Capital Accumulation, Sector Productivity, and Economic Growth

Dissertation zur Erlangung des akademischen Grades

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Preface

Knowing that this list can never be complete, I nevertheless would like to thank a few people. I owe a major gratitude to my supervisor and co-author, Jochen Michaelis. Thank you, Jochen. For working on this research project, and on our tasks at your chair, at an equal eye level. Thank you for always having an open ear for my ideas and for my (sometimes strange) concerns, and thank you, for your endless comments to improve my dissertation. Your ability to take and to assume the perspective of the people around you inspired me. This ability of you is a gift that I will miss after leaving the chair. Despite that I was always working in side-jobs somewhere else during my Bachelor and during most of my Master, but almost never at the University, you gave me the opportunity to become a Ph.D. student at your chair. The gratitude I felt to you when you accepted being my supervisor lasts until today. My journey did not begin in Summer 2018 (your supervision of my master thesis), and not in Summer 2016 (your supervision of my bachelor thesis), but in Summer 2013, when I took part in your lecture on macroeconomics (‘VWL2’). Your way of ‘explaining the world’ motivated me and kept me connected with macroeconomics for almost one decade now. While I was working on this dissertation, some people did cast doubt on whether my work on this thesis is a *good time*. Working on our project on every Christmas and on every weekend until late at night, skipping (my) birthday and new year celebrations to continue working in our research, making barely holiday, having nearly no days off. In the belief that our research can contribute. Was it a *good time*? It was the best. Thank you Jochen, for your fairness.

I thank Rainer Voßkamp for taking the position of the second supervisor of my thesis. I thank my colleagues Max Fuchs, Stefan Büchele, Anastasios Demertzidis, Alexander Günther, Andreas Hanl, Jan Hattenbach, Philipp Kirchner, and Luzie Thiel for their very helpful suggestions to improve this dissertation. I thank Heike Krönung for being the *manager in the background* at our chair, and for having an open ear for topics also other than academia. I also thank Beverley Locke for her helpful suggestions to improve this dissertation. I thank Thomas Schill for his company during my studies. His support was a significant help *and motivation*, on an organizational level, and on a personal one.

I thank the financiers of my research. Most of the time when I was preparing for my Ph.D. thesis (since summer 2018) and when I was working on my Ph.D. thesis (since summer 2019) I worked at K+S Aktiengesellschaft, Kassel, Treasury department. The split of my time between three responsibilities (working in K+S Treasury department, working as a tutor at the University, working on my Ph.D. thesis) was only possible with the flexibility that Thomas Gerke (K+S) gave me in scheduling my tasks. I also thank my other colleagues at K+S for their interest in my work. I thankfully acknowledge a graduate school scholarship granted by the University of Kassel.

I also thank my family. I thank my father Gerd, who I know, is looking down on us. Despite the time we had together ended long before I started working on this dissertation, your mind contributed to this work. You took me to the constructions sites you were working at when I was a young boy. You showed me how to work with my hands and to believe in them. I thank my mother Ilona, for her support in organizing the daily things in the background. It is now my turn to give something back, and the safe future that this dissertation opens will help our family. My parents taught me a proper working moral, which I regard as the benefit of growing up in a working-class family. I thank my brother, Julian, for the motivation and emotions that we give to each other. I am proud on you. In five years, you will join my team. I thank my godmother Beate, and my godfather Jörg, for showing me a perspective to develop to, since I was young.

Finally, I thank my dear Katjuscha. For her continuous support in this work and for her belief in us during the ups and downs while I was working on this thesis. Your bravery inspired me through the working on this dissertation. Working on this thesis limited the time available for us, a burden I have to say *sorry* for. Now the work is done, and this dissertation will open a good future for us. A safe future that I was always looking forward to, for the family and for me, after the passing of my father. Now we will prosper together, like two foxes.

Motivation

The European macroeconomic integration of peripheral European economies in the 1990s and 2000s has resulted in a long-lasting economic weakness of tradable production (sectors producing tradable goods) in peripheral Europe. Sinn (2015) argues for a lost competitiveness (of tradable production) in peripheral Europe, because of merged European currencies. Benigno and Fornaro (2014) argue for adverse/burdening effects that European (financial) integration had on (total-factor) productivity in Spanish tradable production.[1] Despite Benigno and Fornaro (2014) and Sinn (2015) theorize different mechanisms to explain a negative effect of European integration on tradable production in peripheral Europe, they both build on a common core, namely the reduction of interest rates in peripheral Europe, induced by European integration.

Doing so, by focusing on the Spanish economy, Benigno and Fornaro (2014) theoretically model a small open economy, producing tradable and non-tradable goods, using labour as the single production factor. They show theoretically that low interest rates from European (financial) integration promotes (debt financed) consumption of tradable and non-tradable goods in peripheral Europe. While the promoted consumption of tradable goods can be satisfied by additional imports, the promoted consumption of non-tradable goods must be satisfied by additional domestic non-tradable production (sectors producing non-tradable goods). Thus, to satisfy promoted domestic consumption of non-tradable goods, domestic non-tradable production needs to grow. Thus, in the model of Benigno and Fornaro (2014), non-tradable production demands more labour resources. These labour resources depart tradable production. As Benigno and Fornaro (2014) see tradable production as the origin of productivity advances (technology or knowledge accumulation), the relocation of labour resources out of tradable production reduces learning-by-doing and technology accumulation in tradable production. These negative effects *potentially* undermine the welfare of the small open economy. Benigno and Fornaro (2014) term this effect *Financial Resource Curse.*

This dissertation is motivated by a limitation that the Benigno and Fornaro (2014) theory has. The fact that Benigno and Fornaro (2014) model the production of tradable and non-tradable goods by utilizing labour as the single production factor rules out a second, important effect that low interest rates and the eased access to international capital from European integration should have. Low interest rates and the eased access to international capital (credit expansion) namely should also have a supply-side effect of promoted capital accumulation in tradable (T) and non-tradable (N) production (see, e.g., Gorton, Ordoñez, 2020, Tornell, Westermann, 2003, Blanchard, Giavazzi, 2002, Benigno, Converse, Fornaro, 2015, Mian, Sufi, Verner, 2020). The promotion of capital accumulation in both sectors (N and T) should potentially result in higher labour productivity and welfare, when a small open economy faces lower interest rates from European integration.

[1] A burden/depressed (for) total-factor-productivity can be mirrored in declining total-factor-productivity, or in a declining/low growth rate of total-factor-productivity. Benigno and Fornaro (2014) empirically show for Spain a burdened/declining total-factor-productivity during the years of decreasing interest rates and of ongoing European integration (1995-2008). Bennett et al. (2008) show empirically a burdened (growth rate of) total-factor-productivity for Portugal and Italy during the years of ongoing European integration from 1996 to 2006. Sinn (2012) also shows decreasing interest rates for (among others) Portugal and Italy during this period of European integration (mid 1990s to approximately 2007). Benigno and Fornaro (2014) refer to (European) financial integration. I refer to European *macroeconomic* integration, as it paves the way to the findings of my Ph.D. thesis (see particularly chapter 3).

Two research questions guide the dissertation at hand.

First, do the negative effects of low interest rates on employment in tradable production and on technology accumulation and productivity, shown in the Benigno and Fornaro (2014) model, prevail, after extending their model by capital as a second production factor (installed in sectors N and T), and by capital goods production as a third sector. This (first) research question is addressed in chapters 1 and 2 of the dissertation at hand.

As a result, taking capital accumulation into account, the model in chapter 1 and the model in chapter 2 of the dissertation at hand indicate that low interest rates do not sufficiently explain the sectoral reallocation of labour resources out of tradable production. Thus, low interest rates also do not sufficiently explain the slowdown of technology accumulation and of productivity in peripheral Europe as a response to macroeconomic integration. This result contradicts the theory of Benigno and Fornaro (2014), and selected empirics they show for Spain. A requirement for the results in chapter 1 and chapter 2 is the assumption that capital stocks in tradable production and in non-tradable production benefit simultaneously from macroeconomic integration, lower interest rates and capital accumulation. This motivates the second research question (researched in chapter 3):

Second, if macroeconomic integration affects (capital costs in) tradable and non-tradable production asymmetrically, does it induce a reallocation of labour resources out of tradable production, into non-tradable production, and a slowdown of productivity in the macroeconomically integrating economy?

Overview

Chapter 1 ('The Financial Resource Curse Revisited: The Supply-Side Effect of Low Interest Rates') was written in co-authorship (joint research project) with my supervisor and co-author, Prof. Dr. Jochen Michaelis, University of Kassel. An earlier version of chapter 1 was published as MAGKS Discussion paper No. 22-2022 in May 2022 (see Hildebrandt, Michaelis, 2022, in the list of references in chapter 4). Moreover, an earlier version of chapter 1 was submitted (for publication) to a journal in May 2022. We are currently waiting for an answer (20th September 2022).

The core of my dissertation are 3 similar theoretical models that rest on each other. Each of the 3 theoretical models has a separated chapter in this dissertation (chapters 1, 2, 3).

The theoretical model in chapter 1 (precisely chapter 1.3) extends the theoretical model (and computer code) of Benigno and Fornaro (2014) by capital as a second production factor, and by a third sector, producing capital goods, based on the model of de Cordoba and Kehoe (2000). Repeating the experiments of Benigno and Fornaro (2014), we show that low interest rates do not necessarily induce a reallocation of (labour) resources out of tradable production (see also, Mian, Sufi, Verner, 2020). As Benigno and Fornaro (2014) (and our model in chapter 1) assume that technology accumulation depends on tradable production employment (learning-by-doing), we find no negative effect of low interest rates and of European (financial/macroeconomic) integration on technology accumulation and (total-factor-) productivity. One requirement for our findings was our assumption that capital stocks in tradable production and in non-tradable production benefit simultaneously from low interest rates, capital accumulation and macroeconomic integration.

The theoretical model in chapter 2 (precisely chapter 2.3) extends the theoretical model (and computer code) of chapter 1 (precisely of chapter 1.3) by technology accumulation from inflowing foreign capital. This is motivated by the findings of, among others (see chapter 2.2), Baltabaev (2014), Eaton and Kortum (2001) and Amann and Virmani (2015), and by one argument in Blanchard and Giavazzi (2002). Repeating the experiments of Benigno and Fornaro (2014), chapter 2 shows that low interest rates and macroeconomic integration should not burden/reduce (total-factor) productivity in the (macroeconomically) integrating economy. Instead, the vast inflow of foreign capital goods into a macroeconomically integrating economy as a reaction to macroeconomic integration pushes technology accumulation and thus, productivity there, as inflowing foreign capital (goods) transfer foreign technology (see, e.g., Baltabaev, 2014, Eaton, Kortum, 2001, Amann, Virmani, 2015). Like in chapter 1, one requirement for my findings in chapter 2 was my assumption that capital accumulation in tradable production and in non-tradable production benefits simultaneously from low interest rates and macroeconomic integration. Further research should improve the calibration of the model in chapter 2. Chapter 3 will loosen the assumption, that capital accumulation in tradable (T) and non-tradable (N) production benefits simultaneously from low interest rates and macroeconomic integration. Moreover, chapter 3 will improve the calibration of the model shown in chapter 2 (precisely in chapters 2.3 and 2.4).

The theoretical model in chapter 3 (precisely chapter 3.3) extends the theoretical model (and computer code) of chapter 2 (precisely of chapter 2.3) by an asymmetric effect of macroeconomic integration on capital costs in tradable and non-tradable production. This is motivated by the intuition, that European macroeconomic integration should affect (export oriented) tradable production stronger than it affects non-tradable production. One motivation for this argument is mentioned in Griffith, Harrison, Simpson (2010), shown in chapter 3. Another motivation for this argument is found in Piton (2019, see also 2021). In contrast to the findings of chapter 1 and chapter 2, macroeconomic integration (in chapter 3 modelled by an asymmetric effect on capital costs in tradable and non-tradable production) does now (in chapter 3) induce a reallocation of labour resources out of tradable production into non-tradable production. Depending on the calibration, this slows (the growth rate of) productivity. The central finding of chapter 3 is that macroeconomic integration does not slow productivity by reducing interest rates. Macroeconomic integration slows productivity if it asymmetrically reduces capital costs in tradable production. Further research should consider a stronger empirically based calibration of the model in chapter 3 (precisely chapter 3.3 and 3.4). Moreover, further research should consider frictions in capital accumulation, like shown in, for example, Gopinath et al. (2017).

Chapters 2.3 and 3.3 and their description are based on and are borrowed from (the descriptions in) chapter 1.3. Chapters 2.4 and 3.4 and their description are based on and are borrowed from (the descriptions in) chapter 1.4. Chapter 1 was a joint research project with my supervisor and co-author, Jochen Michaelis. Thus, the work and its description of Jochen Michaelis contributed to a large extent to the (descriptions in) chapters 2.3 and 2.4 and to the (descriptions in) chapters 3.3 and 3.4.

As chapter 2 and chapter 3 are based on and borrow from chapter 1, there are similarities of chapter 2 and chapter 3 with the published version of chapter 1 (Hildebrandt, Michaelis, 2022, MAGKS Discussion Paper). The list of references of this *'Motivation'* chapter is included in chapter 4.

1. The Financial Resource Curse Revisited: The Supply-Side Effect of Low Interest Rates [2] [3]

The theory of Benigno and Fornaro (2014) explains that interest rate reductions affected the peripheral eurozone in the 1990s and 2000s, focusing on Spain. Low interest rates push consumption, which is crowding out tradable production by non-tradable production. Consequently, labour resources depart tradable production and relocate to non-tradable production, to satisfy promoted non-tradable consumption. This depresses learning-by-doing, (the growth rate of) (labour-) productivity and potentially welfare, termed as *Financial Resource Curse* (Benigno, Fornaro, 2014). This theory did not consider the beneficial supply-side effect that lower interest rates and credit expansion (eased capital access) have by accelerating capital accumulation (see, e.g., Mian, Sufi, Verner, 2020, Blanchard, Giavazzi, 2002, Gorton, Ordoñez, 2020), potentially pushing labour productivity and welfare. Extending the model and computer code of Benigno and Fornaro (2014) by capital as a second production factor (by using the model of de Cordoba, Kehoe, 2000), we find that the beneficial supply-side effect outweighs the *Financial Resource Curse* (for most of the parameter constellations we checked for), modelling a three-sector, two-factor small open economy.

1.1 Introduction

During European integration, actors in peripheral Europe realized reductions of interest rates when borrowing globally, from the eased access to international capital (Benigno, Fornaro, 2014, Sinn, 2012, 2015). The group of peripheral European economies is often called *GIPS* economies, Greece, Italy, Portugal, and Spain.[4] Spain's suffering from low interest rates Benigno and Fornaro (2014) named *The Financial Resource Curse*.

Theory explains (Benigno, Fornaro, 2014, see also Sinn, 2012, 2015):

[2] We thank Max Fuchs, Beverley Locke, Matthias Kapa, Luzie Thiel, Andreas Hanl, Jan Hattenbach, and Philipp Kirchner for their helpful suggestions to improve this chapter. We also thank the participants of the 25th Annual International Conference on Macroeconomic Analysis and International Finance, University of Crete in Rethymno, July 2021. We thank Pierre-Olivier Gourinchas and Tomas Havranek for their helpful suggestions to improve this chapter. We also thank Gianluca Benigno and Luca Fornaro for sharing and introducing their computer code with/to us. Moreover, we thank Gonzalo Fernandez de Cordoba and Timothy Kehoe for their computer code and support. We also thank the participants at the Graduate school 'Economic Behavior and Governance' seminars in Kassel.

This chapter (chapter 1) 'The Financial Resource Curse Revisited: The Supply-Side Effect of Low Interest Rates' was written in co-authorship (joint research project) together with my supervisor and co-author, Prof. Dr. Jochen Michaelis, University of Kassel.

[3] An earlier version of this chapter (chapter 1) 'The Financial Resource Curse Revisited: The Supply-Side Effect of Low Interest Rates' was published as MAGKS Discussion paper No. 22-2022 (May 2022) (Hildebrandt, Michaelis, 2022). We also submitted (for publication) an earlier version of this chapter (chapter 1) at a journal (May 2022) and are waiting for an answer (20th September 2022).

[4] Sinn (2012, 2015) also includes Cyprus and Ireland in his analysis of peripheral European economies and their response to European (macroeconomic) integration. We focus on GIPS economies, as Ireland has managed to recover disproportionally fast from the adverse effects of European (macroeconomic) integration (Sinn, 2012, 2015), and Cyprus adopted the Euro (a major step of European integration) later (in 2013) than GIPS economies.

Before European (macroeconomic) integration[5], Spain was historically used to high interest rates which compensated international bankrollers for economic risk. European (macroeconomic) integration lowered such risk, resulting in lower interest rates that Spanish actors had to pay. Lower interest rates from risk lowering macroeconomic integration induced Spanish actors to raise international debt, promoting a debt-financed domestic consumption boom. Increasing domestic consumption induced in an economy divided in tradable production (tradable sector T, simplified: manufacturing) and non-tradable production (non-tradable sector N, simplified: services), productive resources to depart sector T and to relocate to sector N. Increased domestic consumption of non-tradable goods is satisfied by growing domestic non-tradable production, demanding productive resources. Increasing domestic consumption of tradable goods is satisfied by running trade deficits (Benigno, Fornaro, 2014, see also Sinn, 2012, 2015).

Promoted economic activity in sector N and slowed economic activity in sector T slows (the growth rate of) economy wide total-factor-productivity, as particularly sector T promotes economy wide (total-factor) productivity by adapting foreign technology and knowledge (Benigno, Fornaro, 2014, and Benigno, Fornaro, Wolf, 2020, based on Duarte, Restuccia, 2010, and Rodrik, 2013). Following Benigno and Fornaro (2014), a slowdown in (the growth rate of) (total-factor) productivity *potentially* undermines output and welfare.

Following the literature on the potentially promoted catching up of emerging economies when integrating macroeconomically (see, e.g., Blanchard, Giavazzi, 2002, for European integration), we challenge the Benigno and Fornaro (2014) hypothesis of potentially harmful interest rate reductions and international capital access. We address that low interest rates and the eased access to (international) capital (credit expansion) may also have a beneficial supply-side effect by promoting capital accumulation (see, e.g., Gorton, Ordoñez, 2020, Tornell, Westermann, 2003, Blanchard, Giavazzi, 2002, Benigno, Converse, Fornaro, 2015, Mian, Sufi, Verner, 2020). Potentially, the supply-side effect *increases* domestic output, welfare, and labour-productivity.

In their theoretical model, Benigno and Fornaro (2014) restricted tradable and non-tradable production to using a single production factor, labour. We investigate if the theoretical findings of Benigno and Fornaro (2014) prevail, after extending the Benigno and Fornaro (2014) model and their computer code by a second production factor, capital, and a third sector, producing capital goods, by using the model of de Cordoba and Kehoe (2000).

Finding evidence on our hypothesis, our results show for a meaningful calibration that the supply-side effect outweighs the *Financial Resource Curse*, for many parameter constellations we checked for.

Referring to a *Resource Curse,* Benigno and Fornaro (2014) underline the adverse effects that interest rates reductions may have by arguing for a crowding out of sector T employment. Discussed in the literature on resource curses, the adverse impact of temporarily increasing global *commodity prices* on commodity exporting economies results from a crowding out of sector T employment. The adverse impact materializes when considering sector T employment as an enabler of technology/knowledge accumulation from learning-by-doing (Alberola, Benigno, 2017, Benigno, Fornaro, 2014, Harms, 2008).

[5] Benigno and Fornaro (2014, p.59) refer to (European) '*financial* integration'. We refer to 'European *macroeconomic* integration', as it paves the way to the findings of the Ph.D. thesis at hand (see particularly chapter 3).

Benigno and Fornaro (2014) argue like Sinn (2012, 2015). Investigating GIPS economies European (macroeconomic) integration, Sinn (2012, 2015) argues that the eased access to international capital and reduced interest rates was reflected in reduced *yield spreads* on interest rates of GIPS economies, reduced by European integration. Before the European integration of the GIPS economies, such *yield spreads* compensated international bankrollers for economic risk, and for the risk of currency devaluation in GIPS economies. Sinn (2012, 2015) argues that the European (macroeconomic) integration of GIPS economies and merged European currencies reduced (the awareness for) those risks, and thus the yield spreads on interest rates in GIPS economies when borrowing from international bankrollers. Reduced (yield spreads on) interest rates promoted debt-financed private (or governmental) consumption in GIPS economies, resulting in a demand driven economic boom, starting from the progression of European integration of GIPS economies on. Demand driven economic booms drove up economy wide wage levels, undermining the competitiveness of (tradable production in) GIPS economies during their European integration. Sinn (2015) underlines the slowdown of economic activity in the tradable production in GIPS economies from having lost its competitiveness. This went on behalf of a demand-driven economic boom in non-tradable production (public/governmental[6] sectors or construction/real estate) in GIPS economies (see also Sinn, Wollmershäuser, 2012, underlining lost competitiveness).

Motivating our research, figure 1.1 shows the forced private *domestic* investment into GIPS economies' capital stocks (right hand side, rhs) when (yield spreads on) interest rates reduced (left hand side, lhs). 'Yield spread' measures an economy's long-term interest rate yield spreads over long-term interest rates of Germany as a proxy for risk-free assets, based on 10-year government bonds (Sinn, 2012, 2015, Sibbertsen, Wegener, Basse, 2014, Geyer, Kossmeier, Pichler, 2004, Bernoth, von Hagen, Schuknecht, 2012). 'Private Investment to GDP' measures an economy's domestic private investment into domestic capital stocks, relative to the economy's GDP. Private domestic investment accompanies reduced (yield spreads on) interest rates. The clearest pictures are Spain, Italy, and Greece.

Easing international capital flows, European (macroeconomic) integration with reduced (yield spreads on) interest rates (left hand side, lhs) also accompany *international* capital flowing to the macroeconomically integrating economy (right hand side, rhs) in figure 1.2. 'FDI to GDP' measures the economy's net foreign direct investment inflow, relatively to GDP. Clearest pictures are Spain, Greece, and Italy. Portugal does not confirm the hypothesis of our work (chapter 1).

Chapter 1 is organized as follows: Chapter 1.2 overviews the literature related to our research question. Chapter 1.3 describes our theoretical model. Chapter 1.4 shows the calibration of numerical simulations. Chapter 1.5 presents the results of numerical simulations for an economy that experiences a temporary reduction of interest rates. Chapter 1.6 concludes.

[6] Harms (2008) mentions that an increase in public/governmental expenditure goes mostly on behalf of domestic non-tradable sectors. As our theoretical model in chapter 1.3 abstracts from a public/governmental sector, one might also categorize the public/governmental sector as non-tradable production.

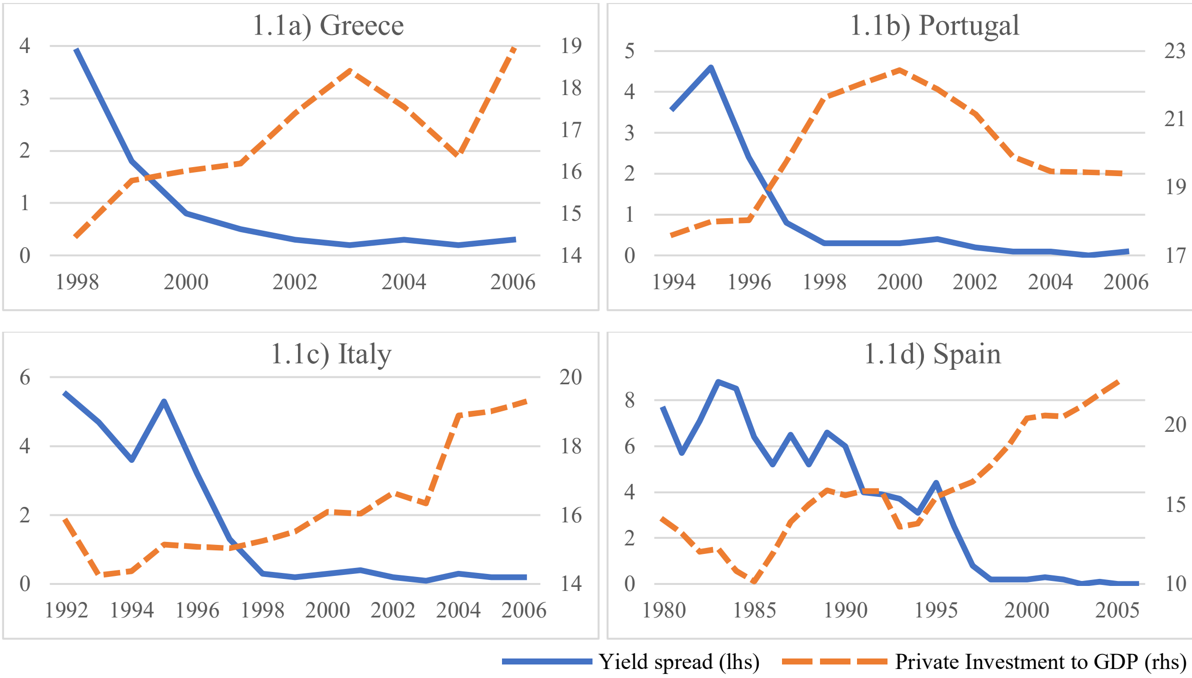

Figure 1.1: GIPS economies interest rate yield spread (lhs) and domestic private investment to GDP (rhs).

