higher level of borrowed capital decreases the social benefit and increases the social cost of bailouts. For a higher probability of crisis, the government must therefore choose a lower level of bailout guarantees to make the benefit equal the cost.

7 Relaxing the commitment assumption in the model

The formal analysis and the policy conclusions of the paper would remain unchanged if in each period, the government were allowed to commit to a bailout policy for the subsequent period. In the centralized economy, the analysis and the results are robust to relaxing the commitment assumption altogether and allowing the social planner to reconsider the level of bailouts, once a crisis has occurred.

As noted in Section 5, the social planner’s problem can be formulated without bailout policies and policy functions for a given level of bailouts. In a centralized economy without the artificial assumption of commitment, the social planner would simply invest foreign capital in production until the marginal product equalled $1/\beta$, and transfer the optimal amount of resources to the public sector in the next period, knowing how much resources he would want to spend on productive capital and government consumption in the event of a crisis. In the actual event of a crisis in the next period, the social planner would not want to act differently than what he foresaw one period ago.

In the market economy, the government’s optimal bailout policy depends on the consumer’s policy function for the level of borrowed capital, which is state independent as noted in the discussion of equation (11). In each period, the government would therefore optimally choose the same level of bailout guarantees for the subsequent period. This level would be identical to the optimal bailout under commitment in period $t = 0$, since the relative magnitudes of the costs and benefits associated with bailouts would be unchanged. In such an environment, the equilibrium for period $t = 0$, which we
defined in Section 3, would be replaced by a definition of equilibrium under one-period commitment, which would be valid for any period $t$.

8 A numerical example

In this section, we present a numerical example to illustrate the model outcomes for the centralized economy and an economy where bailouts are provided for free. This example is not intended to reveal any new results on the optimal bailout policy, but rather to convey a sense of the relative magnitudes of the variables in the model for a reasonable parameterization. The graphs presented in figures 1 and 2 quantify the effects of bailouts that have so far only been analytically investigated in the paper.

We assume the utility function for government consumption to be $v(g) = \gamma \ln(g)$, where $\gamma$ represents the relative weight of government consumption in the consumers’ utility. As stated in Section 2, the production function is assumed to be of Cobb-Douglas form, $f(k) = Ak^\alpha$.

The parameter values used in the numerical example are presented in Table 1. We assume the length of a period to be one year. Using a standard value in the literature, we set $\beta = 0.95$, which implies a world interest rate of about 5 percent. Gollin (2002) shows the capital income share, $\alpha$, to roughly equal 1/3 for a large number of countries around the world. The TFP parameter, $A$, is normalized to unity.

The value for the domestic endowment, $\omega$, should ideally be obtained by matching the model’s ratio of borrowed capital to total output, $k/(Ak^\alpha + \omega)$, with the ratio of short-term foreign debt to GDP in the data. Rodrik and Velasco (1999) consider 16 episodes of financial crisis emerging markets between 1990 and 1998, and find that the average ratio of capital outflows to GDP was 0.09. Interpreting this observed ratio in terms of our model is problematic, however, since the level of borrowed capital in the model depends on the probability of a crisis, $\pi$, and the bailout policy, $x$. However, as shown in section 4, the level of borrowed capital in the model is independent of the bailout policy, if the crisis probability is zero, which might be the case for the largest economies in the industrialized world. Assuming the ratio of short-term foreign debt to GDP to be lower in these economies than in emerging markets, we set the ratio of short-term debt to GDP to 0.05,

$$\frac{k}{\omega + Ak^\alpha} = 0.05, \quad (28)$$

in a country where $\pi = 0$. This enables us to find a value of $\omega$, since when $\pi = 0$,

$$k = (A\beta \alpha)^{1/\alpha}, \quad (29)$$
According to equation (11),

The value for $\gamma$ is also chosen for a country where $\pi = 0$. In this case, the size of the equilibrium government revenues can be expressed as

$$T = \beta \gamma,$$

according to equation (12). The value of $\gamma$ is set so that the ratio of government revenues to total output in the model equals the average ratio of government spending to GDP in the G7 countries between 1990 and 1992. According to Rodrik (1998), the G7 average is 0.28, so that

$$\frac{T}{A k^\alpha + \omega} = 0.28,$$

and

$$\gamma = \frac{0.28}{\beta} (A k^\alpha + \omega).$$

When presenting the solutions to the model, we only consider crisis probabilities up to $1/2$, since it is hard to imagine countries for which the crisis probability would exceed $1/2$ for a prolonged period of time.

For a given probability of crisis, figure 1.a shows how the consumer’s optimal choice of borrowed capital varies with the level of bailout guarantees in the decentralized economy with free bailouts. In line with proposition 5, we see that the level of borrowed capital is increasing in the level of bailout guarantees. As stated in proposition 3, we also see that, for a given $\pi > 0$ and a given $x > 0$, the level of borrowed capital is higher than in figure 1.b, which presents the level of borrowed capital in the centralized economy. Interestingly, figure 1.b reveals that the social planner optimally decreases the level of foreign capital for higher levels of bailouts to reduce the social cost of taking loans.

Analogously, figure 1.c shows that in the decentralized economy, the optimal level of government revenues increases in the level of bailout guarantees for a given probability of crisis, which is in line with proposition 5. Comparing figures 1.c and 1.d, we also see that, for a given $\pi > 0$ and a given $x > 0$, the level of government revenues is higher in

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
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<tr>
<td>$P$</td>
<td>0</td>
<td>Price of bailouts in the decentralized economy</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.95</td>
<td>Discount factor</td>
</tr>
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<td>$\alpha$</td>
<td>$1/3$</td>
<td>Capital income share</td>
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<tr>
<td>$A$</td>
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<td>Productivity</td>
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<tr>
<td>$\omega$</td>
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<td>Domestic endowment of consumption goods</td>
</tr>
<tr>
<td>$\gamma$</td>
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<td>Relative weight of government consumption in utility</td>
</tr>
<tr>
<td>$\pi$</td>
<td>$[0, 1/2]$</td>
<td>Probability of crisis</td>
</tr>
</tbody>
</table>

Table 1: Parameter values used in the numerical example
the market economy than in the centralized economy.

For a given probability of crisis, figure 2.a shows the expected utility attained by the government by committing to different levels of bailout guarantees in the environment where bailouts must be provided for free. At least for higher levels of $\pi$, we can see that Proposition 6 holds, since the expected utility function reaches a unique maximum in the interior of the policy space. Single peakedness and interior solutions are harder to discern in figure 2.b, which shows the expected utility function in the centralized economy. However, figure 2.c numerically verifies proposition 1, by showing that for all crisis probabilities, the socially optimal bailout policy is indeed unique and interior in our numerical example. The same figure also illustrates propositions 2, 7 and 8. We see that the socially optimal bailout policy is increasing in the probability of crisis, that the optimal bailout policy in the decentralized economy is lower than in the social optimum for any positive crisis probability, and that the optimal bailout policy in the decentralized economy is decreasing in the probability of crisis. In figure 2.c, we cannot plot the optimal bailout policies for $\pi = 0$, since the bailout policy is irrelevant if crises never occur.

Finally, in figure 2.d, we compare the expected welfare attained in period $t = 0$ under the optimal bailout policy in the decentralized economy to the social optimum. We see that the value attainable to the government in the environment of free bailouts lies below the social optimum for positive probabilities of crisis, and that the economy is worse off for a higher probability of crisis.

For all crisis probabilities considered in the numerical example, private consumption is positive in the entire policy space.

9 Concluding remarks

The model presented in this paper provides a framework for analyzing the effects of bailout policies in a general equilibrium environment including both benefits and costs of bailouts. Considering both aspects of bailout guarantees, the model provides a beginning to bridging the gap between the two strands in the literature treating bailouts as a 'good' or a 'bad' policy.

We showed that committing to a partial bailout of borrowed capital is always socially optimal in the centralized economy. The extreme policy of No Bailout is inferior, since the benefit of reducing the inefficient liquidation associated with such a policy outweighs the cost of increased volatility in government consumption. Similarly, a policy of Full Bailout can be improved on by reducing the associated volatility of government consumption at the expense of some inefficient liquidation.

In the centralized economy, it was further shown that the social planner optimally
chooses a higher level of bailout guarantees and public sector revenues in countries with a higher probability of crisis. For a higher probability of crisis, the social planner provides more protection against inefficient liquidation and provides more resources to the public sector to guard against low government consumption in crisis periods, at the expense of private sector consumption.

In a decentralized economy, the conclusions of the model depend on the price of bailouts that the government charges the private sector. Empirical evidence indicates that the economically relevant price of bailouts in a decentralized economy is below the price associated with the social optimum in the model. With a sub-optimally low price of bailouts, the decentralized model economy exhibits higher levels of foreign borrowing than what is socially optimal, since the private sector can enjoy the benefits of foreign borrowing without paying its full social cost. In such an environment, bailout guarantees lead to overinvestment in the emerging market.

In the extreme case when bailouts must be provided for free, we showed that, analogously to the centralized economy, the government should commit to a bailout policy only partially protecting private investment against liquidation. The optimal level of bailout guarantees in such an environment will always be lower than in the social optimum, however. Due to the investment distortions induced by bailouts, a given bailout policy leads to larger fluctuations in government consumption in the decentralized economy. In equilibrium, the government must counter the higher cost of bailouts by choosing a lower level of bailout guarantees.

We also showed that, in contrast to the results for the centralized economy, the government optimally bails out a smaller fraction of private investments for a higher probability of crisis. When crises occur more frequently, the government finds it optimal to expose the private sector more to the negative effects of crises, to make the consumers internalize more of the social costs of foreign borrowing.

In this paper, we have restricted our analysis to the optimal bailout policy under commitment and an exogenous price of bailouts. If the government could choose the price of bailouts, the endogenous price would be $P^*$, which is the price of bailouts associated with the social optimum. In such a model, the optimal bailout policy would be time consistent. It would be an interesting topic for future research to investigate what the government should optimally do if it cannot commit nor control the price of bailouts. We believe that a version of our model incorporating a reputational mechanism for the government could provide an appropriate framework for starting to analyze the optimal credible bailout policy.
References


A Derivations of first-order conditions

A.1 Derivation of the consumer’s first-order condition with respect to \( k_{t+1} \)

Using the investment constraint in equation (4) to substitute for \( b_{t+1} \), the consumer’s budget constraint to substitute for \( c_t \), the form of the function \( \kappa(\cdot) \) and the fact that \( R = 1/\beta \), the value function in equation (9) can be written as

\[
V^C(x, h_t) = \max_{k_{t+1}} \left\{ f(\kappa_t) + \omega - (1 - \zeta_t) \frac{1}{\beta} b_t - \zeta_t P\kappa_t - Q_t + v(g_t) + \beta (1 - \pi) \left( f(k_{t+1}) + \omega - \frac{1}{\beta} k_{t+1} - Q(x, S_{t+1,0}) + v(g_{t+1,0}) + \beta E_{t+1} [V^C(x, h_{t+2})]_{\zeta_{t+1} = 0} \right) + \beta \pi \left( f(xk_{t+1}) + \omega - P\kappa_{t+1} - Q(x, S_{t+1,1}) + v(g_{t+1,1}) + \beta E_{t+1} [V^C(x, h_{t+2})]_{\zeta_{t+1} = 1} \right) \right\} \\
\text{s.t. } k_{t+1} \geq 0,
\]

where \( S_{t+1,0} = (K_{t+1}, B_{t+1}, T_t, 0), S_{t+1,1} = (K_{t+1}, B_{t+1}, T_t, 1), g_{t+1,0} = T_t \) and \( g_{t+1,1} = T_t - \frac{\xi}{\beta} B_{t+1}. \) The first-order condition of (33) with respect to \( k_{t+1} \) is given by equation (11).

A.2 Derivation of the government’s first-order condition with respect to \( T_t \)

Using equation (7), we recast the government’s problem in equation (10) as a maximization with respect to bailouts and government revenues. Using the fact that \( k_{t+1} = K_{t+1} \) and \( b_{t+1} = B_{t+1} \), the investment constraint in equation (4) enables us to substitute \( b_{t+1} \) and \( B_{t+1} \) with \( k(x) \). Employing the consumer’s optimal consumption rule, the government’s budget constraint and substituting for \( R = 1/\beta \), the government’s second value function in equation (10) can be written as

\[
V^G(x, S_t) = \max_{k_t} \left\{ f(\kappa(x, K_t, \zeta_t)) + \omega - (1 - \zeta_t) \frac{1}{\beta} B_t - T_t + v(g_t) + \beta (1 - \pi) \left( f(k(x)) + \omega - \frac{1}{\beta} k(x) - T_{t+1} + v(T_t) + \beta E_{t+1} [V^G(x, S_{t+2})]_{\zeta_{t+1} = 0} \right) + \beta \pi \left( f(xk(x)) + \omega - T_{t+1} + v \left( T_t - \frac{xk(x)}{\beta} \right) + \beta E_{t+1} [V^G(x, S_{t+2})]_{\zeta_{t+1} = 1} \right) \right\} \\
\text{s.t. } T_t - \frac{xk(x)}{\beta} \geq 0.
\]

The first-order condition of (34) with respect to \( T_t \) is given by equation (12).
A.3 Derivation of the Social Planner’s first-order conditions with respect to $K_{t+1}$ and $T_t$

Using the budget constraint for private and government consumption to substitute for $c_t$ and $g_t$, the investment constraint to substitute for $B_{t+1}$, the form of the function $\kappa(.)$ and the fact that $R = 1/\beta$, the social planner’s value function in equation (14) can be written as

$$V^{SP}(x, S_t) = \max_{\{K_{t+1}, \z_t\}} \left\{ f(\kappa(x, K_t, \z_t)) + \omega - (1 - \z_t) \frac{1}{\beta} B_t - T_t + v(g_t) \right\}$$

$(35)$

$$+ \beta(1 - \pi) \left( f(K_{t+1}) + \omega - \frac{1}{\beta} K_{t+1} - T_{t+1} + v(T_t) + \beta E_{t+1} [V^{SP}(x, S_{t+2})|\z_{t+1} = 0] \right)$$

$$+ \beta \pi \left( f(xK_{t+1}) + \omega - T_{t+1} + v \left( T_t - \frac{xK_{t+1}}{\beta} \right) + \beta E_{t+1} [V^{SP}(x, S_{t+2})|\z_{t+1} = 1] \right)$$

$s.t. \quad K_{t+1}, T_t - \frac{xK_{t+1}}{\beta} \geq 0.$

The first-order conditions of $(35)$ with respect to $K_{t+1}$ and $T_t$ are given by equations $(17)$ and $(18)$.

A.4 Derivation of the government’s first-order condition with respect to $x$

Using the Implicit Function Theorem, it can be shown that equations $(11)$ and $(12)$ implicitly define the policy functions $k(x)$ and $T(x)$ as continuously differentiable in $x$. This, in turn, implies that the government’s expected utility function in $(22)$ is continuously differentiable in $x$. Since $x$ must be an element of the compact set $[0, 1]$, we know by the Weierstrass Theorem that the government’s set of optimal bailout policies, $X^*$, is non-empty and compact.

Substituting for private and government consumption in $(22)$, and differentiating the government’s expected utility function w.r.t. $x$, we obtain

$$\frac{d}{dx} \left\{ c_0(x) + v(T_{-1}) + \beta E_0 V^G(x, S_1) \right\} =$$

$$-T'(x) + \frac{\beta(1 - \pi)}{1 - \beta} \left[ f'(k(x)) k'(x) - \frac{1}{\beta} k'(x) - T'(x) + v'(T(x))T'(x) \right]$$

$$+ \frac{\beta \pi}{1 - \beta} \left[ f'(xk(x)) \left[ k(x) + xk'(x) \right] - T'(x) \right]$$

$$+ \frac{\beta \pi}{1 - \beta} v' \left( T(x) - \frac{xk(x)}{\beta} \right) \left[ T'(x) - \frac{k(x)}{\beta} - \frac{xk'(x)}{\beta} \right].$$

$(36)$
Rearranging terms and adding and subtracting $\frac{\beta k'(x)}{1 - \beta} \pi Px$, we obtain

$$\frac{d}{dx} \left\{ c_0(x) + v(T_{-1}) + \beta E_0 V^G(x, S_1) \right\} =$$

$$\frac{\beta k'(x)}{1 - \beta} \left[ (1 - \pi) f'(k(x)) + \pi x f'(xk(x)) - \frac{(1 - \pi)}{\beta} - \pi Px + \pi P_x - \frac{\pi x}{\beta} v' \left( T(x) - \frac{xk(x)}{\beta} \right) \right]$$

$$+ \frac{\beta T'(x)}{1 - \beta} \left[ (1 - \pi) v'(T(x)) + \pi v' \left( T(x) - \frac{xk(x)}{\beta} \right) - \frac{1}{\beta} \right]$$

$$+ \frac{\beta \pi k(x)}{1 - \beta} \left[ f'(xk(x)) - \frac{1}{\beta} v' \left( T(x) - \frac{xk(x)}{\beta} \right) \right].$$

Now, $C_1(x) = 0$ by equation (11) and $C_2(x) = 0$ by equation (12), which implies that

$$\frac{d}{dx} \left\{ c_0(x) + v(T_{-1}) + \beta E_0 V^G(x, S_1) \right\} =$$

$$= \frac{\beta}{1 - \beta} \pi \left( k(x) \left[ f'(xk(x)) - \frac{1}{\beta} v' \left( T(x) - \frac{xk(x)}{\beta} \right) \right] + xk'(x)D(x) \right),$$

where $D(x)$ is defined as

$$D(x) = P - \frac{1}{\beta} v' \left( T(x) - \frac{xk(x)}{\beta} \right).$$

## B Proofs of propositions

### B.1 Proof of Proposition 1

Using the Implicit Function Theorem, it can be shown that equations (17) and (18) implicitly define the policy functions $K_{SP}(x)$ and $T_{SP}(x)$ as continuously differentiable in $x$. This, in turn, implies that the expected utility function in equation (19) is continuously differentiable in $x$.

The derivative of the expected utility function w.r.t. $x$ can be found by applying the Envelope Theorem, since the policy functions, $K_{SP}(x)$ and $T_{SP}(x)$, have been defined as the socially optimal choices for each given bailout policy $x$.

To see that a policy of No Bailout is never optimal in the social planner’s solution,
consider the limit of the derivative of the expected utility function in equation (20),

\[
\lim_{x \to 0} \left\{ \frac{\beta}{1-\beta} \pi K_{SP}(x) \left[ f'(xK_{SP}(x)) - \frac{1}{\beta} v'(T_{SP}(x) - \frac{xK_{SP}(x)}{\beta}) \right] \right\} = \frac{\beta}{1-\beta} \pi K_{SP}(0) \left[ f'(0) - \frac{1}{\beta} v'(T_{SP}(0)) \right].
\]

(39)

The limit value in equation (39) is clearly positive when \( \pi > 0 \), since \( K_{SP}(0) > 0 \), \( f'(0) = \infty \) and \( v'(T_{SP}(0)) = 1/\beta \) by equation (18). By continuity of the expected utility function, we can conclude that a policy of No Bailout is never optimal. Formally, \( 0 \notin X_{SP}^* \).

To see that a policy of Full Bailout is never optimal in the social planner's solution, consider the limit

\[
\lim_{x \to 0} \left\{ \frac{\beta}{1-\beta} \pi K_{SP}(x) \left[ f'(xK_{SP}(x)) - \frac{1}{\beta} v'(T_{SP}(x) - \frac{xK_{SP}(x)}{\beta}) \right] \right\} = \frac{\beta}{1-\beta} \pi K_{SP}(1) \left[ \frac{(1-\pi)}{\beta} - \frac{(1-\pi)}{\beta} v'(T_{SP}(1) - \frac{K_{SP}(1)}{\beta}) \right],
\]

(40)

where we have used the fact that

\[
f'(K_{SP}(1)) = (1-\pi)\frac{1}{\beta} + \pi v'(T_{SP}(1) - \frac{K_{SP}(1)}{\beta}) \frac{1}{\beta},
\]

(41)

according to equation (17). The derivative of the expected utility function in equation (20) is negative in the upper limit when \( \pi > 0 \), since by equation (18),

\[
v'(T_{SP}(x) - \frac{x}{\beta}K_{SP}(x)) \geq \frac{1}{\beta}.
\]

By continuity of the expected utility function, we can therefore conclude that a policy of Full Bailout is never optimal in the social planner's solution. Formally, \( 1 \notin X_{SP}^* \).

To prove that the social planner's optimal bailout policy is unique, first note that in equilibrium, the equilibrium values of \( K_{SP}(x), T_{SP}(x) \) and \( X_{SP}^* \) are determined by a system of the three following equations

\[
(1-\pi) f'(K_{SP}(x_{SP}^*)) + \pi x_{SP} f'(x_{SP}K_{SP}(x_{SP})) = (1-\pi)\frac{1}{\beta} + \pi x_{SP} v'(T_{SP}(x_{SP}) - \frac{x_{SP}K_{SP}(x_{SP})}{\beta}) \]

(42a)

\[
(1-\pi) v'(T_{SP}(x_{SP})) + \pi v'(T_{SP}(x_{SP}) - \frac{x_{SP}K_{SP}(x_{SP})}{\beta}) = \frac{1}{\beta}
\]

(42b)

\[
f'(x_{SP}K_{SP}(x_{SP})) = \frac{1}{\beta} v'(T_{SP}(x_{SP}) - \frac{x_{SP}K_{SP}(x_{SP})}{\beta}),
\]

(42c)
where equation (42c) holds because the optimal policy must be interior. Substituting (42c) into (42a) leads to

$$\pi x_{SP}^* f' \left( x_{SP}^* K_{SP} (x_{SP}^*) \right) = (1 - \pi) f' \left( K_{SP} (x_{SP}^*) \right) + \pi x_{SP}^* f' \left( x_{SP}^* K_{SP} (x_{SP}^*) \right) - (1 - \pi) \frac{1}{\beta},$$

which implies that

$$f' \left( K_{SP} (x_{SP}^*) \right) = \frac{1}{\beta} \quad \text{(43)}$$

$$K_{SP} (x_{SP}^*) = f'^{-1} \left( \frac{1}{\beta} \right).$$

Thus, in equilibrium, the social planner's optimal level of investments is constant. We denote it by $K_{SP}^*$.