Source: IMF (2015), OECD (2022a). The approach to calculate an (GIPS) economy's interest rate yield spread as the same (GIPS) economy's ten-year government bond yield deducted by ten-year government bond yield of Germany as benchmark can be found, among others, in Sibbertsen, Wegener, Basse (2014), Geyer, Kossmeier, Pichler (2004) and Bernoth, von Hagen, Schuknecht (2012), and is indicated in Sinn (2012, 2015). OECD (2022a) data on ten-year government bond yields are rounded to one decimal place. Yield spreads are own calculations.

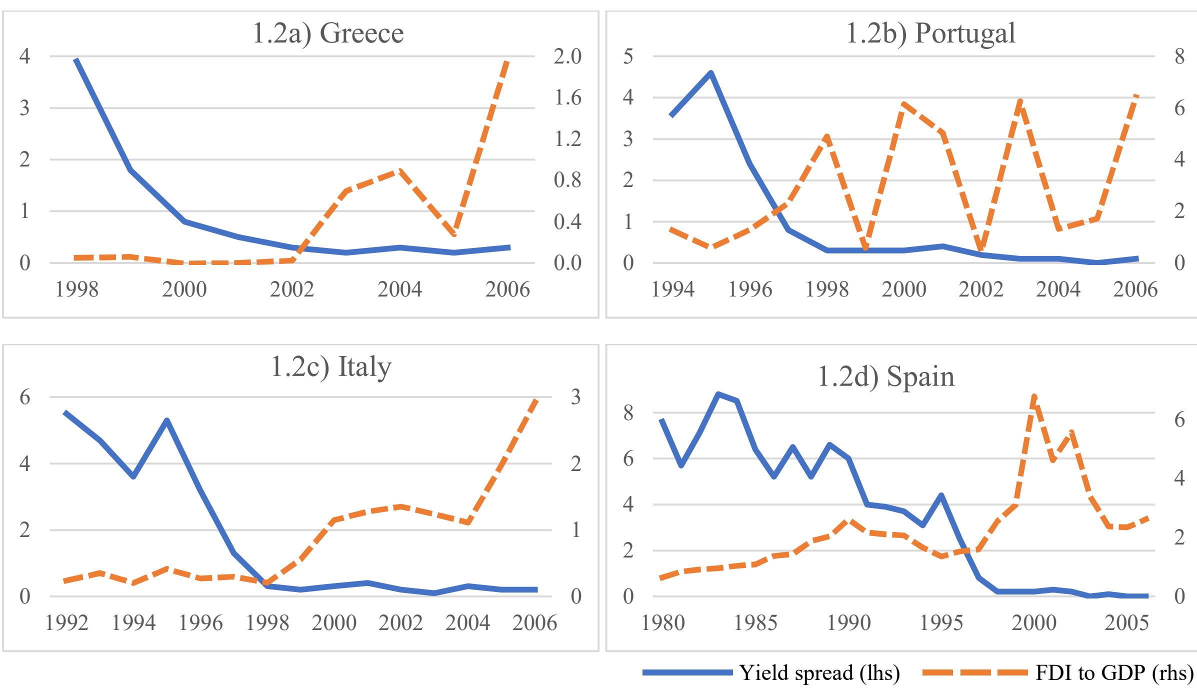

Figure 1.2: GIPS economies interest rate yield spread (lhs) and foreign direct investment net inflow to GDP (rhs).

Source: OECD (2022a), Worldbank (2022). The approach to calculate an (GIPS) economy's interest rate yield spread as the same (GIPS) economy's ten-year government bond yield deducted by ten-year government bond yield of Germany as benchmark can be found, among others, in Sibbertsen, Wegener, Basse (2014), Geyer, Kossmeier, Pichler (2004) and Bernoth, von Hagen, Schuknecht (2012), and is indicated in Sinn (2012, 2015). OECD (2022a) data on ten-year government bond yields are rounded to one decimal place. Yield spreads are own calculations.

1.2 Literature

Related to the mechanics of Resource Curses, Benigno and Fornaro (2014) show how a catching up small open economy potentially *suffers* from temporary reductions of interest rates, despite they imply servicing foreign debt at reduced running off interest payments. In their theoretical approach, Benigno and Fornaro (2014) analyse a two-sector small open economy. Benigno and Fornaro (2014) model the production of non-tradable (N) goods linear in labour deployed in sector N. The production of tradable (T) goods they model as labour deployed in sector T, augmented by a technology (total-factor-productivity) only sector T accesses. Total-factor-productivity grows over time by learning-by-doing of sector T employment, adapting technology from the world technology leader. They find that lower interest rates depress the domestic (growth rate of) (total-factor-) productivity, and potentially welfare (depending on their calibration). Lower interest rates push debt financed domestic consumption, requiring a resource reallocation out of tradable production into non-tradable production. The resource reallocation reduces learning-by-doing and technology accumulation in tradable production. From their modelling, sector T total-factor-productivity equals labour-productivity in their model.

Our work contributes to the research on Resource Curses, the economic response of commodity exporting economies which (temporarily) experience increasing commodity prices. Synonymously the ‘Dutch Disease’ term entered the literature when gas extracting Holland suffered from gas price increases in the 1960s (Bjørnland, Thorsrud, 2016, Sinn, 2012, 2015, Harms, 2008). While one expects that temporary increases in world commodity prices benefit commodity exporting economies, the research on Resource Curses shows adverse effects from technology externalities, summarized in Harms (2008) and Alberola and Benigno (2017).

Alberola and Benigno (2017) extend the Benigno and Fornaro (2014) model by a second production factor, intermediate goods, utilized as input in sectors T and N, and a third sector, producing them (intermediate goods). Alberola and Benigno (2017) investigate an intermediate goods price upswing, to research a commodity exporting economy's response to a temporary world commodity price increase. Allowing for complete sectoral specialization, they found that high world commodity prices slow the commodity exporting economy's (growth rate of) total-factor-productivity. The increase of world commodity prices moves labour force to the domestic commodity sector, out of domestic sector T, that is thus providing less learning-by-doing and technological progress.

From a growth perspective, Funke and Strulik (2000) review models of endogenous growth and categorize them into an economies’ three stages (I, II, III) of development. Models describing early phases of economic development (stage I) describe growth in developing economies particularly by improving their capital endowment. At best and doing so, economies enter stage II, enabling economic growth of emerging economies particularly by accumulating human capital (for example developed at the world technological frontier, see also Benigno, Fornaro, 2014). Gone through the same, economies worked up to a developed economy (stage III) grow by inventing (new ideas, knowledge, products, production processes or services) by research and development. The Funke and Strulik (2000) model unites all three stages capably but does not model sectoral resource allocations and their growth implications.

Benigno, Converse, and Fornaro (2015) research empirically the impact of 'large' net capital inflows on domestic growth and on sectoral resource allocation, using data from 1980 to 2015 for 70 middle- and high-income economies. They find significant net capital inflows to initially benefit total-factor-productivity. Here, Benigno Converse and Fornaro (2015) argue that this might also mirror improved capacity utilization, resulting from the economic boom that capital flows induce. For the end of the period of large capital inflows, Benigno, Converse and Fornaro (2015) found a decrease of total-factor-productivity. They also found a slowdown of value added in manufacturing sectors and a promotion of value-added in service sectors during the period of large capital inflows, accompanied by a reduction of manufacturing employment. Opposing these *general* observations, in Baltic economies and in Poland, Hungary, and Bulgaria, significant net inflows of foreign capital related to *increasing* employment in manufacturing.

Emter (2020) researches empirically the connection between international capital inflows, domestic economic growth, and the appearance of economic crises by sudden stops. He samples 98 industrialized, emerging and developing economies from 1990 to 2018. Researching the factors that cause sudden stops in capital inflows, Emter (2020) argues that until his research the attention was on global factors, like contagion and changing global risk aversion. Contrary, he found particularly domestic factors like private sector leverage and domestic productivity shocks that impact the emergence of economic crises by sudden stops after a period of significant capital inflows.

Rodrik (2013) analyses 118 economies, covering a timespan from 1965 to 2005, to analyse the development of labour-productivity of up to 20 industries in each economy. He finds a converging labour-productivity in manufacturing industries (producing mostly tradable goods) towards the industry's world technological leader. Rodrik (2013) provides an indication that this does not seem to hold in industries classified as services (producing mostly non-tradable goods). Rodrik (2013) assigns his observation to the fact that manufacturing companies (producing mostly tradable goods) are included in international production chains. This augments technology accumulation from abroad and reflects that international competition forces companies to adapt new production technologies (see also Duarte, Restuccia, 2010. Moreover, Blanchard, Giavazzi, 2002, underline aggregate productivity effects of competition).

The theoretical approach by de Cordoba and Kehoe (2000) analyses how a three-sector small open economy responds to European macroeconomic integration. Modelling Spain's European integration in the 1990s, both final good sectors (T and N) utilize labour, capital, and a sector specific technology (total-factor-productivity). They find that frictions in resource adjustments between sectors T and N are required to explain the empirical reaction of macroeconomic variables like the trade balance and real exchange rates of the Spanish economy. Contrasting the theoretical approach by Benigno and Fornaro (2014), de Cordoba and Kehoe (2000) do not consider (total-factor-) productivity growth in none of the three sectors (T, N, and K) and no exogenous changes in interest rates but include capital in sectors T and N as production factor.

Benigno, Fornaro and Wolf (2020) analyse in a two-goods, two-factor, two-economies (core and periphery) model the impact that low interest rates have on the performance of the core economy. Low interest rates emerge from the 'core' economy's monetary integration with the 'peripheral' economy. Benigno, Fornaro and Wolf (2020) define the core economy as the centre of the model's economic and financial activity, providing financial assets to the peripheral economy. The peripheral economy enjoys holding the core economy's financial assets. The core economy also embodies the technological leader of the model, growing from innovations generated by economic activity in domestic sector T, promoting domestic productivity. The peripheral economy grows by adapting the core economy's technology. In autarky, from higher consumption propensity, the core economy realizes lower savings and higher interest rates. Contrary, in autarky, the peripheral economy realizes lower interest rates from a higher propensity of saving. Should both economies integrate (macroeconomically), the ‘global’ interest rate emerging in the new equilibrium averages the two autarky interest rates. For the core economy, this reduces interest rates, fostering consumption of both tradable and non-tradable goods, relocating resources into sector N, away from sector T (comparable to the Benigno, Fornaro, 2014, mechanism). This slows the productivity in the core economy. As the peripheral economy’s productivity grows by adapting the core's technology (productivity), productivity in the peripheral economy slows as well. Benigno, Fornaro and Wolf (2020) include labour and intermediate goods as production factors in tradable and non-tradable production, but no capital.

Ranciere, Tornell and Westermann (2008) find that credit expansion from financial liberalization relates to a higher crisis probability (credit might default), but also to higher long-run growth rates from better-working financial markets. From a similar motivation, Ranciere, Tornell and Westermann (2003) provide a small open economy model with goods production in two sectors, N and T. Fulfilling its financial needs, sector N is focussed on the domestic market, if the small open economy is not financially liberalized. When this changes, financial liberalization benefits particularly domestic sector N, enabling it to raise more credit and to build up sector N capital stocks. While the additional raising of credit leads in the short run to occasional economic crises by credit default, in the longer run, first domestic sector N benefits from an improved capital endowment. Later, also domestic sector T benefits from improved capital endowment in sector N, as sector N supplies intermediate service inputs to sector T.

Wagner (2007) surveys that the productivity of firms who are exporting is higher than the productivity of firms who do not export. Wagner (2007) hypothesizes, on the one hand, that firms with a higher productivity self-select into export markets, as exporting is more difficult than selling domestically. On the other hand, he hypothesizes, it is possible that exporting improves productivity, as international competition forces firms to improve themselves. Wagner (2007) finds evidence on the first hypothesis. More productive firms decide to export. Evidence on the second hypothesis, exporting improves firms, he finds mixed.

1.3 Model

Our model (chapter 1.3) and its computer code build on and are based on those of Benigno and Fornaro (2014). We extend their model and their computer code by the production factor capital (K), following the model of de Cordoba and Kehoe (2000). Our model chapter 1.3 borrows heavily from Benigno and Fornaro (2014) and from de Cordoba and Kehoe (2000).

Firms produce three types of goods, tradable (T) and non-tradable (N) consumption goods, and capital goods (K). The perfect foresight small open economy is fully integrated in world markets.

Households

The economy is populated by a continuum of identical households with population size normalized to unity. The representative household maximizes the utility function:

$$U_t = \sum_{t=0}^{\infty} \beta^t log C_t, \tag{1.1}$$

where β is the discount factor, and C_t is a consumption index:

$$C_t = (C_t^T)^{\omega} (C_t^N)^{1-\omega}. \tag{1.2}$$

C_t^T and C_t^N are the consumption of tradable and non-tradable goods. Parameter ω is the expenditure share of the tradable good. From (1.1) and (1.2), and according to Benigno and Fornaro (2014), the elasticity of substitution between two available types of goods and the intertemporal elasticity of substitution between goods across periods is restricted to unity. The household supplies labour inelastically without loss of utility. The budget constraint of the representative household reads:

$$C_t^T + P_t^N C_t^N + \frac{as_{t+1}}{R_t} = W_t L + as_t + \pi_t^T + \pi_t^N + \pi_t^K, \tag{1.3}$$

where

$$as_{t+1} = B_{t+1} + q_t K_{t+1}^{TD} + q_t K_{t+1}^{ND}. \tag{1.4}$$

Like in de Cordoba and Kehoe (2000), the tradable good serves as numeraire, the price is given by the world market and is normalized to unity; P_t^N is the relative price of the non-tradable good in the form of the tradable good, L is the endowment of labour, which receives wage rate W_t (assumed identical across sectors N and T, like in Benigno, Fornaro, 2014). To simplify, we do not allow for foreign direct investment. Domestic firms are wholly owned by domestic households, profits from firms in the tradable sector T, π_t^T, the non-tradable sector N, π_t^N, and the capital goods sector K, π_t^K, go to the representative household.

The (domestic) household purchases and holds assets in three forms, bonds B_{t+1}, domestic capital invested in sector T, K_{t+1}^{TD}, and domestic capital invested in sector N, K_{t+1}^{ND}. All assets purchased in period t are priced at $1/R_t$, and redeemed in period $t+1$. The price of a capital good in the form of the tradable good, q_t, as well as the gross interest rate, R_t, are given by the world market.

Capital goods purchased in period t must be put in place one period before they are used, i.e., these goods turn into capital for production in the subsequent period $t+1$ (like in de Cordoba, Kehoe, 2000).

The representative household chooses C_t^T, C_t^N and as_{t+1} to maximize the utility function (1.1) subject to the budget constraint (1.3). From the solution of this problem, we get the demand function for non-tradable goods:

$$C_t^N = \frac{1-\omega}{\omega}\frac{1}{P_t^N}C_t^T, \tag{1.5}$$

and

$$C_{t+1}^T = \beta R_t C_t^T, \tag{1.6}$$

as standard Euler equation for optimal intertemporal tradable consumption (see Benigno, Fornaro, 2014).

Firms

Tradable Sector (T, tradable production). Firms in the tradable sector combine L_t^T workers with K_t^T units of real capital to produce output Y_t^T. The production-technology is Cobb-Douglas with constant returns to scale:

$$Y_t^T = A_t(L_t^T)^{\alpha}(K_t^T)^{1-\alpha}, \tag{1.7}$$

where the stock of technology A_t is a total-factor-productivity shifter. Emphasized by Benigno and Fornaro (2014), the assumption on the endogenous process of technology accumulation is key for their results. Benigno and Fornaro (2014) term it 'knowledge accumulation'. We term it 'technology accumulation', because of our modelling of the Cobb-Douglas production function:

$$A_{t+1} = A_t\left[1 + cL_t^T\left(1 - \frac{A_t}{A_t^*}\right)\right]. \tag{1.8}$$

There is a world technological leader, whose stock of technology A_t^* grows with the exogenous yearly rate g^*. The domestic economy is well behind, $A_t < A_t^*$, but catches up. The speed of convergence is determined by a convergence parameter *c*, and by employment in the tradable sector. Because of international competition, the tradable sector absorbs foreign technology (Rodrik, 2013, Duarte, Restuccia, 2010. Blanchard, Giavazzi, 2002, underline aggregate productivity effects of competition). For a more detailed motivation of (1.8), we refer to Benigno and Fornaro (2014), who introduced (1.8) to describe sector T technology accumulation in their model.[7]

Regarding capital as input, domestically financed/produced capital (goods), installed in the domestic sector T (in the following: domestic sector T capital) K_t^{TD}, and foreign financed/produced capital (goods), installed in

[7] In our model, we stick to assumption (1.8). However, given the literature (see, e.g., Bijsterbosch and Kolasa, 2010, Lee and Chang, 2009, Girma, 2005, Chamarbagwala, Ramaswamy, Wunnava, 2000, Eaton, Kortum, 2001), we suppose that the inflow of Foreign Direct Investment, foreign capital, and/or multinationals constitutes a second (and probably more direct) mechanism to accumulate foreign technology and to push productivity. Chapter 2 of the Ph.D. thesis at hand investigates the impact of this mechanism in a more detailed manner.

the domestic sector T (in the following: foreign sector T capital) K_t^{TF}, are treated as identical inputs. To be in line with Benigno and Fornaro (2014), we do not include foreign capital into Eq. (1.8).

It is important to underline, that capital received from domestic (D) and foreign (F) capital goods production and utilized by sector T firms (and by sector N firms) is not necessarily equity financed. Particularly, the interpretation of being debt financed is standing to reason.

The capital stock in sector T K_t^T is assumed as an aggregation of foreign and domestic sector T capital. Our model requires foreign capital (K_t^F) to be invested in tradable production (depicted K_t^{TF}) and in non-tradable production (depicted K_t^{NF}) of the small open economy.

We assume:

$$K_t^T = K_t^{TD} + K_t^{TF}, \tag{1.9}$$

with domestic sector T capital, K_t^{TD}, and foreign sector T capital, K_t^{TF}. Capital depreciates with rate δ, capital accumulation follows $K_{t+1}^{TD} = (1-\delta)K_t^{TD} + I_t^{TD}$ and $K_{t+1}^{TF} = (1-\delta)K_t^{TF} + I_t^{TF}$, where I_t^{TD} and I_t^{TF} are investments during period *t* in sector T. I_t^{TD} is produced by the domestic capital goods sector, I_t^{TF} is imported from foreign.

Firms in sector T hire workers up to the point where the marginal product of labour equals the wage:

$$W_t = MPL_t^T = \alpha A_t (L_t^T)^{\alpha-1} (K_t^T)^{1-\alpha}. \tag{1.10}$$

In period $t-1$, firms in sector T decide on the optimal capital stock for production in period t:

$$MPK_t^T + (1-\delta)q_t = R_{t-1}q_{t-1}, \tag{1.11}$$

$$MPK_t^{TF} = MPK_t^{TD}. \tag{1.12}$$

Firms act on behalf of the representative (domestic) household who is the owner of the firms. From the household point of view, bonds and capital invested in sectors T and N are perfect substitutes (see Eq.(1.4)), the rate of return must be equal (see de Cordoba, Kehoe, 2000, for a two-sector-case, see also Funke, Strulik, 2000, for a one-sector case):

In period $t-1$, capital goods cost q_{t-1}, the yield is the additional output in period t (marginal product of capital MPK_t^T) plus the value of the depreciated capital good at the end of period t, $(1-\delta)q_t$. The investment of q_{t-1} in a bond yields the gross return $R_{t-1}q_{t-1}$, embodying opportunity costs (see de Cordoba, Kehoe, 2000, for a two-sector-case, see also Funke, Strulik, 2000, for a one-sector case). Firms can import capital goods from abroad/'foreign', Eq. (1.12) is the no-arbitrage condition.

Non-Tradable Sector (N, non-tradable production). The output of the non-tradable good Y_t^N is produced with labour, L_t^N, and real capital, K_t^N. Again, the production-technology is Cobb-Douglas:

$$Y_t^N = (L_t^N)^{\alpha}(K_t^N)^{1-\alpha}. \tag{1.13}$$

Like in Benigno and Fornaro (2014), total-factor-productivity in sector N is fixed to unity, in the non-tradable sector there is no accumulation of foreign technology, no technological progress, derived from the findings of Rodrik (2013) and of Duarte and Restuccia (2010).

Like Eq. (1.9), we assume a simple aggregation:

$$K_t^N = K_t^{ND} + K_t^{NF}, \tag{1.14}$$

across domestically financed/produced capital (goods), installed in the domestic sector N (in the following: domestic sector N capital) K_t^{ND}, and foreign financed/produced capital (goods), installed in the domestic sector N (in the following: foreign sector N capital) K_t^{NF}. Capital accumulation follows $K_{t+1}^{ND} = (1-\delta)K_t^{ND} + I_t^{ND}$ and $K_{t+1}^{NF} = (1-\delta)K_t^{NF} + I_t^{NF}$, where investment I_t^{ND} is produced by the domestic capital goods sector, investment I_t^{NF} is imported from foreign.

The first-order conditions of firms in sector N for labour and capital are:

$$W_t = P_t^N \cdot MPL_t^N = P_t^N \cdot \alpha(L_t^N)^{\alpha-1}(K_t^N)^{1-\alpha}, \tag{1.15}$$

$$P_t^N \cdot MPK_t^N + (1-\delta)q_t = R_{t-1}q_{t-1}, \tag{1.16}$$

$$MPK_t^{NF} = MPK_t^{ND}. \tag{1.17}$$

Again, in period $t-1$, firms decide on the optimal capital stock for production in period t. Like in common Samuelson Balassa models, from perfect labour mobility across sectors, firms in the non-tradable sector must pay the same wage as firms in the tradable sector. Eqs. (1.16) and (1.17) rest on the assumption that all three forms of assets – bonds, capital invested in sector T, and capital invested in sector N – are perfect substitutes. De Cordoba and Kehoe (2000) model similarly for a two sector (N and T) economy. See also Funke and Strulik (2000) who assume equal capital and bond return in a one-sector-model.

To connect sectoral capital stocks with the budget constraint of the household (1.3) we make use of $K_t^D = K_t^{TD} + K_t^{ND}$ and $K_t^F = K_t^{TF} + K_t^{NF}$.

By combining the optimality conditions, we get:

$$\frac{K_t^T}{L_t^T} = \frac{K_t^N}{L_t^N}, \tag{1.18}$$

$$P_t^N = A_t \; . \tag{1.19}$$

Eq. (1.18) implies that capital stocks per worker are identical across sectors (see also Gopinath et al., 2017). Eq. (1.19) describes the familiar Samuelson-Balassa effect. Total-factor-productivity (A_t) growth in the sector producing tradable goods pushes up labour demand in this sector T. Tradable production increases its wages to attract workers. Non-tradable production has no productivity advances but must pay the same (higher) wage. Thus, non-tradable production faces an increase in the marginal costs of production. This leads to an increase in the relative price (P_t^N) of non-tradable goods.

Employment in sector T and N add up to the labour endowment:

$$L_t^T + L_t^N = L \tag{1.20}$$

We will calibrate $L = 1$ in chapter 1.4. Then, from (1.18) combined with (1.20) it is concluded:

$$L_t^T = \frac{K_t^T}{K_t^T + K_t^N} \, . \tag{1.21}$$

Eq. (1.21) implies that the share of labour supply employed in sector T equals the share of capital goods employed in sector T. As capital stocks K_t^T and K_t^N are set in period $t-1$, this implies that the sectoral labour supply for period t is fixed in period $t-1$. This is important to keep in mind when interpreting the reaction of L_t^T to our experiment with the interest rate in chapter 1.5 on numerical simulations.