Next, by expressing $T_{SP} (x_{SP})$ from (42c), we obtain

$$T_{SP} (x_{SP}^*) = w \left( \beta f' \left( x_{SP}^* K_{SP} \right) \right) + \frac{x_{SP}^* K_{SP}^*}{\beta}, \quad \text{(44)}$$

where $w = (v')^{-1}$ and $x_{SP}$ can then be determined from equation (42b). After substituting the expression for $T_{SP} (x_{SP}^*)$ into (42b) and rearranging it, we obtain

$$(1 - \pi) v' \left( w \left( \beta f' \left( x_{SP}^* K_{SP} \right) \right) + \frac{x_{SP}^* K_{SP}^*}{\beta} \right) = \frac{1}{\beta} - \pi \beta f' \left( x_{SP}^* K_{SP}^* \right). \quad \text{(45)}$$

For uniqueness of $x_{SP}^*$, it needs to be demonstrated that the right-hand side of (45) is increasing in $x$, while the left-hand side of (45) is decreasing in $x$. We have that

$$\frac{\partial}{\partial x} \left\{ \frac{1}{\beta} - \pi \beta f' \left( xK_{SP}^* \right) \right\} = -\pi \beta f'' \left( xK_{SP}^* \right) K_{SP}^*,$$

which is positive since $f''(.) < 0$, and

$$\frac{\partial}{\partial x} \left\{ (1 - \pi) v' \left( w \left( \beta f' \left( xK_{SP}^* \right) \right) + \frac{xK_{SP}^*}{\beta} \right) \right\} =$$

$$(1 - \pi) v'' \left( w \left( \beta f' \left( xK_{SP}^* \right) \right) + \frac{xK_{SP}^*}{\beta} \right) \left( w' \left( \beta f' \left( xK_{SP}^* \right) \right) \beta f'' \left( xK_{SP}^* \right) K_{SP}^* + \frac{K_{SP}^*}{\beta} \right),$$

which is negative, since $v''(.) < 0, w'(.) < 0$ and $f''(.) < 0$. ■
B.2 Proof of Proposition 2

According to equation (42b), the socially optimal bailout policy satisfies

\[
(1 - \pi) v'(T_{SP}(x_{SP}^*)) + \pi v'(T_{SP}(x_{SP}^*) - \frac{x_{SP}^* K_{SP}^*}{\beta}) = \frac{1}{\beta},
\]

where \( K_{SP}^* \) is given by (43) and \( T_{SP}(x_{SP}^*) \) is given by (44). Implicitly differentiating (46) w.r.t. \( \pi \), and rearranging, we obtain

\[
\frac{\partial x_{SP}^*}{\partial \pi} = \frac{v'(T_{SP}(x_{SP}^*)) - v'(T_{SP}(x_{SP}^*) - \frac{x_{SP}^* K_{SP}^*}{\beta})}{(1 - \pi) v''(T_{SP}(x_{SP}^*)) T'_{SP}(x_{SP}^*) + \pi v''(T_{SP}(x_{SP}^*) - \frac{x_{SP}^* K_{SP}^*}{\beta}) (T'_{SP}(x_{SP}^*) - \frac{K_{SP}^*}{\beta})}.
\]

Next, according to equation (44), the derivative of \( T_{SP}(x_{SP}^*) \) w.r.t. \( x_{SP} \) is

\[
T'_{SP}(x_{SP}^*) = \frac{K_{SP}^*}{\beta} + w'(\beta f'(x_{SP}^* K_{SP}^*)) \beta f''(x_{SP}^* K_{SP}^*) K_{SP}^*,
\]

which is positive, since \( w'(.) < 0 \) and \( f''(.) < 0 \). We conclude that \( \frac{\partial x_{SP}^*}{\partial \pi} \) \( > 0 \), since

\[
v'(T_{SP}(x_{SP}^*)) - v'(T_{SP}(x_{SP}^*) - \frac{x_{SP}^* K_{SP}^*}{\beta}) < 0,
\]

\( v''(.) < 0 \), \( T'_{SP}(x_{SP}^*) > 0 \) and since \( T'_{SP}(x_{SP}^*) - \frac{K_{SP}^*}{\beta} > 0 \), according to equation (48). \( \blacksquare \)

B.3 Proof of Proposition 3

For any given bailout policy, \( x \), and any given probability of crisis, \( \pi > 0 \), compare the first-order conditions for borrowed capital in the decentralized and centralized economies, respectively

\[
(1 - \pi) f'(k(x)) + \pi x f'(xk(x)) = (1 - \pi) \frac{1}{\beta} + \pi x P \tag{49}
\]
\[
(1 - \pi) f'(K_{SP}(x)) + \pi x f'(xK_{SP}(x)) = (1 - \pi) \frac{1}{\beta} + \pi x \frac{1}{\beta} v'\left(T_t - \frac{xK_{SP}(x)}{\beta}\right) \tag{50}
\]

For \( P \leq 1/\beta^2 \), the left-hand side of equation (49) must be smaller than the left-hand side of equation (50) if \( x > 0 \). This, together with the concavity of the production function, implies that \( k(x) \geq K_{SP}(x) \), with equality if and only if \( x = 0 \). \( \blacksquare \)
B.4 Proof of Proposition 4

For any given bailout policy, $x$, and any given probability of crisis, $\pi > 0$, compare the first-order conditions for the lump-sum tax in the decentralized and centralized economies, respectively

\[
(1 - \pi) v'(T(x)) + \pi v'(T(x) - \frac{xk(x)}{\beta}) = \frac{1}{\beta},
\]

\[
(1 - \pi) v'(T_{SP}(x)) + \pi v'(T_{SP}(x) - \frac{xK_{SP}(x)}{\beta}) = \frac{1}{\beta}.
\]

By Proposition 3, $k(x) \geq K_{SP}(x)$, when $P \leq 1/\beta^2$, with equality iff $x = 0$. Together with strict concavity of the utility function $v(.)$, this implies that $T(x) \geq T_{SP}(x)$, with equality if and only if $x = 0$.\]

B.5 Proof of Proposition 5

With $P = 0$, the optimality condition for investments in the decentralized economy in equation (11) becomes

\[
(1 - \pi) f'(k_{t+1}) + \pi x f'(xk_{t+1}) = (1 - \pi) \frac{1}{\beta}.
\]

Implicitly differentiating (53) w.r.t. $x$, and rearranging, we obtain

\[
k'(x) = -\frac{\pi \left[ f'(xk(x)) + xk(x)f''(xk(x)) \right]}{(1 - \pi)f''(k(x)) + x^2\pi f''(xk(x))},
\]

which is positive when $\pi > 0$, since $f''(.) < 0$ and $f'(i) + if''(i) > 0$ for any Cobb-Douglas production function.

Implicitly differentiating the first-order condition in equation (12) w.r.t. $x$, and rearranging, we obtain

\[
T'(x) = \frac{\pi v''(T(x) - \frac{x}{\beta}k(x)) \left[ k(x) + xk'(x) \right]}{\beta \left[ (1 - \pi)v''(T(x)) + \pi v''(T(x) - \frac{x}{\beta}k(x)) \right]},
\]

which is positive when $\pi > 0$, since $v''(.) < 0$ and $k'(x) > 0$ according to equation (54).
B.6 Proof of Proposition 6

To see that the government never finds it optimal to choose a policy of No Bailout, consider the limit of (23) when $P = 0$ and $x$ approaches zero,

$$\lim_{x \to 0} \left\{ \frac{\beta}{1-\beta} \pi \left( k(x) \left[ f'(xk(x)) - \frac{1}{\beta} v'(T(x) - \frac{xk(x)}{\beta}) \right] + xk'(x)D(x) \right) \right\} = \frac{\beta}{1-\beta} \pi k(0) \left[ f'(0) - \frac{1}{\beta} v'(T(0)) \right].$$

(56)

The limit value in equation (56) is clearly positive when $\pi > 0$, since $k(0) > 0$, $f'(0) = \infty$ and $v'(T(0)) = 1/\beta$ by equation (12). By continuity of the objective function, we can conclude that the government never finds a policy of No Bailout optimal. Formally, $0 \not\in X^*$. 

To see that the government never finds it optimal to choose a policy of Full Bailout when $P = 0$, consider the limit

$$\lim_{x \to 1} \left\{ \frac{\beta}{1-\beta} \pi \left( k(x) \left[ f'(xk(x)) - \frac{1}{\beta} v'(T(x) - \frac{xk(x)}{\beta}) \right] + xk'(x)D(x) \right) \right\} = \frac{\beta}{1-\beta} \pi \left( k(1) \left[ (1-\pi)\frac{1}{\beta} - \frac{1}{\beta} v'\left(T(1) - \frac{k(1)}{\beta}\right) \right] - k'(1)v'\left(T(1) - \frac{k(1)}{\beta}\right) \frac{1}{\beta} \right),$$

(57)

where we have used the fact that $f'(k(1)) = (1-\pi)/\beta$ according to equation (11) when $P = 0$. The derivative of the expected utility function is negative in the upper limit when $\pi > 0$, since $k'(.) > 0$ according to proposition 5, $v'(.) > 0$ and since, by equation (12),

$$v'\left(T(x) - \frac{x}{\beta} k(x)\right) \geq \frac{1}{\beta}.$$

By continuity of the objective function, we can therefore conclude that the government never finds a policy of Full Bailout optimal. Formally, $1 \not\in X^*$. 

The fact that the optimal bailout policy must lie in the interior of the policy space implies that any optimal bailout policy satisfies

$$f'(x^*k(x^*)) = \frac{1}{\beta} v'\left(T(x^*) - \frac{x^*k(x^*)}{\beta}\right) \left[ 1 + \frac{x^*k'(x^*)}{k(x^*)} \right],$$

(58)

where we have substituted $P = 0$ into equation (23) and rearranged under the condition that the derivative w.r.t. $x$ equals zero. 

To prove that the optimal bailout policy is unique, we now proceed to show that the left-hand side of equation (58) is a decreasing function of $x$, and that the right-hand side is an increasing function of $x$. 

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The derivative of the left-hand side of equation (58) is

\[
\frac{d}{dx} \left\{ f'(xk(x)) \right\} = f''(xk(x)) \left[ k(x) + xk'(x) \right],
\]

which is negative, since \( f''(.) < 0 \) and \( k'(x) > 0 \) according to equation (54).

Let \( p(x) \) denote the second factor on the right-hand side of equation (58). The derivative of \( p(x) \) is

\[
p'(x) = \frac{d}{dx} \left\{ \frac{v'(T(x) - \frac{xk(x)}{\beta})}{T'(x) - \frac{k(x) - \frac{xk'(x)}{\beta}}{\beta}} \right\},
\]

which is positive, since \( v''(.) \) is negative and since

\[
T'(x) < \frac{1}{\beta} \left[ k(x) + xk'(x) \right],
\]

according to equation (55).

For any production function of the form \( f(k) = A k^\alpha, \) \( \alpha < 1, \) the optimality condition in equation (53) implies that the consumer's policy function for borrowed capital is

\[
k(x) = \left[ \frac{A \alpha \beta}{(1 - \pi)} \right]^{1/\alpha} \left[ 1 - \pi + \pi x^\alpha \right]^{1/\alpha},
\]

in an environment where \( P = 0. \) This, in turn, implies that the third factor on the right-hand side of equation (58), which we denote \( q(x), \) can be written as

\[
q(x) = 1 + \frac{xk'(x)}{k(x)}
\]

\[
= 1 + \frac{\alpha}{1 - \alpha} \left[ 1 - \pi + \pi x^\alpha \right]^{-1} \pi x^\alpha.
\]

The derivative of \( q(x) \) is

\[
q'(x) = \frac{\alpha^2 \pi (1 - \pi) x^{\alpha-1}}{(1 - \alpha) (1 - \pi + \pi x^\alpha)^2},
\]

which is positive.