Capital goods sector (K, capital goods production). The modelling of domestic capital goods production very much follows de Cordoba and Kehoe (2000), who assume that real capital goods are produced by using the tradable good and the non-tradable good as inputs. The production-technology[8] is Cobb-Douglas:

$$I_t^D = (A_t)^{\mu} (Z_t^T)^{\gamma} (Z_t^N)^{1-\gamma}, \tag{1.22}$$

where I_t^D is the domestic output of capital goods (machinery), augmenting domestic capital accumulation. Z_t^T is the input of the tradable good into capital goods production, and Z_t^N is the input of the non-tradable good into capital goods production. As de Cordoba and Kehoe (2000, p.57) mention, these inputs "…can be thought of loosely as equipment and structures". We deviate from de Cordoba and Kehoe (2000) by incorporating tradable production total-factor-productivity A_t with parameter μ in capital goods production (1.22). The reason is that sector T and sector K produce physically tangible goods in an industrial or manufacturing production process and both sectors T and K are exposed to international competition. From the exposure to international competition (Rodrik, 2013, Duarte, Restuccia, 2010), we regard it as meaningful, that sector K can use the same technology, A_t, as sector T does. As technology A_t is built up (developed) in sector T, we also regard it as meaningful that the capital goods sector K absorbs foreign technology (via sector T technology A_t) slower than firms in sector T, $0 < \mu < 1$.

[8] We gratefully thank Max Fuchs for his helpful suggestion/comment to improve our design of the capital goods production function.

Maximizing the profit function $\pi_t^K = q_t I_t^D - Z_t^T - P_t^N Z_t^N$ with respect to inputs leads to:

$$\frac{Z_t^T}{Z_t^N} = \frac{\gamma}{1-\gamma} P_t^N. \tag{1.23}$$

Because of the Samuelson-Balassa effect, the relative price P_t^N increases period by period. Therefore, the non-tradable good as factor of production becomes more expensive period by period, and firms in capital goods sector K adjust the optimal production plan by switching from Z_t^N to Z_t^T, the ratio Z_t^T/Z_t^N rises continuously.

Equilibrium

Our economy consists of four markets, two goods markets (tradable and non-tradable goods) and two factor markets (labour and capital goods). A general equilibrium requires that all markets in the economy are simultaneously in equilibrium.

The labour market is in equilibrium when the time inelastic labour supply by households (labour endowment) is equal to labour demand from firms of tradable production (sector T) and non-tradable production (sector N):

$$L = L_t^T + L_t^N. \tag{1.24}$$

The capital goods sector is in equilibrium when the domestic output of capital goods is equal to the demand for domestically produced capital goods from firms of sector T and sector N:

$$I_t^D = I_t^{TD} + I_t^{ND} = K_{t+1}^D - (1-\delta)K_t^D. \tag{1.25}$$

The market clearing condition for the non-tradable good:

$$C_t^N + Z_t^N = Y_t^N, \tag{1.26}$$

implies that sector N output is either consumed by the domestic household or is invested as an input in the domestic production of capital goods (1.22).

Depending on the domestic output (Y_t^N and Y_t^T) and consumption (C_t^N and C_t^T), Z_t^N and Z_t^T go to the domestic capital goods production (1.22).

Making use of (1.4), (1.24), (1.26) and of firms' profit functions (sectors T, N, K), the household budget constraint (1.3) delivers the market clearing condition for the tradable good:

$$C_t^T + \frac{B_{t+1}}{R_t} - B_t = Y_t^T - Z_t^T - q_t I_t^F + \frac{q_t K_{t+1}^F}{R_t} - q_{t-1} K_t^F, \tag{1.27}$$

where $I_t^F = I_t^{TF} + I_t^{NF}$ is the (payment for the) import of capital goods, $q_t K_{t+1}^F / R_t$ is firms' borrowing of funds from abroad/'foreign' in period t, and $q_{t-1} K_t^F$ is the repayment of foreign funds raised in period $t-1$.

In a next step, let us turn to the current account of the considered economy. Like in Benigno and Fornaro (2014), an economy's current account is defined as the change in its net foreign assets, $CA_t = NFA_t - NFA_{t-1}$. The value of bonds acquired by the representative household in period t is B_{t+1}/R_t, the value of foreign funds raised by firms equals $q_t K_{t+1}^F/R_t$, thus $NFA_t = B_{t+1}/R_t - q_t K_{t+1}^F/R_t$. Backdating yields $NFA_{t-1} = B_t/R_{t-1} - q_{t-1}K_t^F/R_{t-1}$. Now the market clearing condition for the tradable good (1.27) can be rearranged for the current account (derived like in Benigno, Fornaro, 2014):

$$CA_t = Y_t^T - Z_t^T - C_t^T - q_t I_t^F + \frac{B_t - q_{t-1}K_t^F}{R_{t-1}}(R_{t-1} - 1). \tag{1.28}$$

The period t current account is given by net exports, $Y_t^T - Z_t^T - C_t^T - q_t I_t^F$, plus the interest earned on net foreign assets acquired in period $t - 1$.

The intertemporal resource constraint (Obstfeld, Rogoff, 1996):

$$\sum_{s=t}^{\infty} Q_{t,s} CA_s = -\frac{B_t - q_{t-1}K_t^F}{R_{t-1}}, \tag{1.29}$$

with:

$$Q_{t,s} = \frac{1}{\Pi_{v=t+1}^{s} R_{v-1}}, \tag{1.30}$$

has well-known interpretations/definitions:

An economy with an initial net claim position against foreigners must receive net resources from foreigners, which in present value terms must equal the initial net claim position. An economy with an initial net debt position to foreigners must transfer net resources to foreigners, which in present value terms must equal the initial net debt position (Obstfeld, Rogoff, 1996, p.66, 67).

Note that we are interested in a temporary change in the interest rate. To rule out arbitrage possibilities, intertemporal prices must adjust. This is captured by the market discount factor $Q_{t,s}$ to describe the relative price of period s consumption in the form of period t consumption (described as in Obstfeld, Rogoff, 1996, p.76). $Q_{t,t}$ is interpreted as one, $Q_{t,t+1} = \frac{1}{R_t}$, $Q_{t,t+2} = \frac{1}{R_t}\frac{1}{R_{t+1}}$ and so on (Obstfeld, Rogoff, 1996, p.76).

1.4 Calibration

Our numerical exercise aims at giving a *rough* estimation of the *qualitative* importance of the supply-side effect of temporary interest rate reductions caused by macroeconomic integration. To facilitate the comparison with the results of Benigno and Fornaro (2014), we follow their parametrization and use their values whenever possible. Regarding capital accumulation, the parametrization borrows to a large extent from de Cordoba and Kehoe (2000). Note that both Benigno and Fornaro (2014) and de Cordoba and Kehoe (2000) parametrize their model to match some key data for Spain in the 1990s. Thus, Spain is at the centre of our calibration. To be clear, our analysis is not motivated by improving the quantitative fit of the model with the Spanish data. Instead, we are interested in the question, whether, for reasonable parameter constellations, the supply-side effect of a temporary interest rate reduction is large enough to (over)compensate and outweigh the (Spanish) *Financial Resource Curse* emphasized by Benigno and Fornaro (2014).

Following the approach of Benigno and Fornaro (2014), we assume that the small open economy faces perfect access to international goods and capital markets. For that reason, the price of tradable goods is exogenously given and normalized to unity. Our economy can borrow and lend at the gross interest rate that in equilibrium is assumed to be R_t = 1.0400, which equals a net level of 4 percent. In contrast to Benigno and Fornaro (2014), our model allows for an international market for capital goods. The home economy can be a (net) importer or (net) exporter of capital goods, the relative price (q_t) of these capital goods (machinery) is exogenously given by the world market and normalized to q = 1.0000.

An important element of the Benigno and Fornaro (2014) model is the process of technology accumulation, see Eq. (1.8). The growth rate of the world technological frontier is set to g^* = 0.0150. This number matches the average yearly growth rate of total-factor-productivity in the United States between 1960 and 1995. The initial value for the technology stock of the world technological leader is set at $A_0^* = 6.4405$, which corresponds to the estimation of Benhabib and Spiegel (2005) for USA in 1995. Adopting the estimation for Spain in 1995, the initial value of the home/domestic small open economy is A_0 = 4.1384. Similarly, to match the evolution of total-factor-productivity in Spain, Benigno and Fornaro (2014) (and we) set the convergence parameter that captures the ability of the home economy to absorb foreign technology to c = 0.1670.

In a next step, let us turn to the production functions of the tradable and non-tradable sector. In line with Benigno and Fornaro (2014), the labour share is assumed to be identical across sectors, we set α = 0.7011 which is the arithmetic mean of the values defined in de Cordoba and Kehoe (2000), who found a labour share of 0.7131 for sector T and 0.6891 for sector N. Following de Cordoba and Kehoe (2000), we choose the yearly capital stock depreciation rate to be δ = 0.0576. The initial capital stock in the tradable sector is set to K_0^T = 1.0000. In de Cordoba and Kehoe (2000), we find an indication that K_0^N is *roughly* 1.84 times higher than K_0^T. Thus, we assume K_0^N = 1.8400 K_0^T, implying K_0^N = 1.8400.

We assume a symmetric initial distribution of domestically financed/produced and foreign financed/produced capital stocks installed in sectors T and N, meaning K_0^{ND} = 0.9200, K_0^{NF} = 0.9200, K_0^{TD} = 0.5000, and K_0^{TF} = 0.5000.

The production function of the capital goods sector (1.22) remains to be calibrated.

As our numerical experiments in the next chapter (1.5) indicate, the parameter μ plays a decisive role, the results are sensitive to a variation in this parameter. This parameter captures the degree of international technology spillovers across sectors T and K. The tradable (non-tradable) sector faces full (no) international competition, the parameter is set to μ=1 (μ=0) (Rodrik, 2013, and Duarte, Restuccia, 2010, argue that international competition transfers technology or promotes productivity). The capital goods sector we assume between the extremes.

As μ influences the productivity of domestic capital goods production, we expect that μ influences the share of capital stocks in sectors N and T made up by domestic capital. We expect a lower μ to induce a higher share of foreign capital flowing into domestic sectors N and T. We expect[9] a (too) high μ to induce domestic capital goods production above the sectoral (N and T) demand for capital goods, implying a total crowding out of foreign capital installed in both sectors N and T, and the small open economy becoming a (net) exporter of capital goods (K_t^F< 0, K_t^{TF}< 0, and K_t^{NF}< 0). Investigating the economic evolution of an emerging / catching-up economy (for the initial periods of simulation) the latter is not meaningful (Eaton, Kortum, 2001).

For example, using Worldbank (2021a – 2021k) data, Spain constantly was a *net importer* of 'capital goods' from 1995 to 2005, the considered period in simulation chapter 1.5. Combined with the findings of Wagner (2007) mentioned in chapter 1.2, the productivity of the (Spanish) capital goods production (controlled by μ) should thus not be too high. Investigating the impact of low interest rates and macroeconomic integration on the Spanish economy, it thus requires foreign capital (goods) to flow into the small open economy (K_t^F> 0) in a low interest rates scenario (see bottom of this chapter). A level of μ = 0.5000 ensures in the numerical experiment (chapter 1.5) that both interest rate scenarios realize a positive stock of K_t^F in the (domestic) small open economy in the first ten periods of simulation, the treatment period of macroeconomic integration (see below in this chapter) from 1995 to 2005.

Regarding the share of tradable goods utilized as input in capital goods production, we again follow de Cordoba and Kehoe (2000) and set γ = 0.3802.

Calibrating the parameters of the representative household, we again follow Benigno and Fornaro (2014) and choose the discount factor at β = 0.9760. As the Euler equation (1.6) indicates, this assumption ensures in steady state that the growth rate of tradable goods consumption equals g^*. The expenditure share of the tradable good is set to ω = 0.4140. Household labour supply (labour endowment) is normalized to L = 1.0000.

Finally, we set the initial bonds holding to $B_0 = 0.0000$.

As our model is made up by more complexity compared to the model of Benigno and Fornaro (2014), we regard it as meaningful to expand the period (years) to transit to the steady state to 225, to improve the accuracy of our results, compared with 200 in the Benigno and Fornaro (2014) model.

[9] We reviewed our expectation with our 'normal interest rates' scenario. There, some parameter constellations confirmed our expectation of a higher μ inducing a lower K_t^F (also K_t^{NF} and K_t^{TF}) in selected periods. For transparency, we also found parameter constellations where a higher μ induced a higher K_t^F (also K_t^{NF} and K_t^{TF}) in selected periods.

The experiment is a temporary reduction of the interest rate, which we study by numerical simulations in chapter 1.5. We follow Benigno and Fornaro (2014) in defining two interest rate *scenarios*:

'Normal interest rates' imply a level of R=1.0400 for gross interest rates over the whole T=225 periods of simulation.

'Low interest rates' imply that gross interest rates are at level R_low=1.0100 for the first ten periods of simulation (from t=0 to and including t=9), as macroeconomic integration reduces interest rates (Benigno, Fornaro, 2014, Sinn, 2012, 2015). This implies that net interest rates are temporarily (for the first tern periods of simulation) at a level of 1 percent. Afterwards (from and including t=10 on), they return to the long run equilibrium R=1.0400 for the rest of the T=225 simulated periods.

We calibrate as in table 1.1.

Parameter	Value	Description
g^*	0.0150	Total-factor-productivity growth rate of the world technological leader
R	1.0400	Interest rate
R_low	1.0100	Interest rate in the low interest rate scenario
q	1.0000	Relative price of capital goods
β	0.9760	Discount factor
ω	0.4140	Share of tradable goods in consumption
L	1.0000	Total endowment of labour
A_0^*	6.4405	Initial total-factor-productivity of the world technological leader
A_0	4.1384	Initial total-factor-productivity of the domestic economy
c	0.1670	Convergence parameter in the process of technology accumulation
α	0.7011	Labour share in the production of tradable goods and non-tradable goods
δ	0.0576	Capital stock depreciation rate
μ	0.5000	Degree of the international technology spillover across sectors K and T
γ	0.3802	Share of tradable goods in capital goods production
K_0^T	1.0000	Initial capital stock in sector T
K_0^{TD}	0.5000	Initial domestically financed/produced capital stock in sector T
K_0^{TF}	0.5000	Initial foreign financed/produced capital stock in sector T
K_0^N	1.8400	Initial capital stock in sector N
K_0^{ND}	0.9200	Initial domestically financed/produced capital stock in sector N
K_0^{NF}	0.9200	Initial foreign financed/produced capital stock in sector N
B_0	0.0000	Initial bond holdings of the small open (domestic) economy
T	225	Number of periods (years) to transition to steady state
t		Periods are years

Table 1.1: Calibration of numerical simulations.

1.5 Results

This chapter provides our results.[10] We show our simulations of the numerical experiments for the endogenous variables during the transition of the small open economy that experiences a transitory reduction of interest rates. Figures 1.3 and 1.4 show the transition process for the first 20 periods (years) of the most important variables. Plain lines show the transition in the normal ('norm') interest rates scenario as a benchmark economy. Dotted lines show the transition in the low ('low') interest rates scenario, mirroring macroeconomic integration in the first ten periods.

Providing the reader with a comparison, we show the results of Benigno and Fornaro (2014), depicted as 'Benigno_Fornaro_2014', for non-tradable and tradable consumption (C_t^N and C_t^T) on the bottom of figure 1.4 (panels 1.4i and 1.4j). In the model of Benigno and Fornaro (2014) it was assumed $C_t^N = L_t^N = Y_t^N$, and $L_t^N + L_t^T = 1$. The results of Benigno and Fornaro (2014) for C_t^N thus show the *share* of labour employed in sector N.

Macroeconomic integration, simulated by low interest rates (Panel 1.3a), has the following effects:

Total capital stocks in sectors N and T, K_t^N and K_t^T (Panels 1.3b and 1.3c), exhibit the expected behavior. K_t^N positively responds to low interest rates, as profit maximizing capital levels increase when facing lower interest rates. The same holds for K_t^T, sector T capital positively responds to lower interest rates. Reflecting increasing capital stocks, sectoral output levels Y_t^N and Y_t^T (panels 1.3d and 1.3e) benefit from low interest rates, like GDP ($GDP_t = Y_t^N P_t^N + Y_t^T$) (panel 1.3f).

Coming to the sectoral allocation of labour resources, L_t^T measures, from assumed full employment, the labour *share* supplied to sector T (panel 1.3g). Our assumptions put it to the extreme, we find labour supply provided to sectors T and N invariant to changing interest rates. This draws a line to Eq. (1.21) where the share of labour resources employed in sector T in period t equals the share of capital goods employed in sector T in period t. As we simulate both interest rates scenarios (normal and low interest rates) by using an identical start ratio of K_0^T and K_0^N, we find no response of L_t^T to the experiments with the interest rate.

[10] Conducting our numerical simulations, we use the standard shooting algorithm code provided by Benigno and Fornaro (2014) to solve the simultaneous system of equations in Matlab. We extend the Benigno and Fornaro (2014) shooting algorithm code by endogenous variables and their definitions introduced to extend the Benigno and Fornaro (2014) model by capital as second production factor, and a third sector, producing capital goods (guided by de Cordoba and Kehoe, 2000). The shooting algorithm starts with an initial assumption for tradable consumption C_0^T. This together with the initial start values of table 1.1 allows the code to solve the simultaneous system for all endogenous variables for the T=225 periods and to check for the fulfilment of the intertemporal resource constraint (1.29). If Eq. (1.29) is not fulfilled using the initial assumption for C_0^T, the algorithm updates the initial assumption of tradable consumption C_0^T and checks again for the fulfilment of Eq. (1.29) at the end of T=225 periods. The algorithm stops doing so when Eq. (1.29) is fulfilled. Precise, the algorithm stops when the deviation from Eq. (1.29) undercuts / falls short of a predefined tolerance parameter. The simultaneous system / shooting algorithm code runs in Matlab, plots for our figures are made in Microsoft Excel.
In our computer code, domestic and foreign investment into capital accumulation (in a current period 't') requires a future (= next period 't+1') sectoral employment assumption. To make capital stocks in tradable and non-tradable production (K_t^T and K_t^N) benefit *simultaneously* from capital accumulation and low interest rates, the code assumes that current (= in current period 't') sectoral employment (L_t^T and L_t^N) will equal future (= in next period 't+1') sectoral employment when calculating future (next period 't+1') sectoral capital stocks (K_{t+1}^T and K_{t+1}^N). In other words, following Eq. (1.21), the code assumes that the future (= next period 't+1') share of capital installed in sector T (and N) equals the current (= current period 't') share of capital installed in sector T (and N). This assumption is the only one that we found maintaining a stable sectoral employment in steady state. Our interpretation of the original Benigno and Fornaro (2014) model is that, by using a Cobb-Douglas consumption index, Benigno and Fornaro (2014. p.67, 75) require stable sectoral employment in steady state to ensure a 'balanced growth path'.
Moreover, our computer code assumes that the domestically financed/produced capital goods are distributed over sectors N and T in the same ratio as total capital (financed/produced from 'domestic' *and* 'foreign') goods are distributed over sectors N and T.

Responding to the simulated interest rate reduction, capital stocks in *both* sectors N and T benefit from lower interest rates simultaneously and the *ratio* (1.21) does not respond to changes in interest rates.[11]

In the Benigno and Fornaro (2014) results for low interest rates, higher consumption of non-tradable goods required labour resources to depart sector T and relocate to sector N to service growing demand for non-tradable goods. In our model, initially higher demand (consumption) for (of) non-tradable goods (see simulations) in the low interest rates scenario (panel 1.3i) is serviced by promoted non-tradable goods *output* (promoted by capital accumulation, see panel 1.3d). This obviates (labour) resources departing sector T and their reallocation to sector N.

As we find the sectoral labour supply invariant to the experiments with interest rates (panel 1.3g), according to (1.8), the accumulation of foreign technology and the evolution of A_t (total-factor-productivity) are resilient to changing the interest rate scenario (panel 1.3h). The *Financial Resource Curse* of an impeded (growth rate of) technology accumulation from sector T employment crowding out, shown in Benigno and Fornaro (2014), does not prevail when extending their model by capital as a second production factor. This holds under our assumption that capital stocks in both sectors (N and T) benefit simultaneously from capital accumulation and low interest rates.

We observe non-tradable and tradable consumption C_t^N and C_t^T *initially* higher in the low interest rates scenario, compared with the normal interest rates scenario (panels 1.3i and 1.3j). It reflects the ability to realize negative bond-holdings at lower interest payments runoff in the low interest rates scenario. Promoting particularly tradable consumption, this according to Eq. (1.5) also influences non-tradable consumption. This qualitatively is like in the basic/original Benigno and Fornaro (2014) model, who show a sharp initial increase in consumption if the economy faces low interest rates (panels 1.4i and 1.4j). In our results, *during* the low interest rates period (first ten periods in scenario 'low'), non-tradable and tradable consumption C_t^N and C_t^T shrinks, reflecting the increased investment of non-tradable and tradable goods Z_t^N and Z_t^T into capital production (panels 1.4a and 1.4b).

When the low interest rates period ends (from period t=10 on), consumption levels are higher in the low interest rates scenario, compared to the normal interest rates scenario. The reason is a constantly higher domestically produced/financed capital stock K_t^D, (panel 1.4c) with two benefits on consumption:

First, it allows a lower investment of non-tradable and tradable goods Z_t^N and Z_t^T into capital goods production in the longer run (panels 1.4a and 1.4b). This leaves more tradable and non-tradable output (Y_t^T and Y_t^N) for consumption.

Second, a higher domestically financed/produced capital stock K_t^D (installed in domestic sectors N and T) allow lower *foreign* financed/produced capital stocks K_t^F (installed in domestic sectors N and T), like confirmed by our simulations for low interest rates scenario from period t=11 on (panel 1.4d).

[11] In our results, sectoral labour supply does not react to variations of interest rates. In our code, this comes from assuming that both sectors T and N benefit simultaneously from capital accumulation and low interest rates, i.e., future sectoral employment equals current sectoral employment when calculating future capital stocks (see previous footnote).

This implies a lower interest payments runoff to the rest of the world ('foreign'). Higher long-run consumption levels in the low interest rates scenario (from period t=10 on) explain higher welfare levels found for the low interest rates scenario (see below).

One can see that foreign (financed/produced) capital, installed in the domestic economy (K_t^F) turns negative after some periods in both interest rate scenarios (panel 1.4d). This implies that the domestic capital goods production/provision by the domestic capital goods sector is higher than the sectoral (N and T) demand for capital goods. Thus, K_t^F is fully crowded out, there are no foreign financed/produced capital goods installed in the domestic economy (in sectors N and T) if $K_t^F < 0$. If $K_t^F < 0$, this mirrors that in period t, there is no foreign capital invested, neither in domestic tradable, nor in domestic non-tradable production. As the domestic production/provision of capital goods exceeds the sectoral (N and T) demand for capital goods, the small open economy becomes a (net) exporter of capital goods ($K_t^F < 0$).

The current account CA_t (relatively to GDP) realizes a higher initial deficit, should the economy face a low interest rate scenario, compared to a normal interest rates scenario (panel 1.4e). It particularly reflects foreign capital (capital goods) entering the small open economy, building up a trade deficit and a current account deficit in the low interest rates scenario. Should the period of low interest rates end, capital stocks in sectors N and T reduce and foreign capital (goods) flow(s) back to international bankrollers, out of the small open economy. Then, a trade and a current account surplus emerges. Net Foreign Assets NFA_t (relatively to GDP) negatively respond to low interest rates (panels 1.4f and 1.4g). Firms based in the small open economy raise foreign debt to import capital goods. When low interest rates end, foreign debt raised by domestic firms reduces and the net foreign debt position of the whole economy reduces.

Reflecting the improvements of firms' capital endowments should the economy face a low interest rates scenario, labour-productivity improves, and wages W_t increase one by one (panel 1.4h).

There emerges a parallel with the findings of Mian, Sufi, and Verner (2020), who investigate the effect of credit expansion on domestic sectoral employment. They argue that, *if* credit expansion affects the economy mostly by promoting productive capital stocks (in both sectors N and T), the share of labour employed in tradable and non-tradable sectors should not respond that much. If, on the other hand, credit expansion affects the economy mostly by promoting household demand and consumption, Mian, Sufi, and Verner (2020) expect non-tradable employment to rise. Empirically, they find that credit expansion accompanies an *increase* in non-tradable employment, in an empirical investigation of the United States and their US Banking deregulation in the 1980s.

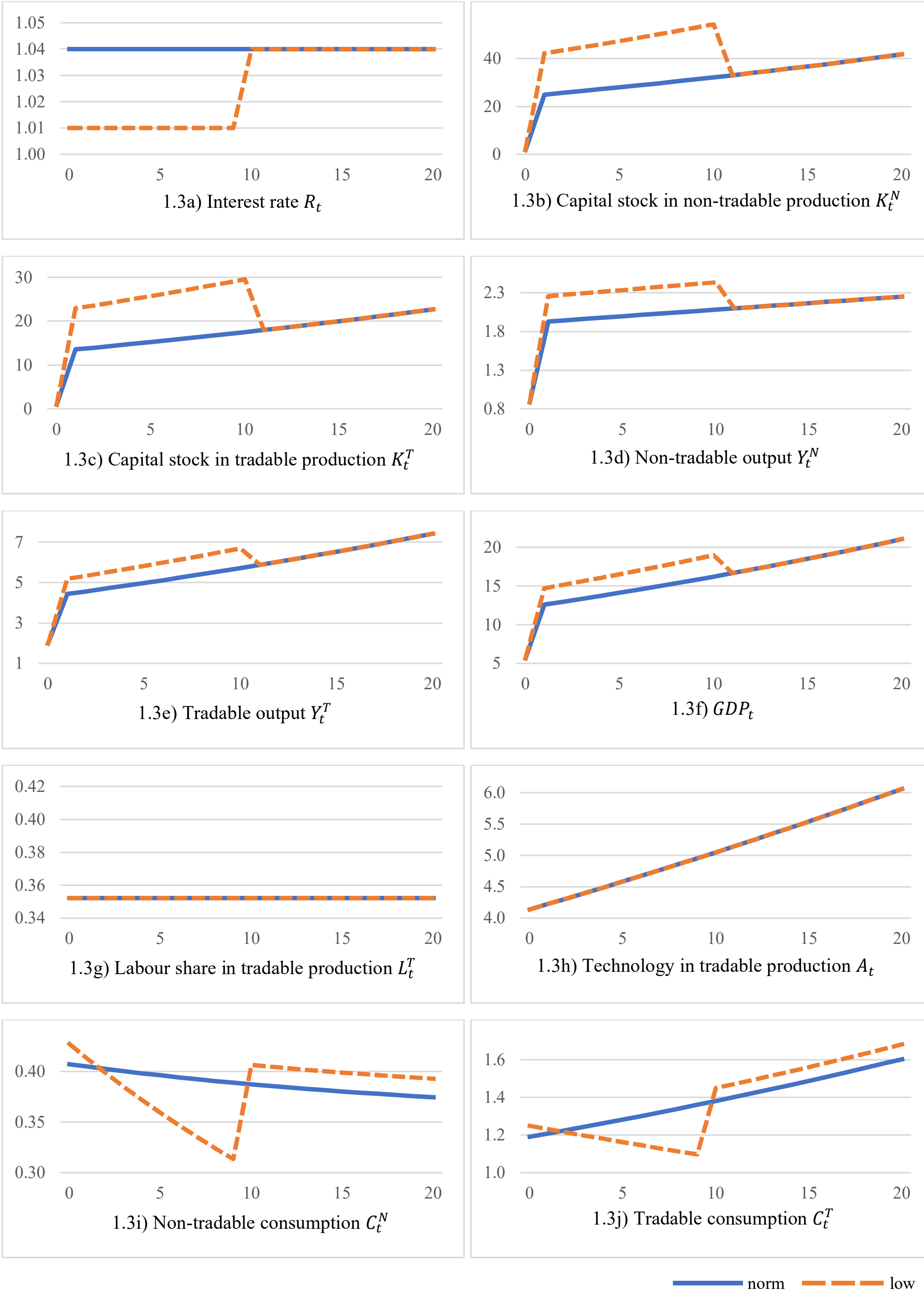

Figure 1.3: Results of numerical simulations. Horizontal/longitudinal axes are periods/years.

‘norm’: normal interest rates scenario, no macroeconomic integration, benchmark economy.
‘low’: low interest rates scenario, macroeconomic integration, treatment economy.

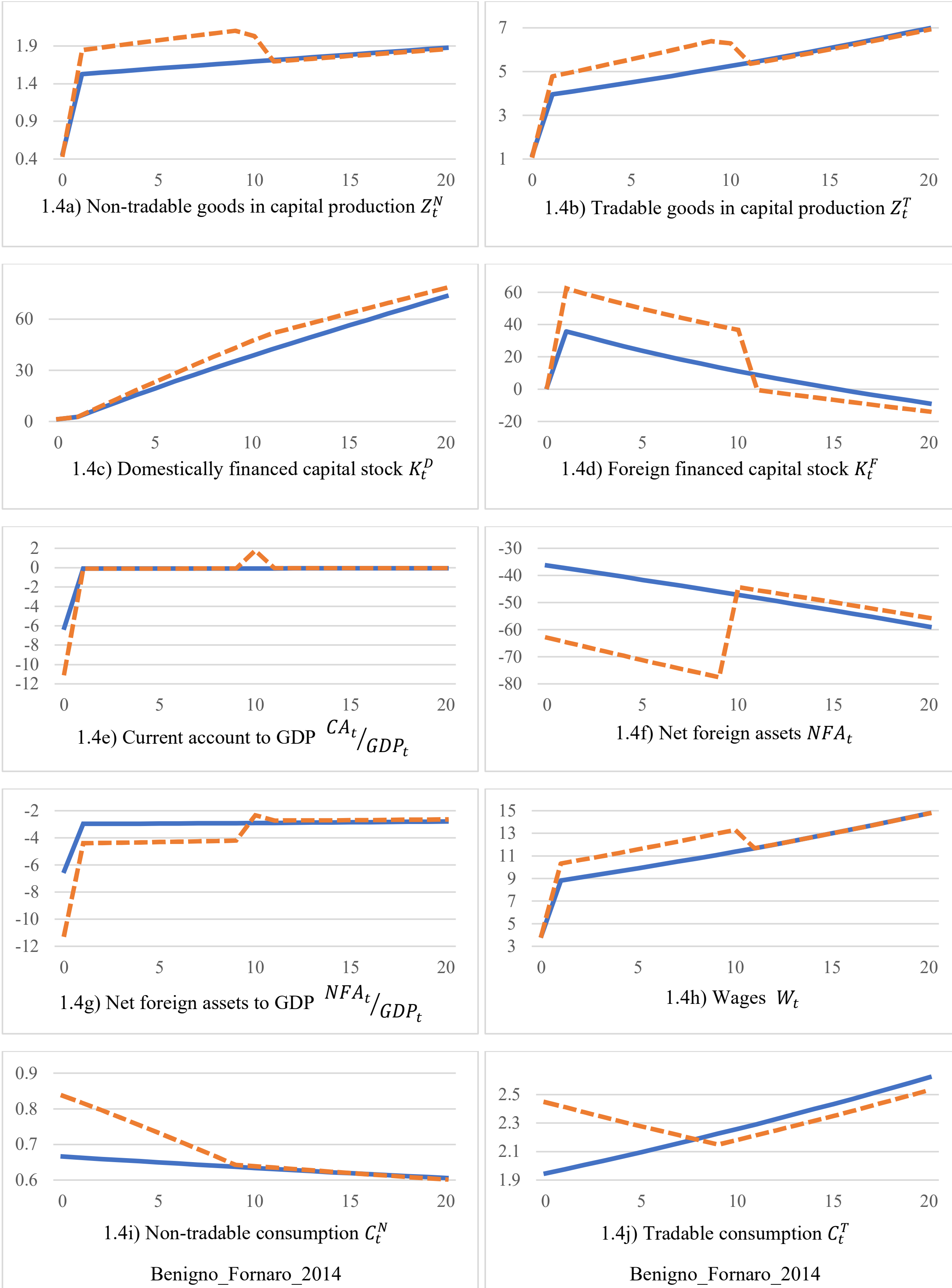

Figure 1.4: Results of numerical simulations. Horizontal/longitudinal axes are periods/years.

'C_t^N Benigno_Fornaro_2014' and 'C_t^T Benigno_Fornaro_2014' (panels 1.4i and 1.4j) are the results of the basic/original Benigno and Fornaro (2014, p.77) model.

'norm': normal interest rates scenario, no macroeconomic integration, benchmark economy.
'low': low interest rates scenario, macroeconomic integration, treatment economy.

Welfare

Benigno and Fornaro (2014) motivated their research by finding for some parameter constellations (high values for parameter c) that low interest rates reduce the small open economy's welfare, compared to when facing normal interest rates.

We calculate the present value of the representative household's lifetime utility. We find that the low interest rate scenario induces a welfare *gain* compared to the normal interest rate scenario, resulting from higher long run consumption levels found in our model's low interest rates scenario.

For our standard calibration[12], the welfare level in the normal interest rates scenario is lower than in the low interest rates scenario, like for the standard calibration of the basic/original Benigno and Fornaro (2014) model, see table 1.2. Negative values result from logging consumption < 1.

	Normal interest rates scenario		Low interest rates scenario
Basic/original model, welfare Benigno, Fornaro (2014) model (without capital as production factor) Standard calibration	+ 8.9	<	+ 9.0
Extended model, welfare Our model (chapter 1.3) (with capital as production factor) Standard calibration	- 10.4	<	- 9.5

Table 1.2: Welfare comparison of the normal interest rates scenario with the low interest rates scenario.
For the basic/original model of Benigno and Fornaro (2014), and for our extended-by-capital model, both models in standard calibration.

[12] In an earlier version of this chapter (chapter 1) (not published), we included a similar table (see table 1.2) comparing the welfare levels of the normal (global) interest rates scenario (no macroeconomic integration) with the low (global) interest rates scenario (macroeconomic integration), for the standard calibration of our chapter 1 model, and for the standard calibration of the basic/original Benigno and Fornaro (2014) model.
Erroneously/incorrectly, we showed in the earlier version of our chapter 1 (not published) that for the standard calibration, welfare levels in the basic/original Benigno and Fornaro (2014) model are higher in the normal (global) interest rates scenario than in the low (global) interest rates scenario. This was erroneous/incorrect. Correcting for this mistake/error, in our results, as well as in the basic/original Benigno and Fornaro (2014) model results, welfare levels are higher in the low interest rates scenario than in the normal interest rates scenario for the standard calibration (see table 1.2 in chapter 1). Our mistake/error resulted from an erroneous/incorrect calculation of the household welfare / present value of lifetime utility and from an incorrect parameter/typo. The old (erroneous/incorrect) welfare data calculated for the basic/original Benigno and Fornaro (2014) model supported the hypothesis/results of Benigno and Fornaro (2014), but by doing so, the old (erroneous/incorrect) welfare data also supported the motivation of our chapter 1. The fact that we calculated erroneous welfare levels for the basic/original Benigno and Fornaro (2014) model in an earlier version of our chapter 1 resulted potentially also in an erroneous calculation for η (eta, see figure 1.5) in the earlier version of our chapter 1 (not published).
The erroneous/incorrect welfare calculations (particularly for the basic/original Benigno and Fornaro, 2014, model) were not included in any publication of our chapter 1. But the old (erroneous/incorrect) welfare data were included in earlier versions of our chapter 1, submitted in the application for conferences/workshops, and in our presentations (marked as *preliminary results*) there.

Coming to the Benigno and Fornaro (2014) motivation, they introduced variable η, measuring the consumption equivalent handed over to the household living in the normal interest rate scenario, to make the household as well off as a household living in the low interest rate scenario, see Eq. (1.31), coming from the Benigno and Fornaro (2014) paper. Benigno and Fornaro (2014) show the evolution of η for a range of variable 'c', the convergence parameter of sector T technology accumulation, keeping the remaining of their calibration unchanged. The Benigno and Fornaro (2014) results for η are in figure 1.5. For a discussion of the Benigno and Fornaro (2014) evolution of η, we refer to their paper.

$$\sum_{t=0}^{\infty} \beta^t \log \left[(1+\eta)\, C_t^{normal\ rates} \right] = \sum_{t=0}^{\infty} \beta^t \log \left[C_t^{low\ rates} \right] \qquad (1.31)$$

Benigno and Fornaro (2014) show that for a high level of c, low interest rates induce a welfare loss.

Extending the Benigno and Fornaro (2014) model by capital as second production factor, we show in figure 1.5 that η is constantly positive in a range of $0.1 \leq c \leq 1.0$, sticking for the remaining parameters with the calibration of table 1.1. This implies that welfare levels in the low interest rates scenario are constantly higher compared with welfare levels in the normal interest rates scenario, over the whole range of $0.1 \leq c \leq 1.0$, taking capital as second production factor into account.

This holds as we do not find a contraction of employment in the sector producing tradable goods, should the economy face a low interest rate scenario. Booming consumption of particularly non-tradable goods in our model is serviced by promoted non-tradable output (promoted by capital accumulation), obviating the movement of labour resources out of sector T into sector N (contrasting the finding in Benigno and Fornaro, 2014).

For that reason, the low interest rates scenario does not slow (the growth rate of) technology accumulation in our model, and there is no welfare loss for the parameter range that we show, compared to the normal interest rates scenario.

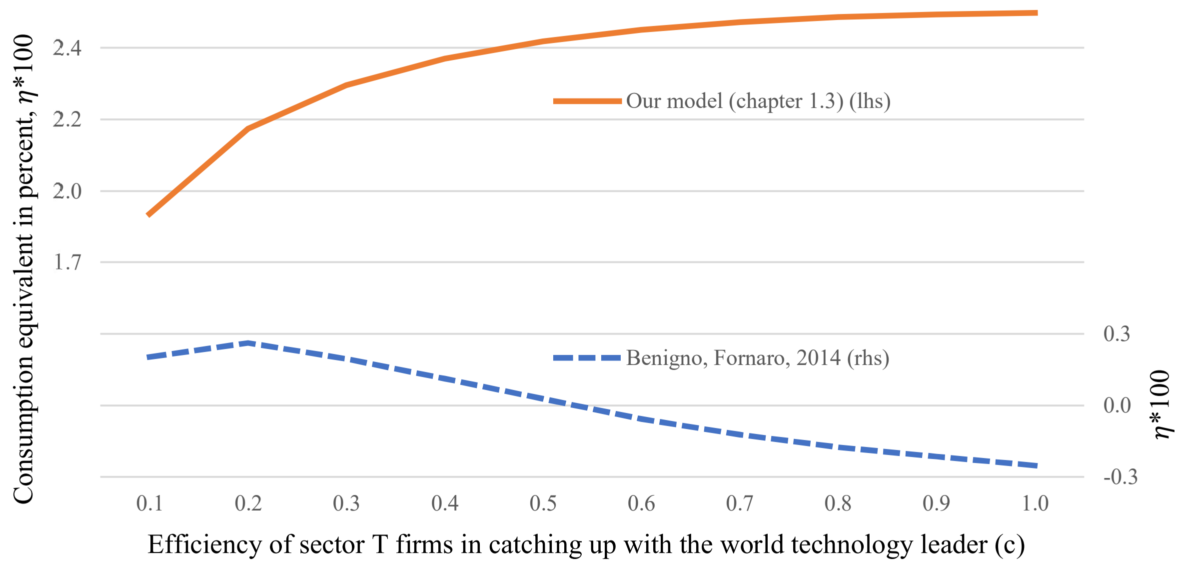

Figure 1.5: Consumption equivalent η*100 for a range of c.
For the basic/original Benigno and Fornaro (2014, p.78) model results (dashed line) and for our model results (solid line).

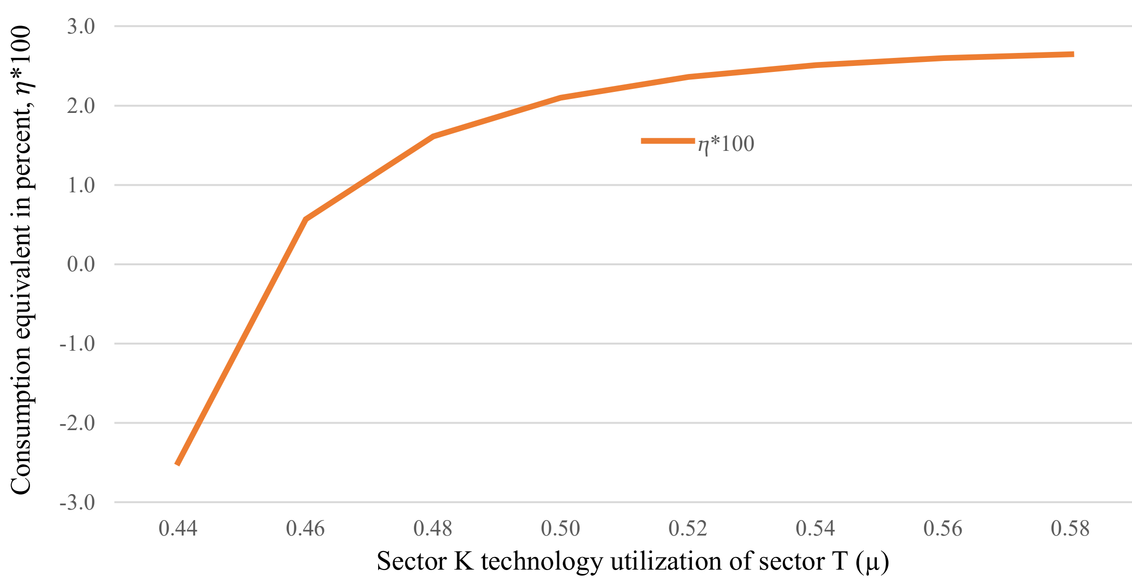

Figure 1.6: Consumption equivalent η*100 for a range of μ.

In figure 1.6, we overview our model's evolution of η, for a range of μ, the degree of the international technology spillover across sector K and T. Like argued, we assume $0 < \mu < 1$. We restrict figure 1.6 on a range of $0.44 \leq \mu \leq 0.58$. Outside this range, there seems to be no model solution. One reason might be, if $\mu < 0.44$, the domestic capital goods production does not suffice to balance the depreciation on domestically financed/produced capital goods, installed in domestic sectors N and T.

As one can see, welfare (gains) emerging from lower interest rates strongly depend on μ.

An increase in μ pushes the welfare gain of low interest rates. An economy can benefit more from low interest rates if it manages to increase its productivity in capital goods production (higher μ). The promotion of capital accumulation, induced by lower interest rates, exerts a stronger impact/benefit on welfare, if capital goods production realizes a higher productivity.

If the economy realizes a very low productivity in capital goods production (μ=0.44), there emerges a welfare loss from low interest rates.[13] If the productivity of domestic capital goods production is too low, the investment boom induced by low interest rates requires too many resources (Z_t^N and Z_t^T) compared to the machinery output, impeding consumption (C_t^N and C_t^T) and thus, impeding welfare.

[13] In an earlier version of our chapter 1 (Hildebrandt, Michaelis, 2022, published as MAGKS Discussion Paper No. 22-2022), we erroneously/incorrectly calculated a positive η (eta) even for $\mu = 0.45$. Moreover, in the aforementioned version we also reported results for η (eta) for levels of $\mu > 0.58$. Both was incorrect/mistaken. Both errors/mistakes resulted from an erroneous/incorrect calculation of capital stocks and from an erroneous/incorrect condition on the level of inputs (Z_t^N and Z_t^T) invested into capital goods production typed in our computer code.

1.6 Conclusion

Using a three-sector, two-factor small open economy model with endogenous growth, temporary low interest rates produce a supply-side economic boom from forced capital accumulation, mostly outweighing the negative *Financial Resource Curse* that was emphasized by Benigno and Fornaro (2014).

After initially consumption levels are higher during the temporary phase of low interest rates, consumption levels reduce during the temporary phase of low interest rates, on behalf of a forced investment activity. For that reason, in the long run, the economy benefits from higher domestically financed capital stocks, allowing higher consumption levels. We find a higher welfare level for a scenario with a temporary reduction of interest rates compared to a baseline scenario with constantly normal interest rates, in our standard calibration. Testing for ranges of our calibrations, this welfare benefit of lower interest rates mostly prevails.

We found the benefit of low interest rates on welfare sensitive to the scale that the domestic capital goods production adopts the technology developed in tradable production (parameter μ).

A higher welfare gain of lower interest rates emerges should capital goods production manage to adopt the technology developed in tradable production better. The promotion of capital accumulation, induced by lower interest rates, exerts a stronger impact on welfare, if domestic capital goods production has a higher productivity (higher level of μ). Only if the capital goods production realizes a very low level of productivity, low interest rates even induce a welfare loss.

The motivation behind the *Financial Resource Curse*, resources departing tradable production when the economy faces lower interest rates - shown in Benigno and Fornaro (2014) - is not found when expanding their model by capital as second production factor. We assume that tradable and non-tradable production capital stocks benefit simultaneously from capital accumulation and from lower interest rates. As capital intensities are identical in both sectors, our assumptions keep (the share of) labour employed in both sectors unchanged.

As pushing the capital accumulation, low interest rates push output in both sectors N and T. Promoted non-tradable and tradable consumption from lower interest rates thus are served from pushed output, instead of from resources moving into non-tradable production. The movement of resources out of tradable production into non-tradable production is obviated. The accumulation of foreign technology, assumed to depend on employment in the sector producing tradable goods (Benigno, Fornaro, 2014, based on Rodrik, 2013, and Duarte, Restuccia, 2010), turns out to be invariant to temporary low interest rates. Besides total-factor-productivity, labour-productivity (wages) responds positively to low interest rates, borne from a sectoral capital stock improvement.

The Spanish[14] adverse experience of lower interest rates accompanying depressed (total-factor-) productivity and declining tradable production during the European integration (Benigno, Fornaro, 2014, see also Sinn, 2012, 2015, for the gone peripheral European competitiveness during European integration), thus cannot solely be attributed to lower interest rates.

It requires a second contributor, parallel with lower interest rates, that relocates resources out of tradable production, depressing technology accumulation and (the growth rate of) productivity. Chapter 3 of the Ph.D. thesis at hand will address this question.

Limitations and further research

Our approach and results must be considered with caution. First, introducing labour shares that vary between the non-tradable sector and the tradable sector might produce a flow of investment emerging from lower interest rates in the direction of one sector.

Another limitation is that our results require the assumption that capital stocks in both sectors, tradable and non-tradable production, benefit simultaneously from capital accumulation, low interest rates and macroeconomic integration. In contrast to our assumption, there are studies, which motivate that tradable and non-tradable sectors have asymmetric capital costs or access to finance and respond asymmetrically to lending booms or macroeconomic integration (Ranciere, Tornell, Westermann, 2003, Piton, 2019, see also 2021, Mian, Sufi, Verner, 2020). Moreover, Di Maggio and Kermani (2017) find that employment in non-tradable production responds positively to credit booms, investigating US credit expansion episodes in the 2000s. Chapter 3 of the Ph.D. thesis at hand addresses such asymmetries.

We found in our simulations initially higher consumption levels (C_t^N and C_t^T) for the low interest rates scenario compared with the normal interest rates scenario. This is qualitatively in line with the results of Benigno and Fornaro (2014). The numerical scale of the initial consumption increase in our model is way smaller than the one found in Benigno and Fornaro (2014).

A motivation for further research is found in the consideration of foreign capital as a mechanism to accumulate foreign technology (see, e.g., Eaton, Kortum, 2001, Amann, Virmani, 2015, Chamarbagwala, Ramaswamy, Wunnava, 2000, Rodrik, 2013, Baltabaev, 2014). This will be considered in chapter 2.

[14] See also Bennett et al. (2008) for a depressed growth rate of total-factor-productivity in Italy and Portugal during European integration from 1996 to 2006. Sinn (2012, 2015) shows declining/low interest rates for (among others) Portugal and Italy roughly in this period.

2. The Financial Resource Gain: Macroeconomic Integration and Technology Accumulation from Foreign Capital [15]

Economic theory of Benigno and Fornaro (2014) explains how European (macroeconomic) integration, by lowering interest rates, affected peripheral European economies. Low interest rates stimulate consumption, requiring resources to relocate out of tradable production into non-tradable production. Resources relocating out of tradable production depresses (the growth rate of) aggregate productivity. This theory, denoted by Benigno and Fornaro (2014) as *Financial Resource Curse,* found support. While empirically confirmed for Spain at the early 2000s, Greece presents a paradox: Macroeconomic integration and collapsed interest rates are for the most part accompanied by growing aggregate productivity. I trace this paradox back to technology accumulation from inflowing foreign capital (see, e.g., Baltabaev, 2014, Eaton, Kortum, 2001, Amann, Virmani, 2015), accelerated by macroeconomic integration (see also Blanchard, Giavazzi, 2002), contradicting the *Financial Resource Curse* theory. Modelling a three-sector, two-factor small open economy (based on Benigno, Fornaro, 2014, and de Cordoba, Kehoe, 2000, and on chapter 1.3) with technology accumulation from inflowing foreign capital, numerical experiments reveal that macroeconomic integration should push aggregate productivity, what I refer to as *Financial Resource Gain.*

2.1 Introduction

Economic theory (Benigno, Fornaro, 2014, also Sinn, 2012, 2015) explains how the European (macroeconomic) integration of GIPS[16] (Greece, Italy, Portugal, Spain) economies helped them to realize lower interest rates. Lower interest rates induced booming private (or governmental/public) consumption, and a crowding out of tradable production by non-tradable production. The crowding out of tradable production (sector T) by non-tradable production (sector N) potentially depresses (the growth rate of) aggregate (total-factor) productivity, as particularly tradable production drives the technology accumulation from the world technological frontier (Benigno, Fornaro, 2014, based on Rodrik, 2013, and Duarte, Restuccia, 2010. See also Harms, 2008). For the adverse effect of low interest rates on aggregate (total-factor) productivity Benigno and Fornaro (2014) introduced the term *Financial Resource Curse,* in their research of the Spanish economy.