The derivative of the right-hand side of equation (58) can now be expressed as

\[
\frac{d}{dx} \left\{ \frac{1}{\beta} p(x)q(x) \right\} = \frac{1}{\beta} \left[ p'(x)q(x) + p(x)q'(x) \right],
\]

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which is positive, since \( p'(x) > 0, \) \( q'(x) > 0 \) and \( v'(\cdot) > 0. \)

**B.7 Proof of Proposition 7**

To construct the proof, we start by noting that in both the decentralized and the cen­
tralized economies, the equilibrium level of resources transferred from the private to
the public sector can be written as a function of the optimal level of borrowed capital.
According to the first-order conditions in equations (12) and (18), \( T(x) = j(k(x)) \) and
\( T_{SP}(x) = j(K_{SP}(x)). \) For a given \( x, \) the partial derivative of \( j(\cdot) \) w.r.t. \( k \) is given by

\[
\frac{\partial j(k)}{\partial k} = \frac{x v'' \left( j(k) - \frac{xk}{\beta} \right)}{\beta \left( 1 - \pi \right) v'' \left( j(k) \right) + \pi v'' \left( j(k) - \frac{xk}{\beta} \right)}.
\]

(66)

Now, consider the bailout policy \( x_{SP}, \) which according to Proposition 1 must be such
that

\[
f' \left( x_{SP} K_{SP}(x_{SP}) \right) - \frac{1}{\beta} v' \left( T_{SP}(x_{SP}) - \frac{x_{SP} K_{SP}(x_{SP})}{\beta} \right) = 0.
\]

(67)

Using the fact that when \( P = 0 \) and \( \pi > 0, \) by Proposition 4, \( k(x) > K_{SP}(x) \) for \( x > 0, \)
we next proceed to show that evaluated at any such bailout policy \( x_{SP}, \) the derivative
of the government’s expected utility function in (23) is negative, i.e. that

\[
k(x) \left[ f' \left( x k(x) \right) - \frac{1}{\beta} v' \left( T(x) - \frac{x k(x)}{\beta} \right) \right] + x k'(x) \left[ P - \frac{1}{\beta} v' \left( T(x) - \frac{x k(x)}{\beta} \right) \right] < 0,
\]

(68)

for \( x = x_{SP}. \)

Notice that, when \( P = 0, \) the last term on the left-hand side in inequality (68) is
negative, since \( k'(x) > 0 \) according to proposition 5 and since \( v'(\cdot) > 0. \) The derivative
of the government’s expected utility function will therefore be negative whenever the
term in the first square brackets in (68) is negative.

Let this term be denoted by \( Z, \) so that

\[
Z(k(x)) = f' \left( x k(x) \right) - \frac{1}{\beta} v' \left( j(k(x)) - \frac{x k(x)}{\beta} \right).
\]

(69)

For a given \( x, \) the partial derivative of \( Z(\cdot) \) w.r.t. \( k \) is given by

\[
\frac{\partial Z(k)}{\partial k} = f''(x k) x - \frac{1}{\beta} v'' \left( j(k) - \frac{x k}{\beta} \right) \left( \frac{\partial j(k)}{\partial k} - \frac{x}{\beta} \right),
\]

(70)
which is negative, since $f''(.) < 0$, $v''(.) < 0$ and since, by equation (66), \[ \frac{\partial j(k)}{\partial k} < \frac{x}{\beta}. \]

Since $Z(K_{SP}(x_{SP}^*)) = 0$ and $k(x_{SP}^*) > K_{SP}(x_{SP}^*)$, the fact that the partial derivative of $Z(.)$ w.r.t. $k$ is negative enables us to conclude that $Z(k(x_{SP}^*)) < 0$ and hence, that the derivative of the government’s expected utility function is negative at $x_{SP}^*$.

The fact that the government’s expected utility function is continuously differentiable and has a positive slope as $x$ approaches zero, together with the result that there is a unique bailout policy which satisfies the first-order condition in equation (27), allow us to conclude that it must be the case that $x^* < x_{SP}^*$.

**B.8 Proof of Proposition 8**

We start by showing that for a given bailout policy $x$ and $P = 0$, the level of borrowed capital, $k(x)$, is an increasing function of $\pi$. For a given bailout policy, the partial derivative of $k(x)$ w.r.t. to $\pi$ is given by
\[
\frac{\partial k(x)}{\partial \pi} = \frac{\partial}{\partial \pi} \left\{ \left[ \frac{A\alpha \beta}{(1 - \pi)} \right]^{\frac{1}{1 - \alpha}} \left[ (1 - \pi) + \pi x^\alpha \right]^{\frac{1}{1 - \alpha}} \right\}
\]
which is positive.

To complete the proof, we next show that for a given bailout policy, the left-hand side of equation (58) is a decreasing function of $\pi$ and the right-hand side is an increasing function of $\pi$.

For a given bailout policy $x$, the partial derivative of the left-hand side of equation (58) w.r.t. $\pi$ is given by
\[
\frac{\partial}{\partial \pi} \left\{ f'(xk(x)) \right\} = f''(xk(x))x \frac{\partial k(x)}{\partial \pi},
\]
which is negative, since $f''(.) < 0$. Put differently, the social benefit associated with a given bailout level shifts downwards for a higher $\pi$.

For a given bailout policy $x$, the partial derivative of the right-hand side of equation (58) w.r.t. $\pi$ is given by
\[
\frac{\partial}{\partial \pi} \left\{ \frac{1}{\beta} p(x)q(x) \right\} = \frac{1}{\beta} \left[ \frac{\partial p(x)}{\partial \pi} q(x) + p(x) \frac{\partial q(x)}{\partial \pi} \right],
\]
which is positive, since $f''(.) < 0$. Put differently, the social benefit associated with a given bailout level shifts downwards for a higher $\pi$. 

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where \( p(x) \) and \( q(x) \) were defined in equations (60) and (63), respectively. To see that the derivative in equation (73) is positive, first consider

\[
\frac{\partial p(x)}{\partial \pi} = v'' \left( T(x) - \frac{xk(x)}{\beta} \right) \left[ \frac{\partial j(k)}{\partial k} - \frac{x}{\beta} \right] \frac{\partial k(x)}{\partial \pi},
\]  

which is positive, since \( v''(.) < 0 \) and since, by equation (66),

\[
\frac{\partial j(k)}{\partial k} < \frac{x}{\beta}.
\]

Second, consider the partial derivative of \( q(x) \) w.r.t. \( \pi \),

\[
\frac{\partial q(x)}{\partial \pi} = \frac{\alpha x^\alpha}{(1 - \alpha)} [(1 - \pi) + \pi x^\alpha]^{-2},
\]

which is also positive. Put differently, the social cost associated with a given bailout level shifts upwards for a higher \( \pi \).

The fact that for a given bailout policy, \( x \), the benefit of bailouts becomes lower and the cost becomes higher when \( \pi \) increases, implies that the government must choose a lower level of bailout guarantees for a higher probability of crisis. As shown in the proof of Proposition 6, the reason is that for a given probability of crisis, a lower level of bailout guarantees increases the marginal benefit and reduces the marginal cost of bailouts. Formally, we have shown that for any \( \pi_1 \) and \( \pi_2 \) such that \( \pi_1 < \pi_2 \), it is the case that \( x^*(\pi_1) > x^*(\pi_2) \).
Figure 1: The optimal decision rules for the level of borrowed capital and government revenues in the decentralized and centralized economies.
Figure 2: Expected utility functions, optimal bailout policies and expected welfare in the decentralized and centralized economies
Economic Growth and Sectoral Adjustments in Central and Eastern European Countries*

Abstract

Since the reforms in the early 1990s, Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Slovakia and Slovenia have experienced economic booms. This paper first summarizes the empirical regularities for the key aggregate real sector variables in the eight countries: GDP, consumption, investment, employment, real exchange rate, real wage, external balance as well as employment and economic activity in traded and nontraded sectors. We then develop and calibrate a two-sector DGE small open economy model and show that it can account for most of the economic adjustments in early post-reform years. Empirical studies have found rapid traded sector productivity growth in Central and Eastern European countries over the last decade. When traded sector productivity growth is added to the model, it captures the development in all key real sector variables during the post-reform period.

JEL classification: F41

Keywords: EU accession countries; non-traded goods; dynamic general equilibrium

*I am grateful to Lars Ljungqvist, Tim Kehoe, Martin Flodén, Juan Carlos Conesa, Gabriel Fagan and Víctor Ríos-Rull for their helpful advice and comments, and to Kristian Jönsson for insightful discussions. I have also benefited from discussions with seminar participants at the European Central Bank, Stockholm School of Economics and the 2004 BeMAD workshop in Malaga. This project was initiated during my visit to the Research Directorate of the ECB, as part of the Graduate Research Program. Hospitality of the institution as well as financial support from Jan Wallander and Tom Hedelius Foundation are gratefully acknowledged.
1 Introduction

Since the reforms in the early 1990s, real sector developments in the eight EU accession countries from Central and Eastern Europe show remarkable similarities. During the first ten years after the reforms, Czech Republic, Hungary, Estonia, Latvia, Lithuania, Poland, Slovakia and Slovenia have all experienced a boom in economic activity, accompanied by a sharp increase in unemployment, negative external balances, persistent real exchange rate appreciation and rapidly increasing real wages. There is also a notable shift in economic activity and employment from the traded to the non-traded sector of the economy.

This paper first summarizes the empirical regularities for the key real sector variables in the Central and Eastern European countries (CEE). Data are now available for each of the countries, at least for the first ten years after the reforms.

We then develop a model that can potentially account for the real sector developments. The model used is a dynamic general equilibrium small open economy (DGE-SOE) model with a traded and a nontraded sector. Important ingredients of the model are: (i) adjustment costs for capital as well as labor, (ii) habit forming consumers, (iii) elastic labor supply, and (iv) an investment production sector requiring traded and nontraded goods as inputs.

The model is then calibrated and simulations of the model economy are compared with the aggregate real sector data. Model simulations assume a closed economy which, after the implementation of reforms, opens up to capital and trade flows with the rest of the world and the EU in particular. When opening, the model economy is capital poor and exhibits a suboptimally high level of economic activity in the traded sector (i.e., over-industrialized). We start with a baseline simulation where a pre-reform level of productivity is used and any subsequent changes in productivity are ruled out. In later simulations, productivity growth is added to the model. Emphasis is put on quantitative rather than mere qualitative comparisons of the model outcomes and the data.

The contribution of this paper can be presented from two different perspectives. First, the modeling of real sector developments in the CEE can help us better understand the developments during the first ten years after the reforms and evaluate the ongoing convergence process between the CEE and the EU. Second, this paper can be viewed as a test of the DGE-SOE model on a new set of data. With their economic exclusion from the rest of the developed world before 1990 and the rapid reforms that followed, the CEE provide eight unique experiments allowing us to test the model.

The results of the simulations show that the baseline model can capture the economic adjustments in the CEE in the initial years after the reforms. However, to account for the development during the whole ten-year period, productivity growth needs to be
added to the model.

We use existing empirical studies to quantify the observed productivity growth in the CEEC and introduce it in the baseline calibration in two distinct ways: (i) as a deterministic sequence of increasing productivity levels and (ii) as annual positive productivity shocks. The results show that the model can better capture the data when productivity growth is unpredicted. In this case, the model can account for the development in all key real sector variables, except the very high investment growth rates.

The results of the model simulations cast doubt on the usefulness of sectoral composition of the economy as an indicator of real convergence between the CEEC and the EU. It is shown that there is a considerable overshooting in the size of the nontraded sector during the transition period, when compared to the steady state. This is the case for both economic activity and employment. The model also provides an estimate for the link between future productivity growth and external sector imbalances in the CEEC.

The rest of the paper is organized as follows. In Section 2, we present the empirical regularities for the key aggregate real sector variables in the CEEC. The theoretical model is presented in Section 3. In Section 4, we calibrate the model parameters and the initial conditions to the CEEC data. Section 5 presents the simulation results for the baseline model. Next, in Section 6, we introduce productivity growth in the model and present the simulation results of the ‘productivity enhanced’ version of the model. Finally, Section 7 concludes and gives suggestions for future research.

2 Reforms and Development in the Real Sector

After the collapse of socialism in Eastern Europe, the CEEC entered a phase of rapid transition. Governments in all sample countries introduced extensive reform packages, where the most important components were (i) trade and capital flow liberalization, (ii) price liberalization, (iii) extensive privatization, and (iv) exchange rate based stabilization programs. In a short period, the CEEC were transformed from planned into market economies. The heavy restrictions imposed by the socialist governments on the interaction between the CEEC and the developed Western economies as well as the scope of the reforms that were implemented after the collapse allow us to model the CEEC as closed economies that open to the rest of the world after reforms.

To compare the data with the model outcomes, we first need to date the reforms in each CEEC. The extensive scale of the reforms inevitably implies that it was a continuous process, which took years to implement. However, to avoid dealing with gradual reforms in the model, we will assign reforms to the most important reform year in each country. In doing so, we follow Fischer et al. (1996), who date reforms in each of the transition economies. Reform years for the CEEC are presented in Table 1.
Next, we look at the key aggregate real sector variables for each of the CEEC. Unless noted otherwise, data were obtained from National Statistical Offices.¹

(i) **GDP** volume index for each of the eight countries is presented in Figure 1. Year T denotes the year of reforms as identified in Table 1. The thick line in the figure represents the average GDP volume index, calculated using the average growth rate for the eight countries in each post reform year. In the average GDP volume index, all countries are given the same weight (average trends in the other figures are calculated in the same way). After the 0-2 years of initial fall, GDP exhibits strong growth, with an average rate of 4.1 percent. The rapid growth is reversed only during the episodes of the 1997 crisis in the Czech Republic and the spillover of the Russian Crisis to the Baltic states. However, these crises are short lived and within 1-2 years, rapid growth resumes.

(ii) Data for components of the GDP – consumption and investments – were obtained from national accounts at constant prices. Figure 2 shows that private consumption also exhibits strong growth at around 4 percent a year. Apart from a few exceptional years, growth rates are similar across countries. Note that, in contrast to the GDP, the average consumption volume grows already in the first year after reforms.²

(iii) Volume index for investments is taken from data for gross fixed capital formation. It is considerably more volatile than GDP or consumption.³ Nevertheless, the growth trend is once more present in the data (see Figure 3). After stagnation during the initial two years, the investment volume shows rapid growth from T+3 and onwards in all countries. Similar to output and consumption data, there are several short country-specific episodes with negative investment growth rates, which can be attributed to particular crises.

(iv) **Employment** index also exhibits the same trend across the CEEC and is depicted in Figure 4. In the initial years after reforms, there is a sharp decrease and from T+3 onwards, employment remains at a relatively constant level.⁴ In general, data on hours worked would be more appropriate to compare with the model

¹The obtained data was cross-checked with data from IMF International Financial Statistics database and EBRD Transition Reports. No notable deviations between the different data were found.
²We did not include government in the consumption data, since the model with which the data will be compared does not include a government sector. Adding government consumption does not change the empirical findings. In this case, the average yearly consumption growth rate in the CEEC decreases by a mere 0.4 percent.
³Data for gross fixed capital formation was preferred over data for gross capital formation, since the latter also includes changes in inventories, which can contain both consumption goods and investments.
⁴Data for total as well as traded and nontraded sector employment was obtained from ILO Yearbook of Labor Statistics.
outcomes. However, such data for the CEEC are available only starting with 1998-2000, depending on the country. Another alternative to the employment index would be to use unemployment rates. In this case, the outcomes are similar to what can be observed in Figure 4.

(v) Data for employment in traded and non-traded sectors show that the decrease in employment in the CEEC can be attributed almost entirely to the traded sector, which throughout the paper is defined as industry (excluding construction) and agriculture (see Figure 5). All other sectors are defined as non-traded. In the traded sector, each of the sample countries has experienced a large and persistent contraction, so that by T+10, the average traded sector employment stood at 67 percent of the pre-reform level. In contrast, nontraded sector employment between T and T+10 increased in each of the sample countries, with an average increase of 7 percent. Thus, despite the sharp fall in the overall employment index, employment in the nontraded sector has absorbed some of the losses in the traded sector. The differences in the employment indices in the two sectors are evident from Figure 5.

(vi) In line with the sectoral employment indices, economic activity in the traded sector, as a fraction of total economic activity, is also decreasing in all CEEC (see Figure 6). The size of industry has, on average, decreased by 20 percent over the 10 years, with a pronounced downward trend during the first 7 years. The decreasing trend for agriculture is even stronger, at around 50 percent over the 10 years, and there is no indication of a slowdown in the trend.

(vii) Trade balances, depicted in Figure 7, gradually decreased after the reforms and, with the exception of Poland, were negative in all CEEC by T+5. The decreasing trend continues until T+6, reaching an average of -7 percent of GDP. Thereafter, the balances have shown slight improvement. The same trends are present in other measures of external balance, e.g. current account.

(viii) To make the data comparable with the model outcomes, real wages are expressed in terms of traded goods by deflating nominal wages with the price index for traded goods, which is captured by the producer price index. The resulting data are presented in Figure 8. Real wages have steadily increased by around 8 percent a year throughout the post reform years.5

(ix) To obtain a real exchange rate, which can be compared with the model outcomes, the solid line in Figure 9 depicts the real exchange rate between each of the CEEC

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5Lithuania is omitted from the figure, since no comparable data were available.
and Germany from the reform year onwards (a decrease represents appreciation). Exchange rates are obtained using the standard formula

$$RER_t = S_t \frac{P_t^G}{P_t^{AC}},$$

where consumer prices (CPI) are used to capture the price indices, $P_t^G$ and $P_t^{AC}$, and $S_t$ is the nominal exchange rate between the two countries. Superscript $G$ stands for Germany and $AC$ stands for an accession country. This exchange rate can be decomposed into an external component, which captures deviations from PPP for traded goods, and an internal component, which captures the relative change in the price of nontraded goods in terms of traded goods in each of the countries. We write the decomposition as

$$RER_t = RER_t^{ext} * RER_t^{int},$$

$$rer_t = rer_t^{ext} + rer_t^{int},$$

where the last line is in logarithmic form. Producer prices (PPI) are used to capture the traded price indices, $P_t^G$ and $P_t^{AC}$, in each of the countries. The same Figure 9 also depicts the decomposed real exchange rate, with the dashed line representing the internal component and the difference between the solid and the dashed line representing the external component. Since our model will assume PPP to hold in the traded sector, the best we can hope for in terms of the real exchange rate is that the model will account for the persistent appreciation in the internal component of the real exchange rate, $rer_t^{int}$. In the subsequent sections, only $rer_t^{int}$ will be compared to the model outcomes. For this purpose, Figure 10 depicts the internal component of the real exchange rate for each of the CEEC. While there are very large differences in the extent of appreciation for the real exchange rate (e.g. the appreciation in Lithuania is 10(!) time larger than the appreciation in Slovenia), the extent of appreciation for the internal component of the real exchange rate is similar across the CEEC.

It should be noted that the CEEC are not exclusive in terms of the empirical regularities presented in this section. Similar trends for key macroeconomic variables have been found after stabilization programs in other countries around the world (see Rebelo and Vegh (1995), Calvo and Vegh (1999)).

In the next section, we present the model, which will then be calibrated using the CEEC data. In general, we could calibrate the model to each of the CEEC and thus,
let the model explain separately the real sector developments in each of the countries. However, there are several reasons why it is at least equally interesting to test the model by comparing the model outcomes with the average trends for each of the real sector variables. First, by taking the average trends, country-specific volatility is avoided (e.g. crises, data quality problems), which the model cannot be expected to capture. Second, all eight countries exhibit the same trends for each variable of interest. Thus, the qualitative story for the real sector development is the same in all CEEC. Figure 11 presents a summary of the trends for all real sector variables. The model presented in the next section will be tested against this data.

3 The Model

We model the CEEC as a small open economy inhabited by a representative consumer. There are five goods: traded good, non-traded good, capital, labor and investment good. The representative consumer maximizes the infinite horizon utility function which contains consumption, $c_t$, and leisure, $1 - l_t$

$$
\max_{\{c_t, c_{Nt}, k_{t+1}, b_{t+1}, l_t\}} \sum_{t=0}^{\infty} \beta^t \left[ (c_t - \nu c_{t-1}) (1 - l_t)^{1-\rho} \right]^{1-\rho} - 1
$$

subject to the following per-period budget constraint

$$
c_{Tt} + p_{Nt} c_{Nt} + q_{t+1} k_{t+1} + b_{t+1} \leq w_t l_t + (1 + r_t) b_t + h_t k_t,
$$

where

$$
c_t = c_{Tt} c_{Nt}^{1-\xi}, \quad \rho > 0, \quad \xi > 0, \quad \nu \in [0, 1),
$$

The initial conditions $k_0, b_0, c_{-1}$ are given.

Total time endowment is normalized to unity. In this formulation of the consumer problem, $\rho$ governs the consumer’s relative risk-aversion. Since there is no uncertainty in the model, $\rho$ can be interpreted as consumer’s willingness to shift consumption and leisure between different periods. $\xi$ is the preference parameter for leisure, $\beta$ is the subjective discount rate and $\nu$ is the habit formation parameter. Consumption in each period is composed of traded and nontraded goods, $c_{Tt}$ and $c_{Nt}$, with a unitary elasticity of substitution between the two components. $\varepsilon$ then represents the share of traded consumption in total consumption expenditures in each period. The price of traded
good is the numeraire. \( p_{NT} \) is the price of nontraded goods and \( w_t \) is the wage. In addition to investments in foreign assets, \( b_{t+1} \), which are denominated in traded goods and earn interest \( r_{t+1} \), consumers can invest in physical capital, \( k_{Tt+1} \). \( q_{t+1} \) is the price of investment goods and \( h_t \) the price of capital.