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[15] I thank my supervisor, Jochen Michaelis, for his support when I was working on this chapter, and for his suggestions to improve this chapter. I also thank the participants of the 26th Annual International Conference on Macroeconomic Analysis and International Finance, University of Crete in Rethymno, May 2022, for their suggestions for improvements. Particularly, I thank Anna Pestova for helpful suggestions to improve this chapter. I also thank Matthias Kapa, Beverley Locke, Max Fuchs, Jan Hattenbach, and Luzie Thiel for their helpful suggestions to improve this chapter. I also thank the participants of the 11th International Conference of Economics and Finance Research, University of Plymouth, April 2022 (online). Moreover, I thank the participants at the MAGKS Research Seminar in Rauischholzhausen, and at the Graduate School 'Economic Behaviour and Governance' in Kassel for their helpful suggestions to improve this chapter. I also thank Gianluca Benigno and Luca Fornaro for sharing and introducing their computer code with/to me. Moreover, I thank Gonzalo Fernandez de Cordoba and Timothy Kehoe for their computer code and support.

[16] Benigno and Fornaro (2014, p.59) refer to (European) '*financial* integration' of Spain. I refer to 'European *macroeconomic* integration', as it paves the way to the findings of my Ph.D. thesis (see particularly chapter 3). Sinn (2012, 2015) also includes Cyprus and Ireland in the group of peripheral European economies, see footnote 4 in chapter 1 of the dissertation at hand.

Sinn (2012, 2015) argues that low interest rates in GIPS economies reflected reduced economy specific interest rate yield spreads when borrowing internationally, reduced by European (macroeconomic) integration from the 1990s on. Before European integration, debtors in GIPS economies had to pay yield spreads on interest rates when borrowing internationally, to compensate international bankrollers for a higher country risk in GIPS economies. Sinn (2012, 2015) argues that reduced interest rate yield spreads reflected the fact that European (macroeconomic) integration in the 1990s and in the early 2000s eliminated exchange and default risks, also through expected potential European crisis support (see also Gopinath et al., 2017).

For Spain, figure 2.1 confirms that low (yield spreads on) interest rates are accompanied by depressed aggregate total-factor-productivity in the 2000s (panel 2.1a and 2.1c), as seen in Benigno and Fornaro (2014). Greece, however, presents a paradox: Collapsed (yield spreads on) interest rates are accompanied, for the most part, by growing aggregate total-factor-productivity (except the decline in 2005), contradicting the *Financial Resource Curse* theory (panel 2.1b and 2.1d). Figure 2.1 also shows a poorly responding net inward Foreign Direct Investment (growth rate) in Spain to macroeconomic integration. In Greece, the net inward Foreign Direct Investment (growth rate) responded significantly[17] (panel 2.1e).

Motivated by the Greek example and by the literature on Foreign Direct Investment and on technology accumulation (see, e.g., Baltabaev, 2014, Keller 1996), I challenge the Benigno and Fornaro (2014) hypothesis/theory that argues that interest-rate-lowering macroeconomic integration depresses technology accumulation and depresses (the growth rate of) aggregate total-factor-productivity (TFP). I argue that macroeconomic integration and low interest rates potentially *promote* technology accumulation, as macroeconomic integration promotes foreign capital (goods) inflows (like seen in chapter 1, see also, Blanchard, Giavazzi, 2002), which transfer foreign knowledge and technology to the integrating economy (see, e.g., Eaton, Kortum, 2001, Baltabaev, 2014. See also Keller, 1996, and Barro, Sala-i-Martin, 1997, on growth effects of technology diffusion).

Thus, macroeconomic integration may have two effects on technology accumulation and productivity: First, a potentially negative *Financial Resource Curse* effect described by Benigno and Fornaro (2014). Second, a potentially positive effect of promoted inflowing foreign capital (goods), which transfer foreign technology.

Potentially, through macroeconomic integration, the positive *inward foreign capital* effect outweighs the negative *Financial Resource Curse* effect. If this is the case, I term it a *Financial Resource Gain* of promoted technology accumulation and aggregate total-factor-productivity through macroeconomic integration. Modelling a three-sector, two-factor small open economy, considering technology accumulation from foreign capital, my numerical experiments reveal that macroeconomic integration *pushes* (the growth rate of) aggregate productivity, contradicting/outweighing the *Financial Resource Curse* theory. Chapter 2 is organized as follows: Chapter 2.2 provides an overview on the literature. Chapter 2.3 introduces a simple model of a two-factor, three-sector small open economy with technology accumulation from inflowing foreign capital. Chapter 2.4 calibrates the model for numerical experiments of chapter 2.5. Chapter 2.6 concludes.

[17] For panel 2.1e) in figure 2.1 I also experimented with an illustration showing ‘net inward FDI to GDP’ in absolute levels (instead of in growth rates) for Spain and Greece. Then, the effect did not look as striking as in panel 2.1e). Data are available upon request. See panels 1.2a) and 1.2d) in figure 1.2 in chapter 1.

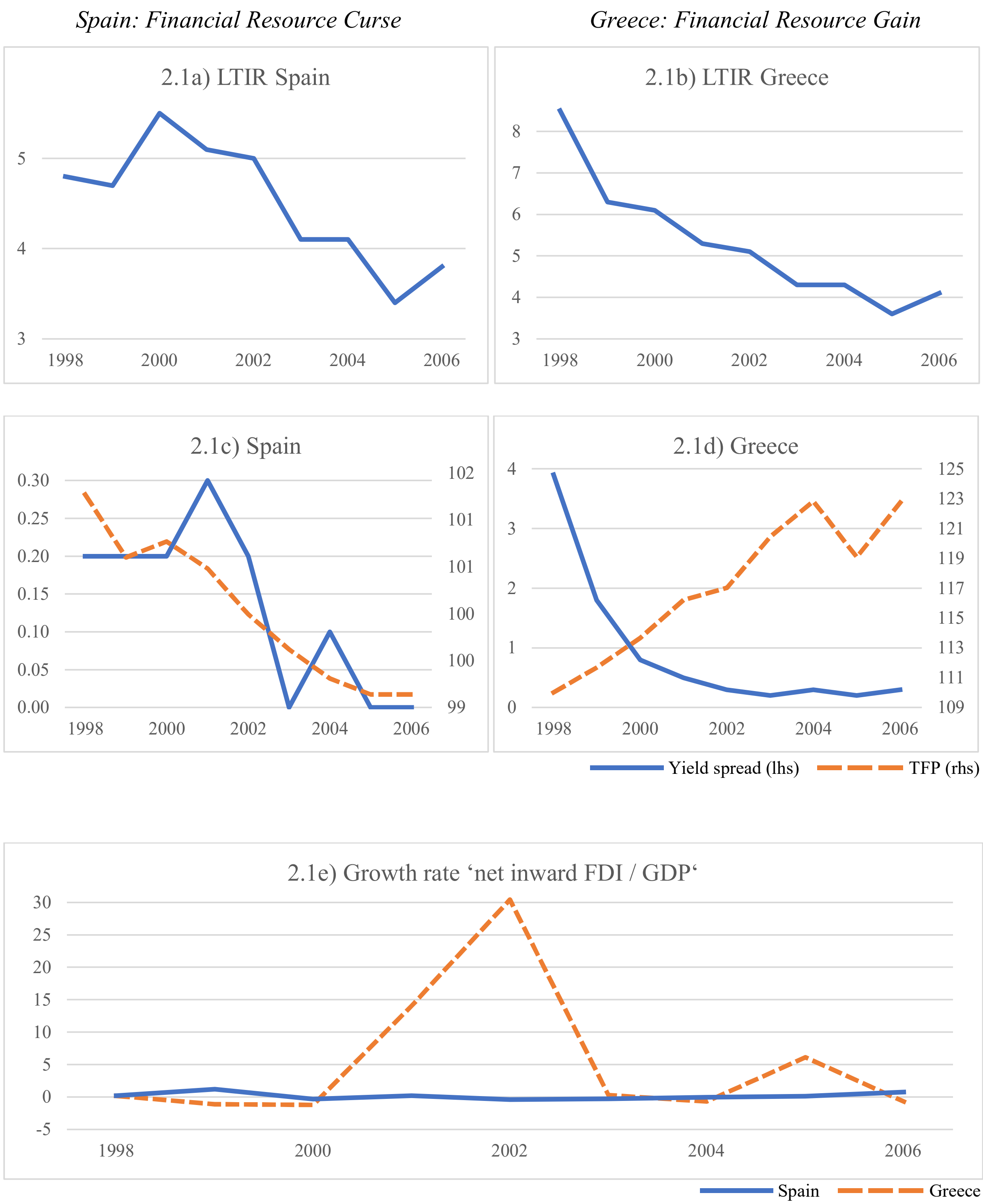

Figure 2.1: Evolution of macroeconomic indicators in Greece and Spain. LTIR stands for the long-term interest rate, measured by an economy’s 10-year government bond interest rate. Yield spreads measure the difference of an economy’s 10-year government bond interest rate over the 10-year government bond interest rate of Germany. A ‘Growth rate net inward FDI / GDP’ of 30 for a given year implies that ‘net inward FDI/GDP’ increased circa thirtyfold from one year to the next year. TFP is indexed 2015=100 and stems from OECD multifactor productivity data. Data source: OECD, 2022a, OECD, 2022b, Worldbank, 2022. The approach to calculate an economy’s interest rate yield spread as the same economy’s ten-year government bond yield over the ten-year government bond yield of Germany as benchmark can be found in Sibbertsen, Wegener, Basse (2014), Geyer, Kossmeier, Pichler (2004), Bernoth, von Hagen, Schuknecht (2012) and is indicated in Sinn (2012, 2015). OECD (2022a) data on ten-year government bond yields (‘Long Term Interest Rates’) are rounded to one decimal place. Yield spreads and growth rates are own calculations.

2.2 Literature

Based on a similar research question, my literature chapter 2.2 borrows heavily from chapter 1.2.

Benigno and Fornaro (2014) research Spain's European integration in the 1990s and 2000s. Modelling a two-sector, one factor small open economy with labour as the single production factor, they model that European integration reduces interest rates (by lowering risk). This stimulates (debt financed) consumption of tradable and non-tradable goods. As a result, labour force departs tradable production and relocates to non-tradable production, to satisfy stimulated demand for non-tradable goods. Stimulated demand for tradable goods is satisfied from imports. As labour force employed in tradable production is supposed to accumulate technology from the world technological frontier, lower interest rates slow (the growth rate of) technology accumulation. This negatively affects output, productivity, and potentially, welfare. These negative effects were termed by Benigno and Fornaro (2014) as the *Financial Resource Curse.* Modelling a small open economy with labour as the only production factor neglects a beneficial supply-side effect that lower interest rates and credit expansion (from macroeconomic integration) have by accelerating capital accumulation in the integrating economy (see, e.g., Blanchard, Giavazzi, 2002, Gorton, Ordoñez, 2020). In the Benigno and Fornaro (2014) model, total-factor-productivity equals labour productivity, borne from their way of modelling.

This gap is addressed by chapter 1 (see also Hildebrandt, Michaelis, 2022), by extending the Benigno and Fornaro (2014) model by a second production factor, capital, and a third sector, producing capital goods (following de Cordoba and Kehoe, 2000). This allows the consideration of the beneficial supply-side effect that lower interest rates have on output, labour productivity and welfare by accelerating capital accumulation. Repeating the experiments of Benigno and Fornaro (2014), chapter 1 shows that macroeconomic integration benefits the small open economy for most of the parameter constellations. The beneficial supply-side effect overcompensates/outweighs the *Financial Resource Curse* in terms of output, productivity, and (for most of the parameter constellations) welfare. Moreover, chapter 1 of the Ph.D. thesis at hand found that the beneficial impact that lower interest rates exert on the small open economy's welfare significantly depends on TFP in capital goods production. The linkage that macroeconomic integration improves an economy's access to foreign capital (goods) that transfer(s) foreign technology (see, e.g., Eaton, Kortum, 2001, Baltabaev, 2014, Amann, Virmani, 2015), was not considered in chapter 1.

As emphasized by Amann and Virmani (2015), Foreign Direct Investment (FDI) potentially accumulates/transfers foreign technology via *two* channels.

First, Amann and Virmani (2015) describe that in the classical manner, emerging and developing economies accumulate foreign technology from inflows of FDI (iFDI), particularly from developed economies. Factors that motivate iFDIs are market entry in developing and emerging economies, realizing low production costs in emerging or developing economies, and lower research and development costs. As Amann and Virmani (2015) point out, the ability of the emerging or developing economy to accumulate foreign technology from iFDIs depends on human capital or knowledge in the host (emerging or developing) economy. As foreign technology and knowledge sticks in products produced by iFDI financed facilities, iFDI may establish positive externalities when those products are sold in the host economy, justifying policy interventions to accumulate iFDI (Amann, Virmani, 2015, describe a similar channel for outward FDI, see also Wang, 2010. See also Blalock, Gertler, 2008, Baldwin, Braconier, Forslid, 2005, for policy justification). Accumulated foreign technology also spreads through the emerging or developing host economy by the fluctuation of employees, out of iFDI financed facilities, into companies inside the emerging or developing host economy (see also Baltabaev, 2014).

Second, Amann and Virmani (2015) mention that developing and emerging economies also grow by conducting outward Foreign Direct Investment (oFDI) into technological hubs of developed economies to accumulate foreign technology and to transfer it home (to the developing/emerging economy). For such channel, the ability of the holding company of the oFDI financed facilities is key for the accumulation of foreign technology and knowledge. For the oFDI channel, Amann and Virmani (2015) emphasize that firms with low technological knowledge have difficulties to accumulate technology and knowledge available in a host economy.

Sampling 52 emerging, developing and developed economies, Amann and Virmani (2015) find that in developing and emerging economies particularly the first channel via iFDI is an important driver of foreign knowledge and technology accumulation (measured by TFP growth). This motivates the iFDI channel of technology accumulation in my model in chapter 2.4.

Eaton and Kortum (2001) analyse the effect that capital goods (machinery and equipment) trade has on per capita GDP. They empirically analyse 34 developed and developing economies, with data for 1985. Eaton and Kortum (2001) find that capital goods are produced and exported particularly by developed economies. Developing economies particularly import capital goods. Eaton and Kortum (2001) explain that capital goods export to developing economies entails high costs of market entry, language difficulties when installing machinery and obstacles in after sales services and in maintenance. This explains a friction that developing economies have in accessing capital goods. Such friction Eaton and Kortum (2001) found responsible for about *one quarter* of per capita GDP differences that the ten poorest developing economies in their sample suffer from.

Lee and Chang (2009) analyse how the impact of iFDI on economic growth is moderated by financial development. Sampling 37 economies from 1970 to 2002, they find that the short run impact of iFDI and financial development on economic growth is in inverted causality, namely that it is growth of real domestic GDP that is attracting iFDI and pushes financial development. In the long run, the causality reverses. Lee and Chang (2009) find evidence that iFDI and financial development promote real GDP growth in the long run. Particularly, financial development impacts real GDP growth more strongly than iFDI does. Testing for bi-directional causality, Lee and Chang (2009) find that the beneficial impact of iFDI on real GDP growth positively depends on financial development of domestic capital markets. Lee and Chang (2009) motivate that developed domestic financial markets promote domestic institutions and sound corporate governance. This eases the transfer of foreign technology into the domestic economy. Lee and Chang (2009) motivate their research with, among others, the (theoretical) findings of Hermes and Lensink (2003).

On a macroeconomic level, Baltabaev (2014) researches empirically, sampling 49 economies for the years 1974 to 2008, how an economy's *(cumulative) stock* of iFDI (relatively to GDP) affects its TFP growth. Baltabaev (2014) investigates, how an economy's ability to accumulate foreign technology benefits from having a *low* technology level (relatively to the world technological frontier, 'distance to the frontier'). Baltabaev (2014) motivates the 'distance to the frontier' idea with the fact that economies (on microeconomic level: local firms) with low technology levels (or human capital levels) can learn more from domestically operating foreign high-tech entities and benefit more easily from iFDI (see also Blalock, Gertler, 2009, Keller, Yeaple, 2009).[18]

Baltabaev (2014) argues that there are studies that find a positive impact of (different measures of) a higher 'distance to the frontier' (Griffith, Redding, van Reenen, 2004, Madsen, Islam, Ang, 2010) when researching the impact of Research and Development activities on TFP.

Baltabaev (2014) also mentions that there are studies that miss positive/clear effects of (different measures of) a higher 'distance to the frontier'. Li and Liu (2005) miss a positive effect of a 'distance to the frontier' in the case of developing economies. Blalock and Gertler (2009) find that low *human capital* levels of firms burden the benefit of iFDI on TFP. Low *technology* levels of firms Blalock and Gertler (2009) find to augment the benefit of iFDI on TFP. One reason for a missing positive effect of a higher 'distance to the frontier' might be a *lower* learning ability should the economy have a low technology/human capital level (Baltabaev 2014, Keller, 1996, Keller, Yeaple, 2009, Li, Liu, 2005, see also Amann, Virmani, 2015).

Baltabaev (2014) finds that iFDI *stocks* (relatively to GDP) benefit TFP growth. This is the reason for my modelling of technology accumulation depending on inward foreign capital *stocks* in chapter 2.3. Baltabaev (2014) finds that a higher 'distance to the frontier' benefits the effect of iFDI stocks on TFP.

Following Baltabaev (2014), iFDI transfers foreign technology or knowledge to the host economy as follows. First, by transferring foreign technology or knowledge directly into the firm in which iFDI is invested in. The channels may be management and engineering know-how, or eased patent access (Dasgupta, 2012, Branstetter, 2006, Cipollina et al., 2012). While this is a direct channel, it embodies positive internalities. Further, iFDI may transfer foreign technology by promoting competition in the receiving economy, by pushing incumbent firms to adapt new technologies (Glass, Saggi, 1998, Baldwin, Braconier, Forslid, 2005). When working in firms which receive iFDI, domestic workers acquire foreign skills that enrich the education of domestic labour. After job rotation, foreign skills enter other domestic firms (Dasgupta, 2012, Fosfuri, Motta, Rønde, 2001, Cipollina et al., 2012). Generally, firms which receive iFDI utilize foreign technology to produce sophisticated goods or services. When sold domestically to other firms in the host economy, foreign technology embodied in sophisticated goods or services enters domestic firms (Wang, 2010, see also Amann, Virmani, 2015, for a similar oFDI channel).

[18] Barro and Sala-i-Martin (1997) note that poorer economies with lower factor endowment (comparable to a 'distance to the frontier') grow faster because of decreasing marginal returns that factor endowment has. Also, Barro and Sala-i-Martin (1997) argue that the costs of imitating technology are low but increase, as followers start at imitations that are cheapest to adopt. This promotes the economic growth of followers who are further away from the frontier and who can start with cheap imitations.

Rodrik (2013) empirically finds, by sampling up to 118 economies, an international convergence in labour productivity of manufacturing industries. He analyses up to four decades, starting in 1965, ending in 2005. For industries other than manufacturing, such a trend seems to be missing. These findings are in line with Duarte and Restuccia (2010) who find empirically that catching-up is present in productivity of manufacturing industries (producing mostly tradable goods). Rodrik (2013) provides an indication that in services (producing mostly non-tradable goods), catching-up in productivity seems weak. One explanation is that global competition forces manufacturing industries to increase productivity (Rodrik, 2013, Duarte, Restuccia, 2010, Benigno, Fornaro, 2014, Blanchard, Giavazzi, 2002).

Kinfemichael and Morshed (2019) contrast the finding of Rodrik (2013). They find convergence in labour-productivity in services. But they attribute their finding to the fact that services have become increasingly tradable in recent times, and the exposure to international competition pushed productivity.

Blanchard and Giavazzi (2002) investigate the European integration of peripheral economies. Their research is motivated by the Feldstein-Horioka Puzzle, which describes the unexpected observation that in open economies, saving and investment empirically depend on one another. Blanchard and Giavazzi (2002) find that during the years when peripheral European economies integrated macroeconomically, the Feldstein-Horioka Puzzle vanished more and more. In other words, saving and investment became independent of one another. During their European integration, Greece, Ireland, and Portugal strongly accumulated net foreign capital inflows in the 1990s. On the one hand, those capital imports and resulting current account deficits could, for some of the economies, reflect lost competitiveness from abolished devalued currencies (Sinn, 2012, 2015). On the other hand, they could mirror a natural process of catching up by importing capital when poorer economies integrate macroeconomically (Blanchard, Giavazzi, 2002). While Blanchard and Giavazzi (2002) mention some arguments favouring the latter argument, history indicates the first argument (Sinn, 2012, 2015, see also Sinn, Wollmershäuser, 2012, mentioning the lost peripheral competitiveness) for some peripheral European economies.

Gopinath et al. (2017) empirically find a hint on a size-dependent borrowing constraint in firms of Spanish manufacturing industries. This friction limits the amount of debt available particularly for smaller firms. As Gopinath et al. (2017) mention from a theoretical perspective, for a frictionless economy, an exogenously given interest rate equalizes the marginal capital productivity across firms, which optimally allocates capital resources. With frictions, interest-rate-lowering macroeconomic integration funnels the additionally accessible capital particularly into larger firms, as smaller firms suffer from borrowing constraints. This movement reduces marginal capital productivity of larger firms and causes marginal capital productivity to diverge between larger and smaller firms. When aggregating across all firm sizes, aggregate marginal capital productivity deteriorates because of interest-rate-lowering macroeconomic integration.

For US firms from 1987 to 1996, Keller and Yeaple (2009) find that the inflow of iFDI into an industry benefits the TFP of firms operating in that industry. Keller and Yeaple (2009) find that the positive impact of iFDI into one industry on the TFP of firms operating in that industry is strongest in those industries that are regarded as technology intensive (e.g., chemicals, computers, instruments, among others).

Keller and Yeaple (2009) make for their US sample the following finding: TFP of firms with a higher 'distance to the frontier' benefits stronger from iFDI flowing into the industry of the firms.

Keller (1996) underlines the required skills the iFDI receiving economy needs to utilize foreign technology and knowledge that become accessible from receiving iFDI. He distinguishes between (non-tradable) human capital as education of domestic workers, and (tradable) technology embodied in blueprints and technical manuals. While technology *can* be imported *or* be produced domestically, human capital *must* be produced domestically. Keller (1996) theoretically argues that integrating (macroeconomically) makes *technology* domestically cheaper, as it can be imported at the low (marginal) costs that technology production has abroad (see also Barro, Sala-i-Martin, 1997, for cost incentives to imitate/import technology). As human capital is required to utilize newly accessible foreign technology, growth of an integrating economy particularly benefits, should it also invest in human capital accumulation.

The following 4 papers were also summarized in Baltabaev (2014).

Dasgupta (2012) models two economies (home and foreign), with labour divided into 'managers' and 'workers'. Economy 'home' has a low human capital (knowledge) endowment, economy 'foreign' has a high human capital (knowledge) endowment. In economy 'home', managers have higher human capital than workers. Each manager runs and owns a firm, in which many workers work in. In autarky, by working in firms, workers accumulate knowledge from the(ir) manager, enabling the workers to be a manager later, when the accumulated knowledge suffices. Should the economy integrate, multi-national firms emerge. Thus, a part of domestically working managers (=firms) come from 'foreign', which utilize lower wages of workers resulting from lower human capital in the 'home' economy. After integration, domestic managers become a worker in a multi-national firm (run by a manager from 'foreign'), to learn from the foreign manager who has higher human capital. Having learned from and worked for the foreign manager, workers return to become a manager in 'home'. This transfers foreign knowledge into the 'home' economy.

Woo (2009) analyses empirically the long-run relationship between iFDI (relatively to GDP) and TFP growth, using data on 92 economies from 1970 to 2000. Woo (2009) finds that iFDI benefits TFP growth. The effect is significant, for an instant effect of iFDI on TFP, and for a lagged effect of iFDI on TFP.

Investigating the impact of iFDI on growth, Cipollina et al. (2012) use cross-country data on sectoral value added as main dependent variable. They use the ratio of the iFDI stock in a sector to the total capital stock in that sector as explanatory variable (this modelling is a main advantage of the Cipollina et al., 2012, study). They find that the ratio of the *stock* of iFDI in a sector to total capital installed in that sector promotes growth. Their finding is augmented in sectors that are capital and technology intensive. Moreover, they check the robustness by using sectoral TFP as dependent variable. They confirm a positive effect of their iFDI measure (see above) on TFP. They use data from 1992 to 2004, for 22 developing and developed economies, with up to 14 sectors per economy.

Li and Liu (2005) empirically research the impact of iFDI on per capita real GDP growth. Besides standard explanatory variables, they check how the interaction of the 'distance to the frontier' ('technology gap') with iFDI influences real per capita GDP growth. Using data from 1970 to 1999 for 84 developing and developed economies, they find that particularly from the 1980s on, iFDI promotes per capita real GDP growth. Li and Liu (2005) found that a higher technology gap burdens growth, underlining the importance of high technology levels for keeping pace in catching up.

Checking the effect of the interaction term 'technology gap' × 'inward FDI' on growth, Li and Liu (2005) find that the impact is indicated (insignificantly) positive for developed economies, and significantly negative for developing economies. Li and Liu (2005) argue as follows. If developed economies receive iFDI, they *benefit* from being further away from the world technological frontier, as developed economies have higher overall technology/knowledge levels and thus a higher capability to learn from iFDI. If developing economies receive iFDI, they *suffer* from being distant from the world technological frontier, as developing economies further away from the world technological frontier have *too* low technology/knowledge levels, undermining the capability to learn from iFDI.

2.3 Model

This model (chapter 2.3), its description, and its computer code are based on and are borrowed from those of chapter 1.3[19] (see also Hildebrandt, Michaelis, 2022). The model and the computer code of chapter 1.3 are based on the ones of Benigno and Fornaro (2014), who model a perfect foresight small open economy utilizing labour as the single production factor. Chapter 1 extends the model of Benigno and Fornaro (2014) by a second production factor, capital, and a third sector, producing capital goods, based on the model of de Cordoba and Kehoe (2000). Being based on chapter 1.3, the only essential extension considered in the following (in chapter 2.3) is the accumulation of foreign technology from imported foreign capital goods, installed in domestic tradable production, see Eq. (2.8). My model in chapter 2.3 and my computer code to a large extent borrow from chapter 1.3, from Benigno and Fornaro (2014) and from de Cordoba and Kehoe (2000).

Households

The economy is populated by a continuum of identical households with population normalized to unity. The representative household maximizes the utility function:

$$U_t = \sum_{t=0}^{\infty} \beta^t log C_t, \tag{2.1}$$

where β is the discount factor, and C_t is a consumption index defined as:

$$C_t = (C_t^T)^{\omega}(C_t^N)^{1-\omega}. \tag{2.2}$$

Here, C_t^T and C_t^N are the consumption of tradable (T) and non-tradable (N) goods, respectively. The parameter ω is the expenditure share for the tradable good. From (2.1) and (2.2), and according to Benigno and Fornaro (2014), the elasticity of substitution between the two available types of goods as well as the intertemporal elasticity of substitution between goods across periods is restricted to unity. The household supplies labour inelastically without a loss of utility.

The budget constraint of the representative household reads:

$$C_t^T + P_t^N C_t^N + \frac{as_{t+1}}{R_t} = W_t L + as_t + \pi_t^T + \pi_t^N + \pi_t^K, \tag{2.3}$$

where

$$as_{t+1} = B_{t+1} + q_t K_{t+1}^{TD} + q_t K_{t+1}^{ND}. \tag{2.4}$$

Like in de Cordoba and Kehoe (2000), the tradable good serves as numeraire, the price is given by the world market and normalized to unity; P_t^N is the relative price of the non-tradable good in the form of the tradable good, and L is the endowment of labour, which receives the wage rate W_t (assumed identical across sectors N and T, like in Benigno, Fornaro, 2014). Domestic sector N, T, and K firms are owned by domestic households. Thus, profits from sectors N, T, and K, π_t^N, π_t^T, π_t^K, go to the representative domestic household.

[19] Chapter 1 was written in co-authorship with Jochen Michaelis (joint research project). Thus, the work and its description of Jochen Michaelis contributed to a large extent to (the descriptions in) this chapter (chapter 2.3).

The (domestic) household purchases and holds assets in three forms, bonds B_{t+1}, domestic capital invested in sector T, K_{t+1}^{TD}, and domestic capital invested in sector N, K_{t+1}^{ND}. All assets purchased in period t are priced at $1/R_t$, and redeemed in period $t+1$. The price of a capital good in the form of the tradable good, q_t, as well as the gross interest rate, R_t, are given by the world market. Note that capital goods purchased in period t must be put in place one period before they are used, i.e., these goods turn into capital for production in the subsequent period $t+1$ (like in de Cordoba, Kehoe, 2000).

The representative household chooses C_t^T, C_t^N and as_{t+1} to maximize the utility function (2.1) subject to the budget constraint (2.3). From the solution of this problem, I get the demand function for non-tradable goods:

$$C_t^N = \frac{1-\omega}{\omega}\frac{1}{P_t^N}C_t^T, \tag{2.5}$$

and

$$C_{t+1}^T = \beta R_t C_t^T, \tag{2.6}$$

as the standard Euler equation for the optimal intertemporal allocation of tradable goods consumption (see Benigno, Fornaro, 2014).

Firms

Tradable Sector (T, tradable production). Firms in the tradable sector T combine L_t^T workers with K_t^T units of real capital to produce the output Y_t^T. The production-technology is Cobb-Douglas with constant returns to scale:

$$Y_t^T = A_t(L_t^T)^{\alpha}(K_t^T)^{1-\alpha}, \tag{2.7}$$

where the stock of technology A_t is a total-factor-productivity shifter. Because of international competition, the tradable sector absorbs foreign technology (Rodrik, 2013, Blanchard, Giavazzi, 2002). The expression of Benigno and Fornaro (2014) for the endogenous process of technology accumulation is extended by technology accumulation from the stock of foreign (financed) capital goods, installed in domestic sector T (machinery / capital goods imported from foreign, installed in domestic sector T, K_t^{TF}):

$$A_{t+1} = \begin{cases} A_t\left[1 + c_1\, L_t^T\left(1-\frac{A_t}{A_t^*}\right) + c_2\, K_t^{TF}\left(1-\frac{A_t}{A_t^*}\right)\right] & \text{for } K_t^{TF} > 0 \\ A_t\left[1 + c_1\, L_t^T\left(1-\frac{A_t}{A_t^*}\right)\right] & \text{for } K_t^{TF} \le 0 \end{cases} \tag{2.8}$$

Benigno and Fornaro (2014) term it ‘knowledge accumulation’. I term it ‘technology accumulation’, because of the modelling of the Cobb-Douglas production function. There is a world technological leader, whose stock of technology A_t^* grows with an exogenously given yearly rate g^*. The domestic economy is well behind, $A_t < A_t^*$, but catches up. The speed of convergence is determined by a convergence parameter c_1 and by employment in the tradable sector (L_t^T), to incorporate learning-by-doing. Further, the speed of convergence is determined by the stock of foreign capital goods, installed in domestic sector T (K_t^{TF}), incorporating technology transfers from abroad/'foreign', with the convergence parameter c_2. For a more detailed motivation of (2.8), I refer to Benigno and Fornaro (2014), who introduced the learning-by-doing component (by tradable production employment L_t^T) of (2.8) to describe sector T technology accumulation in their model. The stock of foreign capital goods installed in the domestic sector T (K_t^{TF}) is not necessarily positive in each period.

If the domestic capital goods production exceeds the domestic demand for capital goods exerted by sectors N and T, there are no foreign capital goods flowing/installed in the domestic economy. Thus, I incorporate the accumulation of foreign technology from employment in sector T, L_t^T, *and* from the stock of inward foreign capital, K_t^{TF} in Eq. (2.8).

Conditional on the calibration of the model, foreign (financed) capital (goods), installed in domestic sector T, K_t^{TF}, and installed in domestic sector N, K_t^{NF}, can numerically turn negative. This (K_t^{TF}<0, K_t^{NF}<0) implies that domestic capital goods production (by sector K) is higher than the domestic sectoral (N and T) demand for capital goods, and a crowding out of foreign capital installed in the domestic economy. Then, the domestic economy builds up a capital stock abroad / in 'foreign' (net machinery export). Terminologically, I introduce:

$$K_t^{TF} = \begin{cases} K_t^{TF} & for\ \ K_t^{TF} > 0 \\ -K_t^{*\,TF} & for\ \ K_t^{TF} < 0 \end{cases} \tag{2.9}$$

and

$$K_t^{NF} = \begin{cases} K_t^{NF} & for\ \ K_t^{NF} > 0 \\ -K_t^{*\,NF} & for\ \ K_t^{NF} < 0 \end{cases} \tag{2.10}$$

So, the (empirical) evidence is captured on the positive impact of inward foreign capital *stocks* on total-factor-productivity (see, e.g., Baltabaev, 2014, on the effect of inward FDI *stocks* on TFP, and Eaton, Kortum, 2001, on technology transfers from foreign capital goods).

It is important to underline, that capital received from domestic (D) and foreign (F) capital goods production and utilized by sector T firms (and by sector N firms) is not necessarily equity financed. Particularly, the interpretation of being debt financed is standing to reason. Regarding capital as input, *apart* from technology accumulation, domestically financed/produced capital (goods), installed in the domestic sector T (in the following: domestic sector T capital) K_t^{TD}, and foreign financed/produced capital (goods), installed in the domestic sector T (in the following: foreign sector T capital) K_t^{TF}, are perfect substitutes.

My model requires foreign capital (K_t^F) to be invested in tradable production (depicted K_t^{TF}) and in non-tradable production (depicted K_t^{NF}) of the small open economy, I assume:

$$K_t^T = K_t^{TD} + K_t^{TF} \tag{2.11}$$

Capital depreciates with the rate δ, capital accumulation follows $K_{t+1}^{TD} = (1-\delta)K_t^{TD} + I_t^{TD}$ and $K_{t+1}^{TF} = (1-\delta)K_t^{TF} + I_t^{TF}$, where I_t^{TD} and I_t^{TF} is the investment during period *t*. I_t^{TD} is produced by the domestic capital goods sector, I_t^{TF} are capital goods imported from abroad/'foreign'.

The first order condition for a profit maximum of firms in sector T is:

$$W_t = MPL_t^T = \alpha A_t (L_t^T)^{\alpha-1}(K_t^T)^{1-\alpha}. \tag{2.12}$$

In period $t-1$, firms in sector T decide on the optimal capital stock for production in period t:

$$MPK_t^T + (1-\delta)q_t = R_{t-1}q_{t-1}, \tag{2.13}$$

$$MPK_t^{TF} = MPK_t^{TD}. \tag{2.14}$$

Note that firms act on behalf of their owners, domestic households. From the household point of view, bonds and capital invested in sectors T and N are perfect substitutes, thus, the rate of return must be equal, see Eq. (2.4) (see de Cordoba, Kehoe, 2000, for a two-sector-case, see also Funke, Strulik, 2000, for a one-sector case).

In period $t-1$, the capital good costs q_{t-1}, the yield is the additional output in period t (marginal product of capital MPK_t^T) plus the value of the depreciated capital good at the end of period t, $(1-\delta)q_t$. The investment of q_{t-1} in bonds yields the gross return $R_{t-1}q_{t-1}$, embodying opportunity costs (see de Cordoba, Kehoe, 2000, Funke, Strulik, 2000). Firms can import capital goods from abroad/'foreign', Eq. (2.14) is the no-arbitrage condition.

Non-Tradable Sector (N, non-tradable production). The output of the non-tradable good, Y_t^N, is produced with the help of labour, L_t^N, and real capital, K_t^N. Again, the production-technology is Cobb-Douglas:

$$Y_t^N = (L_t^N)^{\alpha}(K_t^N)^{1-\alpha}. \tag{2.15}$$

Like in Benigno and Fornaro (2014), total-factor-productivity in sector N is fixed to unity, in the non-tradable sector there is no accumulation of foreign technology and thus no technological progress, in line with the findings of Rodrik (2013) shown in chapter 2.2. Like Eq. (2.11), I assume a simple aggregation:

$$K_t^N = K_t^{ND} + K_t^{NF} \tag{2.16}$$

for domestically financed/produced capital (goods), installed in the domestic sector N (in the following: domestic sector N capital) K_t^{ND}, and foreign financed/produced capital (goods), installed in the domestic sector N (in the following: foreign sector N capital) K_t^{NF}. Capital accumulation follows $K_{t+1}^{ND} = (1-\delta)K_t^{ND} + I_t^{ND}$ and $K_{t+1}^{NF} = (1-\delta)K_t^{NF} + I_t^{NF}$, where the investment I_t^{ND} is produced by the domestic capital goods sector, and the investment I_t^{NF} are capital goods imported from abroad/'foreign'.

The first-order conditions of firms in sector N for labour and capital are:

$$W_t = P_t^N \cdot MPL_t^N = P_t^N \cdot \alpha(L_t^N)^{\alpha-1}(K_t^N)^{1-\alpha}, \tag{2.17}$$

$$P_t^N \cdot MPK_t^N + (1-\delta)q_t = R_{t-1}q_{t-1}, \tag{2.18}$$

$$MPK_t^{NF} = MPK_t^{ND}. \tag{2.19}$$

Again, in period $t-1$, firms decide on the optimal capital stock for production in period t. Because of perfect labour mobility across sectors, firms in the non-tradable sector must pay the same wage as firms in the tradable sector.

Eqs. (2.18) and (2.19) rest on the assumption that all three forms of assets – bonds, capital invested in sector T, and capital invested in sector N – are perfect substitutes and must yield an equal return (see de Cordoba, Kehoe, 2000, for a two-sector-case, see also Funke, Strulik, 2000, for a one-sector-case).

By combining the optimality conditions, I also get:

$$\frac{K_t^T}{L_t^T} = \frac{K_t^N}{L_t^N}, \tag{2.20}$$

$$P_t^N = A_t \tag{2.21}$$

Eq. (2.20) implies that the capital stock per worker is identical across sectors (see also Gopinath et al., 2017). Eq. (2.21) describes the familiar Samuelson-Balassa effect. Total-factor-productivity (A_t) growth in the sector producing tradable goods pushes up labour demand in this sector T. Tradable production increases its wages to attract workers. Non-tradable production has no productivity advances but must pay the same (higher) wage. Thus, non-tradable production faces an increase in the marginal costs of production. This leads to an increase in the relative price (P_t^N) of non-tradable goods. From (2.20), in combination with the calibration of Benigno and Fornaro (2014) to be referred to in chapter 2.4, $L_t^T + L_t^N = 1$, it can be concluded:

$$L_t^T = \frac{K_t^T}{K_t^T + K_t^N}. \tag{2.22}$$

Eq. (2.22) implies that the share of labour supply employed in sector T is equal to the share of capital goods employed in sector T. As capital stocks K_t^T and K_t^N are set in period $t-1$, this implies that sectoral labour supply for period t is fixed in period $t-1$. This is important to be kept in mind when interpreting the reaction of L_t^T to my numerical experiment with the interest rate in chapter 2.5. To connect sectoral capital stocks with the budget constraint of the household (2.3), I make use of $K_t^D = K_t^{TD} + K_t^{ND}$ and $K_t^F = K_t^{TF} + K_t^{NF}$.

Capital goods sector (K, capital goods production). The modelling of the domestic capital goods sector very much follows de Cordoba and Kehoe (2000), who assume that real capital goods are produced by using tradable goods and non-tradable goods as inputs. The production-technology[20] is Cobb-Douglas:

[20] I gratefully thank Max Fuchs for his helpful suggestion/comment to improve my/our design of the capital goods production function.

$$I_t^D = (A_t)^{\mu}(Z_t^T)^{\gamma}(Z_t^N)^{1-\gamma}, \tag{2.23}$$

where I_t^D is the domestic output of capital goods, augmenting domestic capital accumulation. Z_t^T is the input of the tradable good used in the capital goods production sector, and Z_t^N is the input of the non-tradable good used in the capital goods production sector. As de Cordoba and Kehoe (2000, p.57) mention, these inputs "…can be thought of loosely as equipment and structures". Following chapter 1.3, both, sector T and sector K, produce physically tangible goods in an industrial or manufacturing production process. Thus, it is regarded as meaningful that sector K uses the same technology, A_t, as sector T does. So, the modelling of Eq. (2.23) deviates from de Cordoba and Kehoe (2000), as A_t is included. As the technology A_t is built up / developed in sector T, and must diffuse to sector K, it was also regarded as meaningful that the capital goods sector K absorbs foreign technology (via sector T technology A_t), to a lesser extent than firms in sector T, meaning $0 < \mu < 1$.

Maximizing the profit function $\pi_t^K = q_t I_t^D - Z_t^T - P_t^N Z_t^N$ with respect to the inputs (Z_t^N and Z_t^T) leads to:

$$\frac{Z_t^T}{Z_t^N} = \frac{\gamma}{1-\gamma} P_t^N. \tag{2.24}$$

Because of the Samuelson-Balassa effect, the relative price P_t^N increases period by period. Therefore, the non-tradable good as a factor of production becomes more expensive period by period, and firms in the capital goods sector adjust the optimal production plan by switching from Z_t^N to Z_t^T, the ratio Z_t^T/Z_t^N rises continuously.

Equilibrium

The economy consists of four markets, namely two goods markets (tradable and non-tradable goods) and two factor markets (labour and capital goods). A general equilibrium requires that all markets in the economy are simultaneously in equilibrium.

The labour market is in equilibrium when the time inelastic labour supply by households (labour endowment) is equal to labour demand of firms of tradable production (sector T) and non-tradable production (sector N):

$$L = L_t^T + L_t^N. \tag{2.25}$$

The capital goods sector is in equilibrium when the domestic output of capital goods is equal to the demand for domestically produced capital goods from firms of sector T and sector N:

$$I_t^D = I_t^{TD} + I_t^{ND} = K_{t+1}^D - (1-\delta)K_t^D. \tag{2.26}$$

The market clearing condition for the non-tradable good:

$$C_t^N + Z_t^N = Y_t^N, \tag{2.27}$$

implies that sector N output is either consumed by the domestic household or is invested as an input in the domestic production of capital goods (2.23). Depending on the domestic output (Y_t^N and Y_t^T) and consumption (C_t^N and C_t^T), Z_t^N and Z_t^T go to the domestic capital goods production (2.23).

Making use of (2.4), (2.25), (2.27) and the firms' profit functions (sectors T, N, K), the households' budget constraint (2.3) delivers the market clearing condition for the tradable good:

$$C_t^T + \frac{B_{t+1}}{R_t} - B_t = Y_t^T - Z_t^T - q_t I_t^F + \frac{q_t K_{t+1}^F}{R_t} - q_{t-1} K_t^F, \tag{2.28}$$

where $I_t^F = I_t^{TF} + I_t^{NF}$ is the (payment for the) import of capital goods, $q_t K_{t+1}^F / R_t$ is the firms' borrowing of funds from abroad/'foreign' in period t, and $q_{t-1} K_t^F$ is the repayment of foreign funds raised in period $t-1$.

In a next step, let us turn to the current account of the small open economy. Like in Benigno and Fornaro (2014), an economy's current account is defined as the change in its net foreign assets, $CA_t = NFA_t - NFA_{t-1}$. The value of the bonds acquired by the representative household in period t is B_{t+1}/R_t, the value of the foreign funds raised by firms is equal to $q_t K_{t+1}^F / R_t$, thus one gets $NFA_t = B_{t+1}/R_t - q_t K_{t+1}^F / R_t$. Backdating yields $NFA_{t-1} = B_t / R_{t-1} - q_{t-1} K_t^F / R_{t-1}$. Now the market clearing condition for the tradable good (2.28) can be rearranged to get to the current account (derived like in Benigno, Fornaro, 2014):

$$CA_t = Y_t^T - Z_t^T - C_t^T - q_t I_t^F + \frac{B_t - q_{t-1} K_t^F}{R_{t-1}} (R_{t-1} - 1). \tag{2.29}$$

The period t current account is given by net exports, $Y_t^T - Z_t^T - C_t^T - q_t I_t^F$, plus the interest earned on net foreign assets acquired in period $t-1$.

The intertemporal resource constraint (Obstfeld, Rogoff, 1996):

$$\sum_{s=t}^{\infty} Q_{t,s} CA_s = -\frac{B_t - q_{t-1} K_t^F}{R_{t-1}}, \tag{2.30}$$

with:

$$Q_{t,s} = \frac{1}{\Pi_{v=t+1}^{s} R_{v-1}}, \tag{2.31}$$

has well-known interpretations/definitions:

An economy with an initial net claim position against foreigners must receive net resources from foreigners, which in present value terms must equal the initial net claim position. An economy with an initial net debt position to foreigners must transfer net resources to foreigners, which in present value terms must equal the initial net debt position (Obstfeld, Rogoff, 1996, p.66, 67).

Note that the numerical experiment in chapter 2.5 is a temporary change in the interest rate. To rule out arbitrage possibilities, intertemporal prices must adjust. This is captured by the market discount factor $Q_{t,s}$ to describe the relative price of period s consumption in the form of period t consumption (described as in Obstfeld, Rogoff, 1996, p.76). $Q_{t,t}$ is interpreted as one, $Q_{t,t+1} = \frac{1}{R_t}$, $Q_{t,t+2} = \frac{1}{R_t}\frac{1}{R_{t+1}}$ and so on (Obstfeld, Rogoff, 1996, p.76).

2.4 Calibration

This calibration chapter (2.4) of the model at hand is like the calibration chapter 1.4. The description of my calibration (chapter 2.4) is borrowed from and is based on chapter 1.4[21] (see also Hildebrandt, Michaelis, 2022).

My numerical exercise aims at giving a *rough* estimation of the *qualitative* importance of inflowing foreign capital for the accumulation of foreign technology, spurred-on by macroeconomic integration. Benigno and Fornaro (2014) postulate a depressed (growth rate of) (total-factor-) productivity induced by macroeconomic integration, a result that I challenge. To facilitate a best comparison with their results, I use their parameters whenever possible. Regarding capital accumulation, the parametrization to a large extent borrows from de Cordoba and Kehoe (2000).

Note that both Benigno and Fornaro (2014) and de Cordoba and Kehoe (2000) parametrize their model to match some key data for Spain in the 1990s. Thus, Spain is at the centre of my calibration. To be clear, my analysis is not motivated by the objective to improve the quantitative fit of the model neither with the Spanish data, nor with the Greek data. Instead, I am interested in the question, of whether, for reasonable parameter constellations, the negative impact of macroeconomic integration on (total-factor-) productivity postulated by the *Financial Resource Curse* (Benigno, Fornaro, 2014) theory prevails. Or, in the other case, of whether technology accumulation from promoted inflows of foreign capital outweighs the *Financial Resource Curse*.

Following the approach of Benigno and Fornaro (2014), I assume that the small open economy has perfect access to international goods and capital markets. For that reason, the price of tradable goods is exogenously given and normalized to unity. The small open economy can borrow and lend at the gross interest rate that in equilibrium is assumed to be R_t = 1.0400, which equals a net interest rate level of 4 percent. In contrast to Benigno and Fornaro (2014) and in line with chapter 1, my model allows for an international market for capital goods. The home economy can import and export capital goods, the relative price (q_t) of these capital goods (machinery) is exogenously given by the world market and normalized to q = 1.0000.

To calibrate the parameters of the representative household, I again follow Benigno and Fornaro (2014) and choose the discount factor at β = 0.9760. As the Euler equation (2.6) indicates, this assumption ensures that the growth rate of tradable goods consumption in the steady state is equal to g^*. The expenditure share of the tradable good is set to ω = 0.4140, the labour supply of the household (labour endowment) is normalized to L = 1.0000.

An important element of the Benigno and Fornaro (2014) model is the process of technology accumulation, see Eq. (2.8). The growth rate of the world technological frontier is set to g^* = 0.0150. This number matches the average yearly growth rate of total-factor-productivity in the United States between 1960 and 1995. The initial value for the stock of technology of the world technological leader is set at $A_0^* = 6.4405$, which corresponds to the estimation of Benhabib and Spiegel (2005) for USA in 1995. Adopting the estimation for Spain in 1995, the initial value of the home/domestic small open economy is chosen to be equal to $A_0 =$

[21] Chapter 1 was written in co-authorship with Jochen Michaelis (joint research project). Thus, the work and its description of Jochen Michaelis contributed to a large extent to (the descriptions in) this chapter (chapter 2.4).