Physical capital is used in the traded or nontraded sector, \( k_t = k_{Tt} + k_{Nt} \), and in each sector evolves according to

\[
    k_{jt+1} = \Phi \left( \frac{i_{jt}}{k_{jt}} \right) k_{jt} + (1 - \delta) k_{jt}, \quad j = \{T, N\}, \tag{6}
\]

where \( i_{jt} \) represents new investments. We assume the following functional form for the adjustment costs

\[
    \Phi \left( \frac{i_{jt}}{k_{jt}} \right) = \frac{\delta^{1-\eta} \left( \frac{i_{jt}}{k_{jt}} \right)^{\eta} - (1 - \eta)\delta}{\eta}, \tag{7}
\]

\( \eta \in (0, 1] \), \( \Phi(\delta) = \delta \), \( \Phi'(\delta) = 1 \), \( \Phi''(\delta) < 0 \).

This functional form is borrowed from Fernandez de Cordoba and Kehoe (2000). Adjustment costs for capital in each sector satisfy the conditions defined in Uzawa (1969) and Lucas and Prescott (1971). When the adjustment cost parameter is \( \eta = 1 \), the model reduces to the case of no adjustment costs.

This model allows for two alternative interest rate specifications. If the economy is closed, then the foreign asset position is zero, \( b_{t+1} = 0 \), and the interest rate is endogenously determined. If the economy is open, the interest rate is equal to the world interest rate, \( r_t = r^* \), and the foreign asset position is endogenously determined. Note that if the economy is open, the arbitrage condition for investments at home and abroad holds in equilibrium

\[
    h_{t+1} = (1 + r^*) q_{t+1}. \tag{8}
\]

The economy-wide resource constraints for the three production sectors are

\[
    c_{NT} + x_{NT} \leq F_N(\cdot), \tag{9}
\]

\[
    c_{Tt} + x_{Tt} + b_{t+1} - b_t (1 + r_t) \leq F_T(\cdot), \tag{10}
\]

\[
    i_{Tt} + i_{Nt} \leq F_I(\cdot). \tag{11}
\]

In traded and nontraded sectors, output can either be consumed or used as an input in the production of capital, with the latter denoted by \( x_{jt}, \ j = \{T, N\} \). In addition, in the traded sector, domestic absorption can differ from domestic production, with the difference represented by the trade balance with the rest of the world.
In the investment sector, competitive producers solve

$$\max_{\{x_{Ti}, x_{Ni}\}} q_{t+1} F_t(x_{Ti}, x_{Ni}) = x_{Ti} - p_{NTi} x_{Ni}. \quad (12)$$

The output of the investment sector is produced with Cobb-Douglas technology

$$F_t(x_{Ti}, x_{Ni}) = G x_{Ti}^{\gamma} x_{Ni}^{1-\gamma},$$

and is sold to consumers at a price $q_{t+1}$.

Competitive producers of goods in sector $j \in \{T, N\}$ solve

$$\max_{\{k_{jt}, l_{jt}\}} \sum_{t=0}^{\infty} \beta^t \left( p_{jt} F(k_{jt}, l_{jt}, l_{jt-1}) + q_{t+1} k_{jt} (1 - \delta) - w_t l_{jt} - h_t k_{jt} \right), \quad (13)$$

where

$$F_j(k_{jt}, l_{jt}, l_{jt-1}) = A_j (k_{jt})^{\alpha_j} l_{jt}^{1-\alpha_j} - \Psi(l_{jt}, l_{jt-1}), \quad (14)$$

$$\Psi(l_{jt}, l_{jt-1}) = \lambda \left( \frac{l_{jt} - l_{jt-1}}{l_{jt-1}} \right)^2 l_{jt-1}, \quad \lambda > 0,$$

and the initial conditions $l_{Tt-1}$ and $l_{Nt-1}$ are given.

$\Psi(\cdot)$ represents labor adjustment costs, incurred by producers whenever the total labor force in the sector is changed. Notice that, similar to the investment adjustment costs, in steady state the producer’s problem reduces to one without labor adjustment costs.

A perfect foresight competitive equilibrium for the economy is a set of paths for quantities $\{c_t, c_{Ni}, k_{t+1}, l_t, b_{t+1}, x_{Ti}, x_{Ni}, k_{Ti}, k_{Nt}, l_{Ti}, l_{Nt}\}_{t=0}^{\infty}$ and prices $\{p_{NTi}, w_t, q_{t+1}, h_t, r_t\}_{t=0}^{\infty}$, such that (i) in every period $\{c_Tc, c_{Ni}, k_{t+1}, l_t, b_{t+1}\}$ solves the consumer problem, given the path for prices; (ii) in every period $\{x_{Ti}, x_{Ni}\}$ solves the investment producer’s problem, given the prices for traded goods, nontraded goods and investments; (iii) $\{k_{Ti}, l_{Ti}\}_{t=0}^{\infty}$ solves the producer’s problem in the traded sector, given the prices for traded goods, labor and capital; (iv) $\{k_{Nt}, l_{Nt}\}_{t=0}^{\infty}$ solves the producer’s problem in the nontraded sector, given the prices for nontraded goods, labor and capital; (v) in every period, markets for traded goods, nontraded goods and investments in equations (9)-(11) clear. If the economy is closed in period $t$, $b_{t+1} = 0$. If the economy is open in period $t$, $r_{t+1} = r^*$. (vi) in every period, labor and capital markets clear, $l_t = l_{Tt} + l_{Nt}$ and $k_t = k_{Tt} + k_{Nt}$.  

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4 Calibration

In this section, we first discuss the calibration of model parameters (i.e. \(\varepsilon, \gamma, \xi, \alpha_T, \alpha_N, \delta, \beta, \rho, \nu, \lambda, \eta\)) and then introduce the relevant initial conditions (i.e. \(k_{T0}, k_{N0}, c_{T0}, c_{N0}, l_{T0}, l_{N0}, b_0\)). All these values are required to run the simulations.

4.1 Calibration of the model parameters

When calibrating the parameters, the objective is to obtain values representative for the first decade of transition in the CEEC and which would allow for a potential convergence of the income level in the CEEC to that in the EU.

All parameter values are presented in the last column of Table 3. In the calibration, one period is taken as one year. The consumption preference parameter, \(\varepsilon\), was obtained from input-output tables for the CEEC countries. Since there were problems in the data with accounting for consumption of retail sector output, consumption of traded goods was adjusted by subtracting the margin of the (nontraded) retail sector when calculating \(\varepsilon\). Following the empirical evidence in Burstein et al. (2003), a 50 percent retail margin was assumed. Results for six of the sample countries with available input-output tables are presented in Table 2. The value for \(\gamma\) was obtained from PWT 6.1 benchmark data for the CEEC (see Berns (2005)).\(^6\) \(\xi\) was chosen so that in the model's steady state, 1/3 of the time is spent working.

The capital income share in the two sectors, \(\alpha_T\) and \(\alpha_N\), was calculated using the Eurostat data on labor shares. Data show that during 1995-2000, the average labor share in the traded sector of the CEEC was 0.62, while the same number in the non-traded sector was 0.63. Thus, the two sectors appear to have roughly the same labor intensity. Following Gollin's (2002) evidence on underestimated labor shares in developing countries, the capital share parameter for the calibration was obtained from the average labor share for the EU. In the Eurostat data, this share was 0.67. Similar to the CEEC, labor intensities were the same across the two sectors for the EU countries.

\(\delta\) is chosen so that in the steady state, 21 percent of the output is spent on investments. According to data in PWT 6.1, this is a good description of the CEEC as well as the world in general (see Parente and Prescott (2000), Hsieh and Klenow (2003)). The subjective discount factor, \(\beta\), is based on average return on the German government bonds during the 1981-2001 period (see Bems and Jonsson (2003)). We set \(\rho = 2\) so that in the model's steady state, the curvature of the utility function with respect to consumption is in line with the existing estimates (see, e.g., Backus et al. (1995)).

\(^6\)Using the model's first-order conditions, the scale parameter in the investment production function, \(G\), can be expressed as \(G = \left(\frac{1}{(1-\gamma)^{1-\gamma}}\right)^{-1}\).
Empirical evidence on the value of habit-formation parameter, $\nu$, is scarce. We take the value most commonly used in the literature (see, e.g., Constantinides (1990), Ljungqvist and Uhlig (2000)).

Results of empirical studies on investment adjustment costs vary widely, while the existing estimates of labor adjustment costs are more in accordance with each other.\footnote{For a survey, see Hamermesh and Pfenn (1996).} As a result, we use different methods to obtain the two adjustment cost parameters. The labor adjustment cost parameter, $\lambda$, is obtained from empirical estimates by Pfenn and Palm (1993). This particular study of labor adjustment costs was preferred over other empirical studies for several reasons. First, employment data in their estimates include only data for the number of employees and thus, ignores changes in hours worked. Although this might be seen as a shortcoming in general, our study of CEEC makes the same omission. Second, in line with the theoretical model used in this paper, they assume that firms take wages as given, when maximizing their profits. Third, their estimates are based on annual data.

Unfortunately, the labor adjustment cost parameter that Pfenn and Palm (1993) estimate cannot be directly applied to our calibration. In addition to quadratic adjustment costs, the functional form used by Pfenn and Palm (1993) allows for asymmetries between hiring and firing costs. Moreover, the study differentiates between adjustment costs for production workers and non-production workers. However, the asymmetries they estimate, although statistically significant, are small. The same turns out to be the case for differences in adjustment costs for production and non-production workers. For the purpose of our investigation, we therefore apply a simple least square method to estimate the quadratic adjustment cost function best fitting the functional form estimated by Pfenn and Palm (1993). The resulting point estimate for the labor adjustment cost parameter is $\lambda = 2$.

The adjustment cost parameter for capital, $\eta$, is set to match the level of investments observed in the data in the first open year. The resulting value for $\eta$ implies an elasticity of Tobin's $q$ with respect to investments, defined as $e_q = \frac{\delta q'(\delta)}{q'(\delta)}$, equal to $-0.6$. Our value of $\eta$ is not an outlier, when compared to the adjustment costs that have been estimated in the empirical literature. For example, with our calibrated adjustment costs, a net investment equal to 10 percent of the capital stock implies adjustment costs equal to 25 percent of the investment expenditures. Whited (1992) finds such costs to represent 10 percent of the investment expenditures, while Lichtenberg (1988), in contrast, finds that such costs range from 21-35 percent of the investment expenditures.
4.2 Calibration of the initial conditions

With respect to the initial conditions, the objective is to match the relevant observations in the data. There is no reason to expect that in the last year before opening the CEEC was in a market economy steady state. In this respect, the paper deviates from the approach taken in the related literature (see e.g. Burstein et al. (2003), Uribe (2002)), where the initial conditions are obtained by solving the steady state first-order conditions of the model, with pre-set parameter values and a given level of foreign assets.

To calibrate the initial production factors, we assume that in the last closed year a third of the time was devoted to work:\(^8\)

\[ l_{T_0} + l_{N_0} = 1/3. \]  \hspace{1cm} (15)

All prices, except the rental price of capital, in the last closed year are normalized to 1, so that nominal data observations for the last closed year can be directly compared with the real values in the data. Output in traded and nontraded sectors in the last closed year is taken directly from the data, where the average fraction of traded sector output across the CEEC was 0.46. The capital stock for the last closed year is obtained using estimates for Poland in PWT 5.6 and Hungary (see Pula (2003)). We take the average of the two capital stocks as the average of the CEEC, which expressed as a fraction of output was

\[ \frac{k_0}{y_0} = 1.7. \]  \hspace{1cm} (16)

Only fragmental data are available on the division of capital and labor across the two sectors in the last closed year. To deal with this problem, production factors are assumed to be distributed across sectors proportionally to sectoral output,

\[ \frac{y_{T_0}}{y_{T_0} + y_{N_0}} = \frac{k_{T_0}}{k_{T_0} + k_{N_0}} = \frac{l_{T_0}}{l_{T_0} + l_{N_0}} = 0.46. \]  \hspace{1cm} (17)

Table 4 shows that the available data support this assumption.