4.1384. Similarly, to match the evolution of total-factor-productivity in Spain, Benigno and Fornaro (2014) (and I) set the convergence parameter that captures the ability of the home economy to absorb foreign technology by sector T employment to c_1 = 0.1670.

I set the ability of the home economy to absorb foreign technology by sector T foreign capital stocks (K_t^{TF}) to c_2 = 0.0300. A value of c_2 = 0.0300 ensures that in both interest rate scenarios (see chapter 2.5), A_t never reaches A_t^*, despite the vast import of foreign capital into sector T in the initial periods of simulation. The domestic technology levels (A_t) reaching those of the world technological leader (A_t^*) is unrealistic, as I am studying the macroeconomic integration of peripheral Europe in the 1990s. In chapter 2.5, I also check the robustness of my results by calibrating other varieties of c_2. As I am interested in a qualitative assessment, and as I find no reaction of employment in tradable production (L_t^T) to lower interest rates (see below), the exact calibration of the parameter c_2 is qualitatively of a minor importance. Remember that besides foreign capital invested tradable production K_t^{TF}, employment in tradable production L_t^T steers technology accumulation in Eq. (2.8). Thus, regardless of the calibration of c_2, lower interest rates and the thus promoted inflow of foreign capital into tradable production should push productivity (A_t) in a scenario of low interest rates. Regardless of the calibration, A_t is programmed not to exceed A_t^* as a condition in my code.

In a next step, let us turn to the production functions for the tradable sector and the non-tradable sector. In line with Benigno and Fornaro (2014), the labour share is assumed to be identical across sectors, I set α = 0.7011 which is the arithmetic mean of the values defined in de Cordoba and Kehoe (2000), who assume a labour share of 0.7131 for sector T and of 0.6891 for sector N. Following de Cordoba and Kehoe (2000), I choose the yearly capital stock depreciation rate to be equal to δ = 0.0576. The initial sector T capital stock is set to K_0^T = 1.0000. In de Cordoba and Kehoe (2000), I find an indication that K_0^N is *roughly* 1.84 times higher than K_0^T. Thus, I assume K_0^N = 1.8400 K_0^T, implying K_0^N = 1.8400.

I assume a symmetric initial distribution of domestically financed/produced and foreign financed/produced capital stocks installed in sectors T and N, meaning K_0^{ND} = 0.9200, K_0^{NF} = 0.9200, K_0^{TD} = 0.5000, and K_0^{TF} = 0.5000.

The production function of the capital goods sector (2.23) remains to be calibrated. As μ influences the productivity of the domestic capital goods production sector, I expect that μ influences the share of capital stocks in sectors N and T made up by domestic capital. I expect that a lower level of μ induces a higher share of foreign capital flowing into domestic sectors N and T. In line with chapter 1, I expect[22] that a (too) high level of μ in capital goods production induces domestic capital goods production above sectoral (N and T) demand for capital goods, implying a total crowding out of foreign capital installed in both sectors N and T, and the small open economy becoming a (net) exporter of capital goods (K_t^F< 0, K_t^{TF}< 0, and K_t^{NF}< 0). Investigating the economic evolution of an emerging/catching-up economy (for the first periods of simulation) the latter is not meaningful (Eaton, Kortum, 2001) for the initial periods of simulation.

[22] In chapter 1 it is mentioned that some parameter constellations confirmed the expectation that a higher μ induces lower K_t^F (also K_t^{NF} and K_t^{TF}) in selected periods. For transparency, there were also found parameter constellations where a higher μ induced higher K_t^F (also K_t^{NF} and K_t^{TF}) in selected periods.

For example, using Worldbank (2021a – 2021k) data, Spain constantly was a *net importer* of ‘capital goods’ from 1995 to 2005, the period under consideration. Wagner (2007) concludes that the productivity of firms which are exporting is higher than the productivity of firms who are not exporting. Thus, the productivity of the (Spanish) capital goods production (in my model controlled by μ) should not be too high.

To investigate the impact of foreign capital installed in domestic sector T on technology accumulation, it requires foreign capital (goods) to flow into the (domestic) small open economy ($K_t^{TF} > 0$). A level of μ = 0.5000 implies in the numerical experiment (chapter 2.5) that both interest rate scenarios realize a positive stock of K_t^{TF} in the first ten periods of simulation, which make up the treatment period of macroeconomic integration (see below in this chapter).

Regarding the share of tradable goods utilized as input in the production of the capital good, I again follow de Cordoba and Kehoe (2000) and set γ = 0.3802. Finally, I set the initial bond holding to $B_0 = 0.0000$, in line with Benigno and Fornaro (2014).

As my model is more complex compared to the model of Benigno and Fornaro (2014), I regard it as meaningful to expand the period (years) needed to transition to a steady state to 225, to improve the accuracy of my results, compared with 200 in the Benigno and Fornaro (2014) model.

The experiment is a temporary reduction of the interest rate, which I study by numerical simulations in chapter 2.5. I follow Benigno and Fornaro (2014) in defining two interest rate *scenarios*:

‘Normal interest rates’ imply a level of R=1.0400 for interest rates over the whole T=225 periods of simulation.

The effect of macroeconomic integration is investigated in a ‘Low interest rates’ scenario. This implies that interest rates are at level R_low=1.0100 for the first ten periods of simulation (t=0 to and including t=9). This equals a net interest rate of 1 percent. After ten periods (i.e., from and including t=10 on), they return to the long run equilibrium of R=1.0400 for the rest of the T=225 simulated periods.

I calibrate as follows:

Parameter	Value	Description
g^*	0.0150	Total-factor-productivity growth rate of the world technological leader
R	1.0400	Interest rate
R_low	1.0100	Interest rate in the low interest rate scenario
q	1.0000	Relative price of capital goods
β	0.9760	Discount factor
ω	0.4140	Share of tradable goods in consumption
L	1.0000	Total endowment of labour
A_0^*	6.4405	Initial total-factor-productivity of the world technological leader
A_0	4.1384	Initial total-factor-productivity of the domestic economy
c_1	0.1670	Convergence parameter in technology accumulation by sector T employment
c_2	0.0300	Convergence parameter in technology accumulation by sector T foreign capital stock
α	0.7011	Labour share in the production of tradable goods and non-tradable goods
δ	0.0576	Capital stock depreciation rate
μ	0.5000	Degree of the international technology spillover across sectors K and T
γ	0.3802	Share of tradable goods in the production of capital goods
K_0^T	1.0000	Initial capital stock in sector T
K_0^{TD}	0.5000	Initial domestically financed/produced capital stock in sector T
K_0^{TF}	0.5000	Initial foreign financed/produced capital stock in sector T
K_0^N	1.8400	Initial capital stock in sector N
K_0^{ND}	0.9200	Initial domestically financed/produced capital stock in sector N
K_0^{NF}	0.9200	Initial foreign financed/produced capital stock in sector N
B_0	0.0000	Initial bond holdings of the small open (domestic) economy
T	225	Number of periods (years) to transition to steady state
t		Periods are years

Table 2.1: Calibration of numerical simulations.

2.5 Results

This chapter provides an insight into the results of the numerical simulations.[23] In figures 2.2 and 2.3, solid lines simulate the 'normal interest rates scenario' (norm) as a benchmark, dashed lines simulate the 'low interest rates scenario' (low) of macroeconomic integration. There are similarities with the results and their description in chapter 1 (precisely chapter 1.5) (see also Hildebrandt, Michaelis, 2022).

Lower interest rates (panel 2.2a) from macroeconomic integration have the following effects:

Responding to lower interest rates, output in sectors N and T, Y_t^N and Y_t^T, increases significantly (panels 2.2b and 2.2c), as capital stocks in sectors N and T, K_t^N and K_t^T, respond positively (panels 2.2g and 2.2h). Simultaneously, reflecting the promotion of sectoral capital levels, total output GDP_t ($GDP_t = Y_t^N P_t^N + Y_t^T$) responds positively (panel 2.2d).

In line with the findings of Benigno and Fornaro (2014), initial consumption levels C_t^N and C_t^T respond positively, as expected (panels 2.2e and 2.2f). Contrasting the findings of Benigno and Fornaro (2014), the initial increase of particularly C_t^N does *not* require a movement of labour resources out of tradable production, into non-tradable production L_t^N (panel 2.2i). The reason is that the initial increase in non-tradable consumption is served from additional sector N output, Y_t^N, which is promoted by additional sector N capital accumulation, see K_t^N (panel 2.2g).

During the phase of low interest rates, consumption levels C_t^N and C_t^T (panels 2.2e and 2.2f) decrease below the levels emerging in the normal interest rates scenario, reflecting the increasing investment of non-tradable goods and tradable goods into domestic capital (goods) production/accumulation, Z_t^N and Z_t^T (panels 2.2j and 2.3a). These levels (Z_t^N and Z_t^T) respond positively to lower interest rates, as the domestic sector producing capital goods (sector K, promoting K_t^D) is facing additional demand for capital goods (panel 2.3f). Firms in sectors N and T can borrow more cheaply, which promotes their demand for capital goods.

[23] I use the standard shooting algorithm code that Benigno and Fornaro (2014) introduced and extend it by technology accumulation from foreign capital stocks. In doing so, my code rests on the code of chapter 1 (precisely chapter 1.3), now extended by technology accumulation from foreign capital inflows according to chapter 2.3. The code of chapter 1 (precisely chapter 1.3) rests on the code of Benigno and Fornaro (2014). The shooting algorithm starts to solve the simultaneous system by using an initial assumption for tradable consumption C_t^T in period 0. In this way it is possible to solve the simultaneous system for the introduced endogenous variables, for the whole T=225 periods, using the starting values of table 2.1. At the end of period T=225, the algorithm checks the deviation from the intertemporal resource constraint Eq. (2.30), mirroring that the present value of total tradable goods' consumption must be equal to the present value of total tradable goods production. Should the deviation from the intertemporal resource constraint exceed a predefined tolerance parameter, using the initial (t=0) assumption for tradable goods consumption C_0^T, the algorithm updates its initial assumption for tradable consumption and checks again the fulfillment of the intertemporal resource constraint Eq. (2.30). I set the tolerance parameter to 2e-9, compared with 2e-8 in Benigno and Fornaro (2014) to improve the accuracy of my (extended) model. As soon as the deviation from the intertemporal resource constraint undercuts / falls short of the tolerance parameter, the algorithm stops and provides the result. The simultaneous system / shooting algorithm code runs in Matlab, figures are made in Microsoft Excel.
In my computer code, domestic and foreign investment into capital accumulation (in a current period 't') requires a future (= next period 't+1') sectoral employment assumption. To make capital stocks in tradable and non-tradable production (K_t^T and K_t^N) benefit *simultaneously* from capital accumulation and low interest rates, the code assumes that current (= in the current period 't') sectoral employment (L_t^T and L_t^N) will equal future (= next period 't+1') sectoral employment when calculating future (= next period 't+1') sectoral capital stocks (K_{t+1}^T and K_{t+1}^N). Shown in Eq. (2.22), this implies that the share of capital invested in sector T (and N) is assumed constant over time. This maintains stable sectoral employment in steady state. My interpretation of the original Benigno and Fornaro (2014) model is that, by using a Cobb-Douglas consumption index, Benigno and Fornaro (2014, p.67, 75) require a stable sectoral employment in the steady state to ensure a 'balanced growth path'.
Moreover, my computer code assumes that the domestically financed/produced capital goods are distributed over sectors N and T in the same ratio as total capital (financed/produced from 'domestic' *and* 'foreign') goods are distributed over sectors N and T.

As expected, inward foreign capital inflows into sector T respond positively (panel 2.3b). The result of the spurred-on attraction of foreign capital is a promotion of technology accumulation A_t in sector T (panel 2.3c).

As one can see, total-factor-productivity A_t is constantly higher during the period of lower interest rates (first ten periods), compared to the scenario of normal interest rates (panel 2.3c). The pattern I observe is connected to the empirical observation on 'good booms' of Gorton and Ordoñez (2020). They term credit booms, that do not end in a crisis 'good booms'. Gorton and Ordoñez (2020) found 'good booms' to be accompanied by a higher productivity level then the productivity level in 'bad booms'. 'Bad booms' they term credit booms that end in a crisis. Thus, by comparing my results (panel 2.3c) with those of the original/basic Benigno and Fornaro (2014) model (panel 2.3d), the picture changes:

Should one neglect the impact of macroeconomic integration on capital accumulation *and* on technology accumulation (like shown in the Benigno and Fornaro, 2014, model), macroeconomic integration induces the *Financial Resource Curse* that Benigno and Fornaro (2014) found. A negative impact of macroeconomic integration on (the growth rate of) technology accumulation emerges (panel 2.3d). This is driven by a movement of (labour) resources out of tradable production, spurred-on by booming consumption of particularly non-tradable goods (Benigno, Fornaro, 2014).

Extending the model of Benigno and Fornaro (2014), considering the positive impact of macroeconomic integration on capital and technology accumulation, lower interest rates induce a positive impact on technology accumulation. Considering capital as a second production factor allows the initially booming tradable and non-tradable consumption to be served by additional tradable and non-tradable output, promoted by growing sectoral capital stocks (like seen in chapter 1).

The harmful movement of resources out of tradable production (shown in Benigno and Fornaro, 2014) is thus prevented. Like in chapter 1, my assumptions incorporated in my model are responsible for the observation, that labour supplied to sectors N and T does not react to lower interest rates.[24] This is in line with chapter 1, I refer to chapter 1 for further technical explanation. The additional inflow of foreign capital in the low interest rates scenario promotes (the growth rate of) technology accumulation (panel 2.3b and 2.3c).

During the period of low interest rates, K_t^F responds positively. If $K_t^F < 0$, this mirrors that in period t, there is no foreign capital invested/installed, neither in domestic tradable, nor in domestic non-tradable production (panel 2.3e). Net foreign assets NFA_t (relatively to GDP) respond negatively (panels 2.3g and 2.3i), reflecting that firms demand foreign capital (K_t^F) (panel 2.3e and 2.3h). As some of the additionally demanded tradable goods (demanded for Z_t^T and C_t^T) are imported, bond holdings $\frac{B_{t+1}}{R_t}$ respond negatively (panel 2.3j).

[24] In chapter 2 (like in chapters 1 and 3), labour shares α are assumed to be similar across sectors N and T. I arithmetically checked for varying labour shares α between sectors N and T in a back-of-the-envelope calculation. As far as I see, I expect most of my core findings shown above to be qualitatively invariant towards such extension, taking the rest of the computer code and of my assumptions as given, particularly if continuing to assume that capital stocks in both sectors (N and T) benefit simultaneously from capital accumulation and low interest rates. Varying labour shares α across sectors N and T would particularly change steady state labour allocation between sectors N and T. In my results, sectoral labour supply is invariant to variations of interest rates. In my code, it comes from assuming, that capital stocks in both sectors N and T benefit simultaneously from capital accumulation and low interest rates. My code assumes that future sectoral employment equals current sectoral employment when calculating future sectoral capital stocks, see previous footnote (see also chapter 1). This strategy fulfills the required stable sectoral employment in steady state (like in Benigno, Fornaro, 2014).

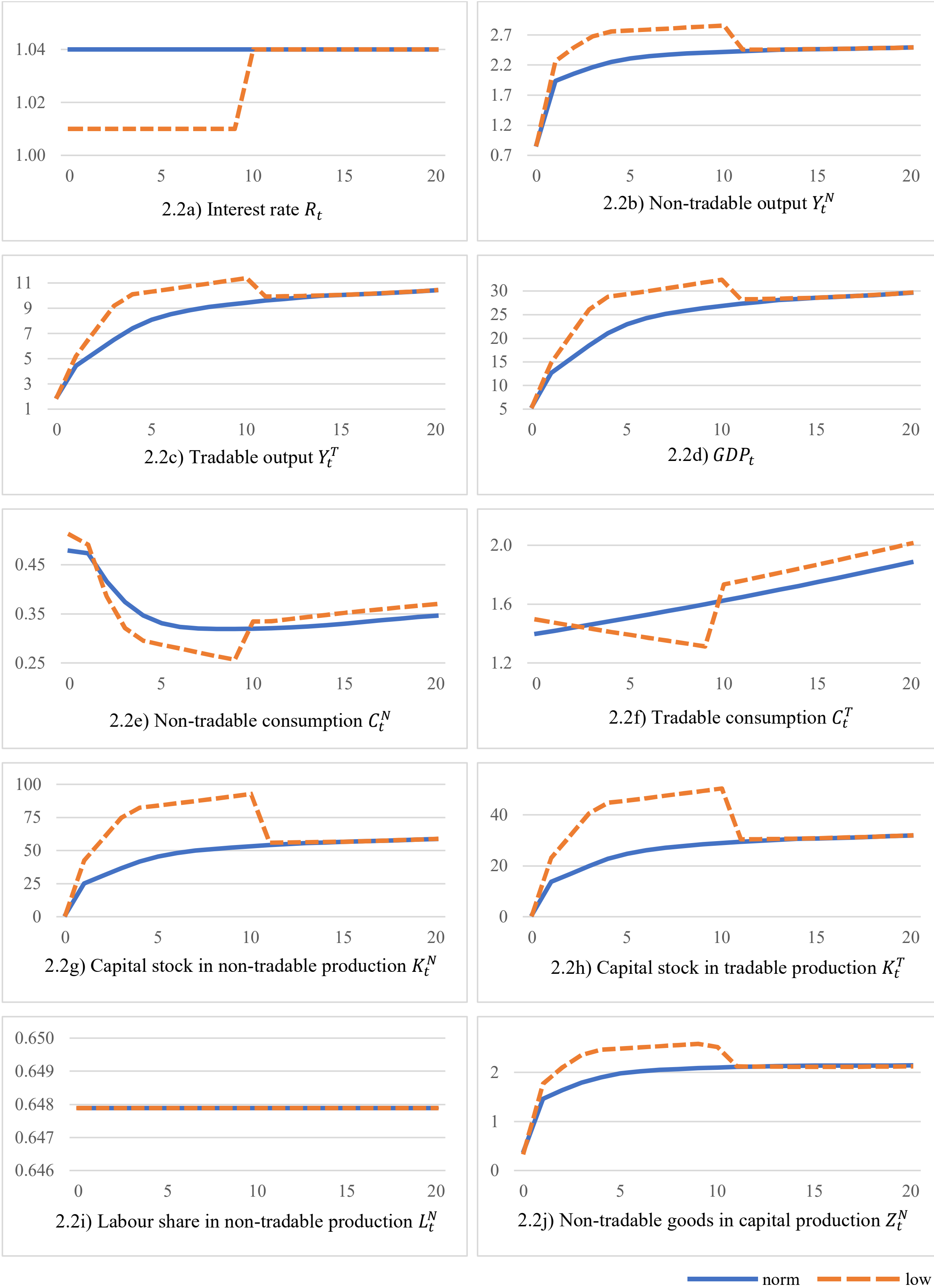

Figure 2.2: Results of numerical simulations. Horizontal/longitudinal axes are periods/years.

‘norm’: normal interest rates scenario, no macroeconomic integration, benchmark economy.
‘low’: low interest rates scenario, macroeconomic integration, treatment economy.

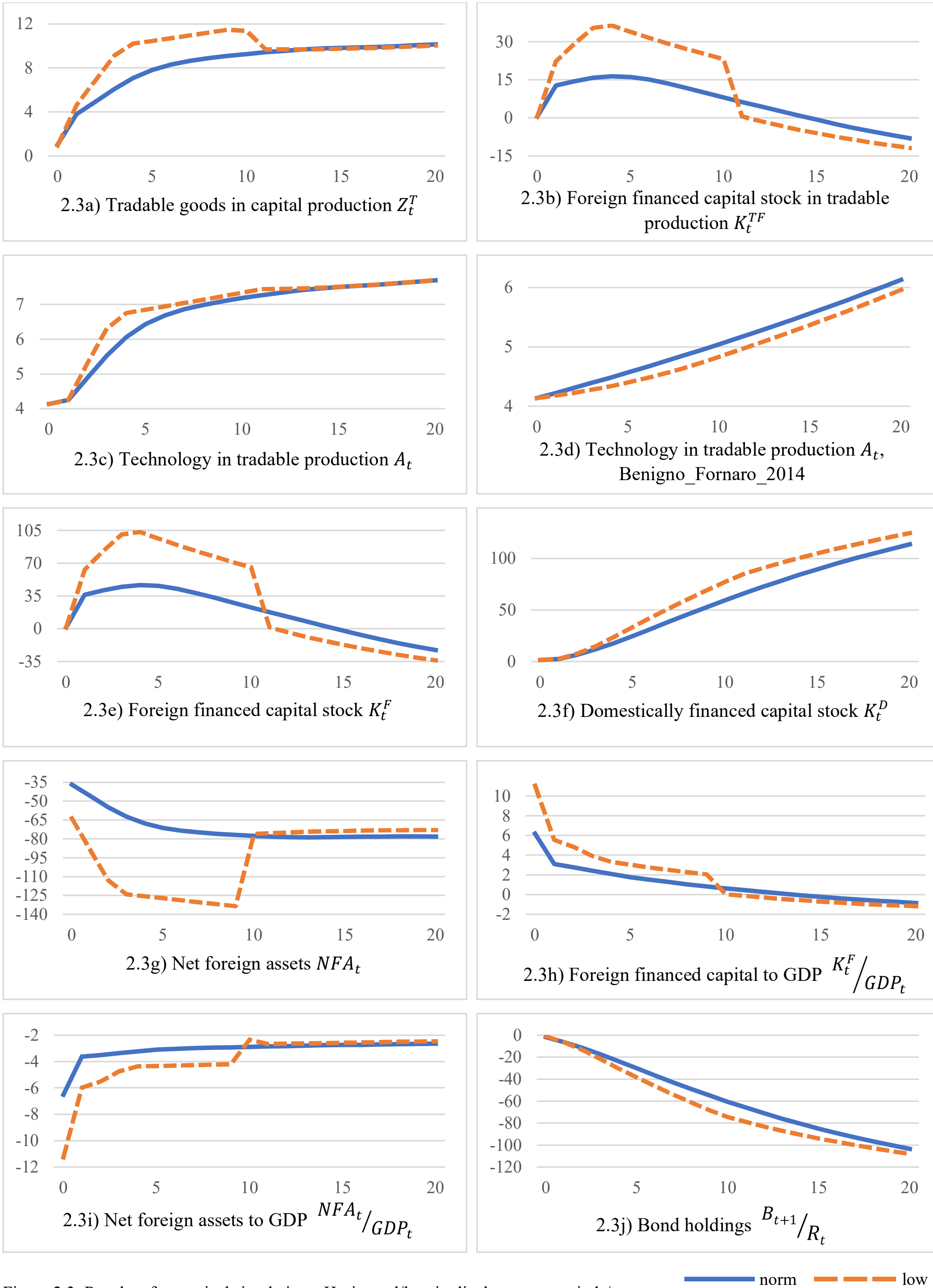

Figure 2.3: Results of numerical simulations. Horizontal/longitudinal axes are periods/years.
'Technology in tradable production A_t, Benigno_Fornaro_2014' (panel 2.3d) are the results for A_t of the basic/original Benigno and Fornaro (2014) model.

'norm': normal interest rates scenario, no macroeconomic integration, benchmark economy.
'low': low interest rates scenario, macroeconomic integration, treatment economy.

Welfare

Coming to a welfare comparison of the economy facing a temporary reduction in interest rates with the economy facing constantly normal interest rates, I calculate the representative household's present value of lifetime utility, for my model that considers the positive response of capital and technology accumulation to low interest rates and macroeconomic integration.

For my standard calibration[25], the welfare level in the 'normal interest rates scenario' is lower than in the 'low interest rates scenario', like in the standard calibration of the original/basic Benigno and Fornaro (2014) model. Table 2.2 summarizes welfare levels. Negative values result from logging consumption < 1.

	Normal interest rates scenario		Low interest rates scenario
Basic/original model, welfare Benigno, Fornaro (2014) model Standard calibration	+ 8.9	<	+ 9.0
Extended model, welfare Chapter 2.3 model Standard calibration	- 7.4	<	- 6.1

Table 2.2: Welfare comparison of the normal interest rates scenario with the low interest rates scenario, for the basic/original model of Benigno and Fornaro (2014) (without capital as a production factor), and for my extended model (with capital as a production factor, and with technology accumulation from foreign capital), both models in their standard calibration.

As a result of the promoted inflow of foreign capital and of promoted technology accumulation, the impact of low interest rates on welfare is positive. This is like for most of the parameter constellations in chapter 1. In the low interest rates scenario, non-tradable and tradable consumption are initially higher before they fall *below* respective levels of the normal interest rates scenario (see panel 2.2e and 2.2f in figure 2.2).