Using (15) and (17), the initial sectoral labor allocations can be derived as \(l_{T_0} = 0.1534\) and \(l_{N_0} = 0.1800\). To find the initial allocations for output, we use the aggregate labor income share from the previous subsection\(^9\)

\[ l_0 = 0.67y_0, \]  \hspace{1cm} (18)

which together with (17) implies that \(y_{T_0} = 0.2289\), \(y_{N_0} = 0.2687\). Then, using (16) and

---

\(^8\)This assumption implies that before the reforms, the same fraction of time was spent working as in the steady state of the model's market economy.

\(^9\)No data about the labor income share in the last closed year was available.
(17), we obtain \( k_{T0} = 0.3891 \) and \( k_{N0} = 0.4568 \).

Next, we observe in the data that average investments, as a fraction of output, in the CEEC in the last closed year was 0.232. Sectoral investment inputs are obtained using the model's first-order conditions and the average value for the fraction of investment expenditures spent on traded goods, \( \gamma = 0.44 \). Data on trade balances show that the CEEC in the last closed year had an average surplus of 4.57 percent of GDP. Given the data on output, investments and trade balance, consumption can be obtained in each of the sectors using sectoral income identities

\[
\begin{align*}
C_{T0} &= y_{T0} - x_{T0} - T_{B0}, \\
C_{N0} &= y_{N0} - x_{N0}.
\end{align*}
\] (19)

The resulting initial conditions for consumption are presented in the third column of Table 5.

Since we simulate a closed economy that opens up to the rest of the world, the initial foreign asset position for the model economy is assumed to be \( b_0 = 0 \). Due to a limited size of the private sector, the foreign asset positions of the CEEC in the last closed year can be captured with the foreign asset positions of their governments. In the case of Estonia, Latvia, Lithuania and Slovenia, the foreign asset position was indeed zero for political reasons. In Czech Republic and Slovakia, the foreign asset position was also close to zero. In Poland and Hungary, governments had foreign debts of 64 and 63 percent of GDP, respectively (see Fischer and Sahay (2000)). However, this initial debt burden was substantially reduced by debt rescheduling.

Given the values for initial output and factor inputs, the remaining model parameters, \( A_T \) and \( A_N \), can be calibrated. These scale parameters are obtained as residuals from the Cobb-Douglas production function. For \( j \in \{T, N\} \)

\[
A_{j0} = \frac{y_{j0}}{k_{j0}^{\alpha_j} l_{j0}^{1-\alpha_j}}.
\] (20)

\( A_T \) and \( A_N \) represent the initial productivity level in the model economy, after it opens to the rest of the world.

\[\text{10Data from the IMF World Economic Outlook.}\]

\[\text{11Given } b_0 = 0, \text{ the observed trade surplus in the last closed year represents a negligible quantity in terms of foreign assets and is thus ignored.}\]
5 Simulation of the baseline model

In this section, we present results from the simulation of the baseline model. Faced with the initial conditions in Table 5, the CEEC opens up to trade and capital flows with Germany, which stands to represent the rest of the world, and the EU in particular. Relative to the final steady state, the CEEC starts out as capital poor and with too much economic activity concentrated in the traded sector (i.e. over industrialized).

In the baseline simulation, we assume that the productivity parameters, $A_T$ and $A_N$, remain constant at the level of the last closed year. Thus, this simulation rules out any productivity growth and there is no income growth in the steady state of the model.

The calibrated model was solved as a system of non-linear equations, which characterize the behavior of each of the model's variables from the first open year until the steady state is reached. The steady state values were obtained by allowing for a sufficiently long transition and taking the foreign asset position of the last transition period as the steady state value of foreign assets. Results of the simulation are presented in Figure 12. Unless noted otherwise, the variables are expressed in terms of percentage deviation from initial values.

From the moment of opening, economic activity shifts towards the non-traded sector. In Figure 12, this is captured by the sharp decrease of output in the traded sector and the decrease of employment in the traded sector and the increase of employment in the non-traded sector. The shift of economic activity in the model is induced by two distinct factors. First, there is a correction of the initial over-industrialization. Under market conditions, less of the traded good is consumed than before the opening. Second, the economic boom following the opening induces the consumer to consume more of both traded and non-traded goods. The necessary quantity of the traded goods can be directly imported from abroad, but non-traded goods need to be produced at home. Since the local economy is capital poor, the increased demand for the two consumption goods implies that from the moment of opening, the non-traded good becomes relatively scarce and its price shoots up. Consequently, during the initial transition phase, it is optimal for the local economy to specialize in the production of non-traded goods and import the traded goods, which leads to the observed shift in economic activity in the model. This shift is in line with the data for the CEEC.

The initial appreciation of the real exchange rate is also a result of the relative scarcity of the non-traded goods after reforms. Since there is no productivity growth in the model and the two production sectors have the same labor intensity, in the steady state the real exchange rate returns to the initial level. Although the initial appreciation of the real exchange rate is supported by the data, the model lacks any persistence in appreciation. Real wage dynamics mimic the movement in the price of nontraded goods. However,
the steady-state level of the real wage is above the initial level, since the economy has accumulated a higher capital stock. Similar to the real exchange rate, real wage lacks any of the persistence present in the data.

The initial fall in the labor force in the economy is induced by the low initial capital stock, which in both sectors is below the steady state level. This induces the representative consumer to substitute labor with leisure. After approximately five years of initial transition, the continued capital accumulation ensures that labor moves back towards the initial level. It is important here to remind the reader of the assumption made in the previous section that in the last closed year, the consumer devotes as much time to work as in the steady state of a market economy. The decrease in labor supply in the model economy falls short of the fall observed in the data. However, in line with the data, the higher demand for nontraded goods leads to an increase in employment in the nontraded sector, which absorbs some of the decrease in the traded sector.

After the opening, the model economy runs a negative trade balance, as resources are borrowed from the rest of the world to facilitate a higher consumption level and accumulation of the capital stock. Interestingly, the trade balance does not decrease smoothly. In the very first open period, habit forming households choose to make a one-time adjustment to foreign assets to be able to support higher consumption in the future.12

Output initially falls, as the decrease in labor exceeds the increase in the capital stock, and from the third year onwards grows, as both labor and the capital stock are increasing. When compared to the data, the initial fall in the model economy is too small. At its minimum, the output index has decreased by three percent as opposed to ten percent in the data. The subsequent growth in the model also falls short of the boom in the data. The initial increase in consumption is in line with the data, although from the fifth year of transition and onwards, consumption growth in the model falls behind the data. The same trend can also be observed for the investments, where the differences in growth rates are even larger.

Differences between data and model outcomes indicate that productivity growth is an important ingredient that is omitted from the baseline simulation. Adding productivity growth would allow for real appreciation of the prices and a higher growth rate for output and its components; thus, in the next section, we introduce productivity growth in the model.

12The same outcome in a model with habit forming consumers was noted by Uribe (2002), p 550. In the setup of the baseline calibration, this effect can be further increased by the suboptimally high amount of resources in the traded sector.
6 Adding productivity growth to the model

6.1 Productivity growth in the CEEC

A growing body of empirical evidence suggests that since the implementation of reforms, the CEEC have experienced substantial productivity growth, especially in the traded sector of the economy. Results from Halpern and Wyplosz (2001), De Broeck and Slok (2001) and Egert et al. (2002) suggest that during the 1992-2000 period, productivity in the traded sector of the CEEC grew 4 – 7 percent faster than in the nontraded sector. The same number for the EU is in the range of 1 – 2.5 percent (see De Gregorio et al. (1995)). Furthermore, according to Halpern and Wyplosz (2001), productivity increased by 1.9 percent in the nontraded sector of the CEEC over the period 1992-1998, which is roughly in line with productivity growth in developed countries. This empirical evidence suggests that a relevant experiment would be to introduce productivity growth only in the traded sector.

Data in the PWT 6.1 indicate that in the last closed year, income per capita in the CEEC was at 35 percent of the average ED level. In the steady state of the baseline simulation income in the CEEC converged to 46 percent of the ED level. The simplest way of setting up the productivity growth experiment is to assume zero growth in the ED, as well as no change in productivity in the nontraded sector of the CEEC, and then bridge the remaining income gap between the CEEC and the ED by increasing productivity in the traded sector. Moreover, in line with empirical evidence for productivity: (i) during the first ten years, the average annual productivity growth should be roughly four percent\(^{13}\) and (ii) productivity should peak after 3-5 years of transition (see Pula (2003)). The resulting productivity growth sequence for the traded sector is presented in Figure 13.

6.2 Simulation results

Economists agree that expectations play an important role in economic outcomes, which is especially the case when a rapid productivity growth takes place. However, the model used in this paper is entirely deterministic and cannot handle expectations. In order to, at least partly, reduce the shortcomings of the deterministic model, the productivity growth presented in Figure 13 is introduced in the model in two distinct ways. In the first simulation, productivity is added to the model as an exogenous sequence of productivity levels, \( A_T \forall t \), where the levels are determined by the assumed growth rates. Thus, we solve the same model as in the baseline case, except that the constant productivity level

\(^{13}\) Obtained as the difference between average productivity growth rates in the CEEC and the EU, i.e. \((7 + 4)/2 - (2.5 + 1)/2\).
in the traded sector is replaced with the increasing productivity trend.\textsuperscript{14}

In the second simulation, the same exogenous sequence of increasing productivity levels is introduced in the model as annual positive productivity shocks. In this case, the consumer in every period $t$ takes $A_T = A_{t+1}$ as the productivity level relevant for solving the infinite horizon maximization problem, presented in Section 3. With this setup, the consumer maximization problem must be resolved in each period as long as the level of productivity in the traded sector increases. In subsequent periods, the optimal solution does not change.

These two alternative simulations can be considered as representing two extremes for forming expectations about the future productivity growth. The first simulation represents a case where already in the first year after opening, the representative consumer knows with certainty that in the future, income in the CEEC will converge to the EU. Or, put in different terms, the representative consumer knows with certainty that the model economy will perform as well as the best performing country in recent economic history – Ireland. Clearly, this case stands for overly optimistic expectations.

It is less straightforward to argue that the second simulation represents a case of overly negative expectations. Here, in the first open year, the representative consumer is certain that apart from convergence induced by capital accumulation, the economy will not grow, i.e. productivity levels will not change in the future. This appears to be a reasonable assessment of reality, since in the neighborhood of the sample countries, there are many examples of both: better as well as worse economic performance than the conditions in the first open year.\textsuperscript{15} What makes this case represent overly negative expectations is that after being continuously shocked with productivity growth, the representative consumer does not expect any continued future increases in productivity.

The results of the first simulation are presented in Figure 14, with the baseline case and the data also included. The differences from the baseline case in the solution are driven by the productivity growth in the traded sector, which puts the model economy further away from the steady state. To converge to the new steady state, the consumer now borrows considerably more from the rest of the world. In the first five years of transition, the model economy runs trade deficits of around 25(%) percent of GDP which, in turn, allows the consumption growth to substantially exceed the growth rate in the baseline case and the data. There is an overshooting in terms of the real exchange rate, the real wage and the size of the nontraded sector, all of which are a consequence of the more rapid initial consumption growth.

Due to large trade deficits, in the steady state foreign liabilities reach 440 percent

\textsuperscript{14}In line with the calibration procedure, there are also changes in the investment adjustment costs and the preference parameter for leisure.

\textsuperscript{15}The CIS, Romania, Albania and parts of former Yugoslavia are examples of a worse performance and the EU is an example of a better economic performance.
of GDP. The interest payments on this amount put a noticeable strain on the model economy, as the size of the traded sector in the steady state is 48 percent of GDP (see Table 6).

The results of the second simulation are presented in Figure 15. Since there is assumed to be no productivity growth in the first open year, the solution for the first year coincides with the baseline case. Thereafter, the productivity growth only has a small effect on the sectoral dynamics and the trade balance, but considerably increases the growth of output, consumption and investments. The simulation also captures the gradual appreciation of the real exchange rate and the real wage, which can be fully attributed to the Balassa-Samuelson effect. Growth of investments is the only variable for which simulation results remain substantially different from the data.

Table 6 compares sectoral dynamics and the external balances for the three difference scenarios, while Table 7 shows the speed of convergence to the average EU income level. Note that the speed of convergence is not directly comparable, since for the case of deterministic convergence to satisfy the calibration criteria discussed in section 4, larger capital adjustment costs have been imposed.

7 Concluding remarks

The prime contribution of this paper is to provide a test case for an often-used macroeconomic model on data that comes from 'natural experiment like' circumstances, after the socialist system collapsed in Central and Eastern Europe. At the same time, the encouraging results of the application of the model to the case of the CEEC offer us an interpretation of the aggregate real sector development in the CEEC during the first ten years of transition. Several interesting insights can be gained from this application.

First, the results point towards the importance of transitional dynamics in the economic development of the CEEC. More specifically, the model questions the usefulness of one of the economic convergence indicators used in the literature – the relative size of traded and nontraded sectors in terms of economic activity and/or employment (e.g., see IMF World Economic Outlook (2000) p 142, Raiser et al. (2003)). Results of the simulations show that the size of the nontraded sector during the transition overshoots the steady state and thus, convergence in terms of sectoral change is not a monotonic process.

Second, the results of the simulations suggest that, although trade deficits peak within the first ten years of transition, depending on the extent of productivity growth, it can take until approximately 2020 for the average CEEC to move to positive trade balances. Our calibrated model provides an estimate for the link between the future productivity growth and the reversal of trade balances in the CEEC.
The results presented in the paper suggest two interesting extensions of the current paper. First, although the real sector developments are very similar in the eight countries considered, there is further evidence that the same exercise should be applied separately to the Baltic state and the countries of Central Europe. Second, it would be interesting to perform the same exercise in a model where the expectations are treated more explicitly.
References


Table 1: Reform years in the CEEC

<table>
<thead>
<tr>
<th>Country</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland, Hungary</td>
<td>1990</td>
</tr>
<tr>
<td>Czech Republic, Slovakia</td>
<td>1991</td>
</tr>
<tr>
<td>Slovenia, Estonia, Latvia, Lithuania</td>
<td>1992</td>
</tr>
</tbody>
</table>

Table 2: Adjusted traded goods share in consumption

<table>
<thead>
<tr>
<th>Country</th>
<th>Year of Input-Output data</th>
<th>Value of $\varepsilon$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estonia</td>
<td>1997</td>
<td>0.281</td>
</tr>
<tr>
<td>Latvia</td>
<td>1998</td>
<td>0.329</td>
</tr>
<tr>
<td>Lithuania</td>
<td>1998</td>
<td>0.386</td>
</tr>
<tr>
<td>Poland</td>
<td>1995</td>
<td>0.315</td>
</tr>
<tr>
<td>Slovakia</td>
<td>1998</td>
<td>0.372</td>
</tr>
<tr>
<td>Slovenia</td>
<td>1996</td>
<td>0.344</td>
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<tr>
<td>Average</td>
<td></td>
<td>0.339</td>
</tr>
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</table>

Source: National Statistical Offices

Table 3: Parameter values for the baseline calibration

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital share in traded goods production</td>
<td>$\alpha_T$</td>
<td>0.33</td>
</tr>
<tr>
<td>Capital share in non-traded goods production</td>
<td>$\alpha_N$</td>
<td>0.33</td>
</tr>
<tr>
<td>Traded goods share in investment production</td>
<td>$\gamma$</td>
<td>0.44</td>
</tr>
<tr>
<td>Traded goods share in consumption</td>
<td>$\varepsilon$</td>
<td>0.34</td>
</tr>
<tr>
<td>Preference parameter for leisure</td>
<td>$\xi$</td>
<td>2.152</td>
</tr>
<tr>
<td>Curvature of consumer's utility</td>
<td>$\rho$</td>
<td>2</td>
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<tr>
<td>Discount factor</td>
<td>$\beta$</td>
<td>0.96</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>$\delta$</td>
<td>0.073</td>
</tr>
<tr>
<td>Habit-formation parameter</td>
<td>$\nu$</td>
<td>0.8</td>
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<td>Capital adjustment cost parameter</td>
<td>$\eta$</td>
<td>0.4</td>
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<tr>
<td>Labor adjustment cost parameter</td>
<td>$\lambda$</td>
<td>2</td>
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</table>

Table 4: Comparison of traded sector output and factor shares in the last closed year

<table>
<thead>
<tr>
<th>Country</th>
<th>$\frac{y_{T0}}{y_{T0}+y_{N0}}$</th>
<th>$\frac{y_{T0}}{y_{T0}+y_{N0}}$</th>
<th>$\frac{y_{T0}}{y_{T0}+y_{N0}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Czech Rep.</td>
<td>0.43</td>
<td>0.46</td>
<td>-</td>
</tr>
<tr>
<td>Estonia</td>
<td>-</td>
<td>0.46</td>
<td>0.45</td>
</tr>
<tr>
<td>Hungary</td>
<td>-</td>
<td>0.48</td>
<td>-</td>
</tr>
<tr>
<td>Latvia</td>
<td>0.47</td>
<td>0.45</td>
<td>0.42</td>
</tr>
<tr>
<td>Lithuania</td>
<td>0.51</td>
<td>0.48</td>
<td>0.50</td>
</tr>
<tr>
<td>Poland</td>
<td>-</td>
<td>0.55</td>
<td>-</td>
</tr>
<tr>
<td>Slovakia</td>
<td>-</td>
<td>0.46</td>
<td>-</td>
</tr>
<tr>
<td>Slovenia</td>
<td>0.42</td>
<td>0.53</td>
<td>-</td>
</tr>
<tr>
<td>Average</td>
<td>0.46</td>
<td>0.48</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Table 5: Initial conditions

<table>
<thead>
<tr>
<th>Description of initial variable</th>
<th>Symbol</th>
<th>Initial value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital in traded sector</td>
<td>$k_{T0}$</td>
<td>0.3891</td>
</tr>
<tr>
<td>Capital in nontraded sector</td>
<td>$k_{N0}$</td>
<td>0.4568</td>
</tr>
<tr>
<td>Labor in traded sector</td>
<td>$l_{T0}$</td>
<td>0.1534</td>
</tr>
<tr>
<td>Labor in nontraded sector</td>
<td>$l_{N0}$</td>
<td>0.1800</td>
</tr>
<tr>
<td>Consumption in traded sector</td>
<td>$c_{T0}$</td>
<td>0.1554</td>
</tr>
<tr>
<td>Consumption in nontraded sector</td>
<td>$c_{N0}$</td>
<td>0.2041</td>
</tr>
<tr>
<td>Foreign asset position</td>
<td>$b_0$</td>
<td>0.0000</td>
</tr>
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</table>

Table 6: Sectoral adjustments and external position

<table>
<thead>
<tr>
<th>Scenario</th>
<th>$\frac{x_{T0}}{y_0}$</th>
<th>min($\frac{x_{T1}}{y_T}$)</th>
<th>$\frac{x_{T,ss}}{y_{ss}}$</th>
<th>$\frac{b_{ss}}{y_{ss}}$</th>
<th>Exp-Imp$&gt;0$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline model</td>
<td>0.46</td>
<td>0.33</td>
<td>0.40</td>
<td>-1.52</td>
<td>T+21</td>
</tr>
<tr>
<td>Deterministic convergence</td>
<td>0.46</td>
<td>0.19</td>
<td>0.48</td>
<td>-4.37</td>
<td>T+19</td>
</tr>
<tr>
<td>Unpredicted convergence</td>
<td>0.46</td>
<td>0.33</td>
<td>0.41</td>
<td>-1.82</td>
<td>T+28</td>
</tr>
</tbody>
</table>

Table 7: Income gap (percent of the EU average)

<table>
<thead>
<tr>
<th>Scenario</th>
<th>T</th>
<th>T+10</th>
<th>T+20</th>
<th>T+40</th>
<th>Steady state</th>
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</thead>
<tbody>
<tr>
<td>Baseline model</td>
<td>35</td>
<td>39</td>
<td>41</td>
<td>44</td>
<td>45</td>
</tr>
<tr>
<td>Deterministic convergence</td>
<td>35</td>
<td>53</td>
<td>71</td>
<td>86</td>
<td>100</td>
</tr>
<tr>
<td>Unpredicted convergence</td>
<td>35</td>
<td>57</td>
<td>79</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>Data</td>
<td>35</td>
<td>47</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>
Figure 1: GDP volume (T=reform year)

Source: National Statistical Offices
Figure 2: Consumption volume

Source: National Statistical Offices
Figure 3: Investment volume

Source: WB, World Development Indicators
Figure 4: Employment index

Source: ILO, Yearbook of Labor Statistics
Figure 5: Employment index (traded and nontraded sectors)

Source: ILO, Yearbook of Labor Statistics
Figure 6: Traded sector value added (fraction of total value added)

Source: National Statistical Offices
Figure 7: Trade balance (% of GDP)

Source: National Statistical Offices
Figure 8: Real wage index

Source: EBRD, Transition Reports, various issues
Figure 9: Real exchange rates

Source: National Statistical Offices
Figure 10: Nontraded component of RER

Source: National Statistical Offices
Figure 11: Summary of trends for key real sector variables

- **real GDP**
- **consumption**
- **investments**
- **traded output (% of GDP)**
- **traded and nontraded labor**
- **total labor**
- **trade balance (% of GDP)**
- **real exchange rate**
- **real wage**
Figure 12: Simulation of the baseline model
Figure 13: TFP growth rates in the traded sector
Figure 14: Simulation of the model with deterministic convergence to the EU
Figure 15: Simulation of the model with unpredicted convergence to the EU

- **real GDP**
- **consumption**
- **investments**
- **traded output (% of GDP)**
- **traded and nontraded labor**
- **total labor**
- **trade balance (% of GDP)**
- **real exchange rate**
- **real wage**

Legend:
- **baseline case**
- **data**
- **unpredicted convergence**
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