Anyway, welfare levels are higher in the low interest rates scenario (see above), as in the long run, consumption levels are higher in the low interest rates scenario (because of promoted technology and capital accumulation).

[25] In an earlier version of this chapter 2 (not published), I included a similar table (see table 2.2) comparing the welfare levels of the normal (global) interest rates scenario (no macroeconomic integration) with the low (global) interest rates scenario (macroeconomic integration), for the standard calibration of my chapter 2/model, and for the standard calibration of the basic/original Benigno and Fornaro (2014) model.
Erroneously/incorrectly, I showed in the earlier version of my chapter 2 (not published) that for the standard calibration, welfare levels in the basic/original Benigno and Fornaro (2014) model are higher in the normal (global) interest rates scenario than in the low (global) interest rates scenario. This was erroneous/incorrect. Correcting for this mistake/error, in my results, as well as in the basic/original Benigno and Fornaro (2014) model results, welfare levels are higher in the low interest rates scenario than in the normal interest rates scenario for the standard calibration (see table 2.2 of chapter 2). My mistake/error resulted from an erroneous calculation of the household welfare / present value of lifetime utility. The old (erroneous/incorrect) welfare data calculated for the basic/original Benigno and Fornaro (2014) model supported the hypothesis/results of Benigno and Fornaro (2014), but by doing so, the old (erroneous/incorrect) welfare data also supported the motivation of my chapter 2.
The erroneous/incorrect welfare calculations (particularly for the basic/original Benigno and Fornaro, 2014, model) were not included in any publication of my chapter 2. But they were included in earlier versions of my chapter 2, submitted in the application for conferences/workshops, and in my presentations (marked as *preliminary results*) there.

Robustness for ranges of c_2

Benigno and Fornaro (2014) introduced variable η (see Eq. (2.32)) that depicts the consumption equivalent to be handed over to the household living in the scenario of normal interest rates, to make him as well off as the household living in the low interest rates scenario in terms of present value lifetime utility.

Benigno and Fornaro (2014) find that low interest rates induce a crowding out of sector T employment by sector N employment, impeding (the growth rate of) technology accumulation, which *potentially* negatively affects welfare, depending on their calibration. For high levels of *c* (c_1) they found that η is negative, as low interest rates in that case in the basic/original Benigno and Fornaro (2014) model led to the crowding out of sector T employment, which would have been highly capable of accumulating foreign technology.

$$\sum_{t=0}^{\infty} \beta^t \log \left[(1+\eta)\, C_t^{normal\ rates} \right] = \sum_{t=0}^{\infty} \beta^t \log \left[C_t^{low\ rates} \right] \tag{2.32}$$

I found a positive impact of macroeconomic integration and low interest rates on welfare (see above in table 2.2), because of improved technology accumulation from inward foreign capital.

I check in the following (figure 2.4) if my result holds for different levels of the efficiency in accumulating foreign technology from sector T inward foreign capital stocks (different levels of c_2).[26]

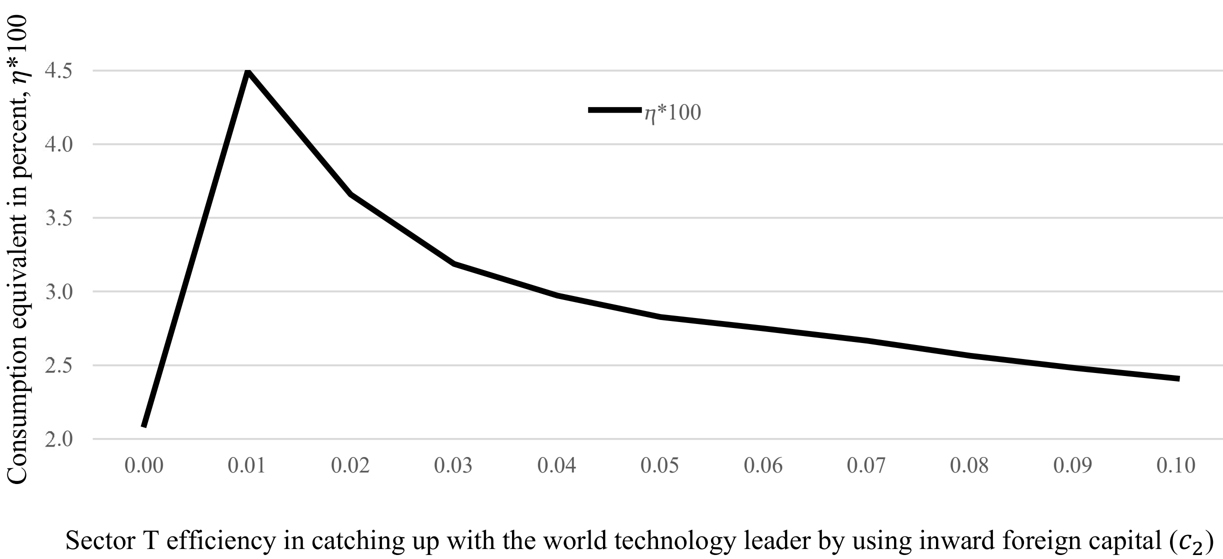

Figure 2.4: Consumption equivalent η*100 of low interest rates for a range of c_2.

For the whole range of $0.00 \le c_2 \le 0.10$, low interest rates produce a positive consumption equivalent η, which implies a constantly higher present value of household lifetime utility in the low interest rates scenario. This confirms the robustness of my results.

[26] Regardless of how well sector T performs in accumulating foreign technology from foreign capital (higher calibrations of c_2), in my code $A_t \le A_t^*$ is set.

The result that η is positive even if c_2 = 0.00 emerges from promoted capital accumulation in the low interest rates scenario. Promoted capital accumulation promotes welfare, like in found in chapter 1 for most of the parameter constellations checked there. The positive value of η over the range of $0.00 \leq c_2 \leq 0.10$ stems from the positive effect of promoted capital inflows on technology and capital accumulation. This benefits household utility should the household live in the low interest rates scenario.

From $c_2 = 0.01$ on, η mostly declines in c_2. The reason is simple. In general, a higher c_2 benefits the welfare of the small open economy, as it augments technology accumulation. The low interest rates scenario as well benefits welfare, particularly as it pushes technology accumulation from additional foreign capital inflows into sector T. Should the small open economy realize a high c_2, the small open economy accumulates foreign technology more sufficiently. Then, welfare levels of the small open economy depend less on the technology accumulation from additional foreign capital inflows into sector T promoted by low interest rates.

2.6 Conclusion

This chapter (chapter 2) considers technology accumulation from foreign capital inflows. When an economy is integrating macroeconomically, foreign technology in the backpack of foreign capital goods inflows promotes technology accumulation and total-factor-productivity in the host economy. In line with the findings of Benigno and Fornaro (2014), an initially booming tradable and non-tradable consumption appears as a reaction to lower interest rates and macroeconomic integration. But like in chapter 1 (see also Hildebrandt, Michaelis, 2022), a harmful movement of resources out of tradable production into non-tradable production is prevented particularly by growing non-tradable output, promoted by additional capital accumulation, serving the booming non-tradable consumption (see also the argument of Mian, Sufi, Verner, 2020, in chapter 1.5). This contradicts the findings of Benigno and Fornaro (2014). When integrating macroeconomically, the promotion of technology accumulation by inflowing foreign capital benefits particularly tradable production. But, because of sectoral spillovers, capital goods production and indirectly also non-tradable production benefit, as it is utilizing domestically produced capital goods. I call this the Financial Resource *Gain*.

Coming back to the Greek and Spanish example mentioned in the introduction, my model shows for a wide range of parameter constellations (efficiency of tradable production in accumulating foreign technology from inflowing foreign capital, c_2) that macroeconomic integration and lower interest rates do not necessarily induce a *Financial Resource Curse* of an impeded/burdened (growth rate of) technology accumulation. Checking the robustness of my results, I found that my findings are consistent over a wide range of how well the domestic sector producing tradable goods performs in accumulating foreign technology from inward foreign capital (c_2). My finding implies that low interest rates cannot be solely attributed to the poor development of productivity in peripheral Europe during European macroeconomic integration (shown in Benigno, Fornaro, 2014, for Spain. See also Bennett et al., 2008, for a burdened/low TFP growth rate in Portugal and Italy from 1996 to 2006. Sinn, 2012, 2015 shows declining/low interest rates for, among others, these two economies, roughly in this time frame).

Limitations and further research

Further research should address the Lucas (1990) Paradox. It describes the anomaly that capital barely flows to poor(er) economies, although one might expect capital to flow to poor(er) economies because of a higher marginal capital productivity in (capital) poor(er) economies. Such anomaly in the movement of capital in the direction of poor(er) economies is not considered in my model yet. Moreover, my model assumes capital to flow without frictions when integrating macroeconomically. Since frictions (see, e.g., Gopinath et al., 2017) might qualitatively change my results, the fact that my model does not consider frictions yet represents a major limitation of my model.

Like in chapter 1, another major limitation is that my results require the assumption that capital stocks in both sectors, T and N, benefit simultaneously from capital accumulation, low interest rates and macroeconomic integration. Recent research (Piton, 2019, see also 2021) challenges this assumption. Piton (2019, see also 2021) found for (selected economies in) the European periphery that the 'user costs of capital' developed asymmetrically between tradable and non-tradable production during the time of European (macroeconomic) integration (late 1990s and early 2000s in Piton, 2019). Ranciere, Tornell and Westermann (2003) as well as Tornell and Westermann (2002) also argue that (capital accumulation in) tradable and non-tradable production responds asymmetrically to credit expansion and financial liberalization.

Connected to the limitations is a gap between empirics and theory, that this chapter (chapter 2) unveiled. Empirically, Benigno and Fornaro (2014) showed that European (macroeconomic) integration, with reduced interest rates, did accompany a burdened/declining (total-factor-) productivity in Spain (see also Bennett et al., 2008, for a burdened total-factor-productivity growth in Italy and Portugal). Theoretically, this chapter (chapter 2) showed that European macroeconomic integration should benefit/push (total-factor-) productivity of the macroeconomically integrating economy. Thus, chapter 2 shows a gap between empirics and theory.

The following chapter 3 of the Ph.D. thesis at hand contributes to closing this gap. Chapter 3 will address asymmetric effects that macroeconomic integration has on capital costs in tradable production and in non-tradable production (motivated by, among others, the findings of Piton, 2019, see also, 2021, see chapter 3) in the integrating economy, capable to explain a burden for (the growth rate of) total-factor-productivity.

In my results, the vast inflow of foreign capital results in skyrocketing technology accumulation, should the economy integrate macroeconomically. Modelling technology accumulation from foreign capital at a slowed pace (lower value of c_2) would make my results more realistic but probably would *qualitatively* not change most of my results (figure 2.4). I lend modelling/calibrating a more realistic (slower) technology accumulation from foreign capital (c_2) to the following chapter 3. Moreover, it is debated how the size of an economy's technology gap to the world technological frontier influences its ability to accumulate foreign technology (see, e.g., Keller, 1996). The model presented here is suitable to contribute to such question.

3. The Riskless Resource Curse: Reducing Risk Slows Productivity and Welfare [27]

Empirically, European integration was accompanied/followed by depressed peripheral (total-factor) productivity, potentially depressing welfare (Benigno, Fornaro, 2014, for Spain. See also Bennett et al., 2008, for a burdened total-factor-productivity growth rate in Italy and Portugal). Earlier economic theory (Benigno, Fornaro, 2014) argued that low interest rates from European integration push consumption in the integrating economy, relocating resources from tradable to non-tradable production. This depresses (the growth rate of) productivity, and potentially welfare, in the integrating economy, termed by Benigno and Fornaro (2014) as *Financial Resource Curse.* Despite this theory found support, subsequent theory in chapter 1 and chapter 2 (of this dissertation at hand) opposed that low interest rates and credit expansion (from European macroeconomic integration) should push capital accumulation (see also, e.g., Gorton, Ordoñez, 2020, Tornell, Westermann, 2003, Blanchard, Giavazzi, 2002, Benigno, Converse, Fornaro, 2015, Mian, Sufi, Verner, 2020) and technology accumulation from inflowing foreign capital, *promoting* (total-factor) productivity (see, e.g., Baltabaev, 2014, Eaton, Kortum, 2001, Amann, Virmani, 2015) and welfare. This shows a gap between empirics and theory. This chapter (chapter 3) contributes to closing this gap. Chapter 3 models a theory with sectoral capital cost differences from risk in tradable production before (European) macroeconomic integration. This chapter assumes that European (macroeconomic) integration reduces risk and thus capital costs particularly in (export oriented) tradable production (derived from the findings/arguments of Piton, 2019, see also, 2021, and Griffith, Harrison, Simpson, 2010, see below) of the integrating economy. Changing relative input prices in tradable production, European (macroeconomic) integration relocates resources, and this *potentially* depresses (the growth rate of) total-factor-productivity, and welfare in the integrating economy.

3.1 Introduction

Economic theory argued that interest rate lowering (European) macroeconomic integration depressed (the growth-rate of) peripheral European productivity, and potentially welfare, around the 1990s and 2000s (Benigno, Fornaro, 2014, researching Spain). Low interest rates from (European) macroeconomic integration[28] promote consumption, requiring productive resources to depart tradable production (sector T), and to enter non-tradable production (sector N) (Benigno, Fornaro, 2014).

[27] I thank my supervisor, Jochen Michaelis, for his support when I was working on this chapter, and for his suggestions to improve this chapter. I thank Ulrich Zierahn for exchanging some thoughts on sectoral risk. I thank the participants of the 16th CEUS workshop in Vallendar, particularly Aaron Putseys, for their helpful suggestions to improve this chapter. I also thank Beverley Locke, Blanca Tena, and Max Fuchs, Jan Hattenbach, Luzie Thiel and Joshua Wimpey for their helpful suggestions/support to improve this chapter. I also thank Gianluca Benigno and Luca Fornaro for sharing and introducing their computer code with/to me. Moreover, I thank Gonzalo Fernandez de Cordoba and Timothy Kehoe for their computer code and support. I also thank the participants of the 23rd European Trade Study Group Meeting in Groningen, September 2022, for their suggestions to improve this chapter. I also thank the participants of the graduate school 'Economic Behaviour and Governance' of the Kassel University for their helpful suggestions for improvements.

[28] Benigno and Fornaro (2014, p.59) refer to (European) '*financial* integration'. I refer to 'European *macroeconomic* integration', as it opens the way to the findings of my Ph.D. thesis (presented particularly in chapter 3).

Productive resources departing tradable production hinders learning-by-doing. This depresses (the growth rate of) productivity and technology accumulation from a world technological frontier in tradable production (Benigno, Fornaro, 2014, based on Duarte, Restuccia, 2010, and on Rodrik, 2013). Benigno and Fornaro (2014) name low interest rates and their depressing effect on productivity and potentially on welfare *'The Financial Resource Curse'*, when researching the Spanish economy.

Despite that *The Financial Resource Curse* theory found support, subsequent recent theory doubts that it are low interest rates which depress (the growth rate of) (total-factor) productivity, and potentially, welfare (chapter 1 and 2 of the dissertation at hand). Chapter 1 showed theoretically that low interest rates from (European) macroeconomic integration push capital accumulation and output, capable to serve the booming consumption that low interest rates induces. Pushed output thus preserves resources in tradable production, and this preserves welfare (for most of the parameter constellations checked there). As pushed output preserves resources in tradable production, technology accumulation from the world technological frontier is preserved as well. Chapter 2 theoretically adds that low interest rates from macroeconomic integration promote capital (goods) imports, which transfer foreign technology (see also, for example, Baltabaev, 2014, Eaton, Kortum, 2001, Amann, Virmani, 2015). This pushes (total-factor-) productivity and welfare of the integrating economy.

Thus, there emerges a gap between:

1) Empirics

   Low interest rates and macroeconomic integration are accompanied/followed by depressed total-factor-productivity in peripheral Europe (Benigno, Fornaro, 2014, for Spain. See also Bennett et al., 2008, for burdened/low total-factor-productivity growth in Italy and Portugal) and
2) Latest theory

   Low interest rates and macroeconomic integration should have pushed total-factor-productivity in peripheral Europe (chapter 2 of the dissertation at hand).

This chapter (chapter 3) contributes to closing this gap between empirics and latest theory. It theoretically argues that (European) macroeconomic integration, *besides* lowering interest rates (Benigno, Fornaro, 2014, Sinn, 2012, 2015), affects sectoral (N and T) capital costs *differently,* from sector specific risk in tradable (T) production.

This chapter (chapter 3) theoretically assumes that, before (European) macroeconomic integration, due to currency risk, transportation risk, and contract risk when importing intermediates and exporting goods, tradable production (sector T) has risk that is minor in non-tradable production (sector N). In my theoretical model, excess risk in tradable production makes capital lenders to expect excess return, explaining higher capital costs in tradable production *before* macroeconomic integration.

Macroeconomic (one might also say, political) integration unites currencies, improves infrastructure, and harmonizes product standards (Baldwin, Wyplosz, 2015, Blanchard, Giavazzi, 2002, Griffith, Harrison, Simpson, 2010). The harmonization of product standards might also improve contract reliability in international trade. These facts reduce risk particularly in (export oriented) tradable production[29].

Thus, lower risk in tradable production lowers return expectations in tradable production, and thus lowers capital costs in tradable production, resulting from macroeconomic integration.

I assume that wages in tradable production equal wages in non-tradable production, regardless/independent of macroeconomic integration (like in Benigno, Fornaro, 2014). Thus, in my theoretical results, the reductions of capital costs in tradable production (resulting from macroeconomic integration) change relative input prices (ratio 'capital costs to labour costs') particularly in tradable production after macroeconomic integration. As a result, I find that tradable production demands more capital and less labour, should the modelled small open economy integrate macroeconomically. As macroeconomic integration lowers capital costs in tradable production, firms in tradable production substitute labour against capital. The hiring of less labour slows learning-by-doing and (total-factor) productivity in tradable production (depending on the calibration) (mechanism of Benigno, Fornaro, 2014). Low learning-by-doing and slow productivity burden welfare.

In a seminal paper, Piton (2019) rationalizes my assumptions summarized above. Piton analyses 12 economies of the Euro area from 1995 to 2015. Piton (2019) shows that tradable production *in general* has higher 'user costs of capital' than non-tradable production. Piton (2019) argues that this is the case, as tradable production utilizes capital (goods) that is/are more technology intensive. A higher technology intensity implies a faster obsolescence of capital goods in tradable production, because of technological progress, augmenting the 'user costs of capital' in tradable production. In non-tradable production, capital is more often embodied in real estate, with a slow obsolescence, slowing/moderating the 'user costs of capital' in non-tradable production.

Next, Piton (2019) also shows empirically that, during the progression of European (macroeconomic) integration (1995-2007), for selected peripheral European economies (Greece and Ireland), the 'user costs of capital' in non-tradable production grew faster than in tradable production (see also Piton, 2021, for peripheral Europe). In other words, relatively to non-tradable production, the 'user costs of capital' declined in tradable production during the progression of European (macroeconomic) integration, in selected peripheral European economies. In contrast to the motivation of chapter 3, Piton (2019) does not assign this observation to changes in sectoral risk resulting from macroeconomic integration. Piton (2019) assigns her observation to changes in the types of capital used (a switch to more technology and thus more cost intensive capital) in non-tradable production.

Chapter 3 continues as follows. Chapter 3.2 overviews the literature. Chapter 3.3 introduces a simple model of a small open economy with tradable production capital costs contingent on macroeconomic integration. Chapter 3.4 calibrates the model. Chapter 3.5 shows the main results for a small open economy, experiencing temporarily low capital cost risk premia in tradable production. Chapter 3.6 suggests policies, and chapter 3.7 concludes.

[29] For example, Griffith, Harrison, and Simpson (2010) analyze the European SMP (Single Market Programme), a generic example of European (goods market) integration in the 1990s. Griffith, Harrison, and Simpson (2010) mention that the programme exerts the strongest impact on sectors categorized as manufacturing. Manufacturing sectors are classical examples for tradable production.

3.2 Literature

Based on a similar research question, my literature chapter 3.2 borrows heavily from chapters 1.2 and 2.2.

Motivated by the Spanish experience of European integration in the late 1990s, Benigno and Fornaro (2014) model a small open economy, which temporarily experiences low interest rates. Benigno and Fornaro (2014) model a two-sector economy which is producing tradable and non-tradable goods. Using labour as the single production factor, lower interest rates require labour resources to relocate to non-tradable production, to serve booming (non-tradable) consumption induced by low interest rates. Labour resources depart tradable production, hindering (the growth rate of) technology accumulation from the world technological frontier. This depresses (the growth rate of) productivity, and potentially welfare. In the Benigno and Fornaro (2014) model, total-factor-productivity equals labour productivity, borne from their way of modelling. Modelling labour as the single production factor neglects the beneficial effect that low interest rates and credit expansion (from European integration) have on capital accumulation (see, e.g., Gorton, Ordoñez, 2020, Tornell, Westermann, 2003, Blanchard, Giavazzi, 2002, Benigno, Converse, Fornaro, 2015, Mian, Sufi, Verner, 2020).

Chapter 1 (see also Hildebrandt, Michaelis, 2022) of the dissertation at hand addresses this shortfall by extending the Benigno and Fornaro (2014) model by capital as a second production factor, and a third sector, producing capital goods, using the model of de Cordoba and Kehoe (2000). Chapter 1 shows that low interest rates push capital accumulation and output. This serves the booming consumption (particularly non-tradable consumption) which low interest rates induces. Pushing output in both sectors, capital accumulation thus obviates a movement of (labour) resources out of tradable production into non-tradable production to serve booming (non-tradable) consumption. The sectoral distribution of resources and thus technology accumulation from the world technological frontier become invariant towards changes in interest rates. This preserves welfare, for most of the parameter constellations checked there.

Chapter 2 extends the model of chapter 1 by technology accumulation from imported capital goods. The import of capital (goods) benefits from low interest rates and macroeconomic integration (like in chapter 1) (see also, Blanchard, Giavazzi, 2002). Chapter 2 shows, like chapter 1, that low interest rates and macroeconomic integration spur-on capital accumulation and output. Spurred-on output serves booming consumption which low interest rates induce, preventing (labour) resources from departing tradable production. The theoretical findings show that low interest rates promote welfare and productivity by promoting technology accumulation from imported capital (goods) (see also, for example, Eaton, Kortum, 2001, Baltabaev, 2014, Amann, Virmani, 2015). This is in contrast of selected empirics of peripheral Europe during macroeconomic integration in the 1990s and 2000s, shown by Benigno, Fornaro (2014) for total-factor-productivity of the Spanish economy, and shown in Bennett et al. (2008) for Italy and Portugal by total-factor-productivity data.

Ranciere, Tornell, and Westermann (2003) theoretically research the reaction of an economy to lending booms from financial liberalization. They distinguish between two sectors, producing tradable (T) and non-tradable (N) goods. Before financial liberalization, Ranciere, Tornell and Westermann (2003) argue that non-tradable production has a limited access to international capital. In contrast, tradable production is assumed to have better access to international capital before financial liberalization. Lending booms particularly benefit non-tradable production, as it can now easier access (international) capital. Thus, capital accumulation particularly in non-tradable production benefits from financial liberalization. As in the Ranciere, Tornell, Westermann (2003) model non-tradable goods are also used as inputs in tradable production, the benefit of financial liberalization to non-tradable production transfers into tradable production. In Ranciere, Tornell, and Westermann (2003), this spurs-on an economic boom in both sectors after financial liberalization, at the costs of an increased credit default risk in non-tradable production.

Tornell and Westermann (2002) analyze empirically and theoretically the asymmetries that exist between sector N and sector T in the access to finance in middle income economies. They find that sector T firms are larger than sector N firms, and that larger firms have easier access to international capital. This implies worse financing conditions in sector N relatively to sector T. When a credit boom evolves (for example from capital market opening, macroeconomic integration, or financial liberalization) particularly those firms benefit whose access to capital was previously restricted (sector N). Thus, smaller and sector N firms benefit, promoting sector N production. In general, a real appreciation reflects increasing relative prices of sector N goods. A real appreciation thus promotes the credibility of sector N firms. The more indebted sector N firms get during a credit boom, the more sensitive their credibility gets towards a real depreciation. Should the real depreciation risk hit, sector N firms suffer from injured credibility, and thus from a credit crunch. Potentially, a crisis emerges. Tornell and Westermann (2002) argue that sector T firms are less (negatively) affected by a real depreciation. Thus, before a crisis, sector N grows faster. After a crisis, sector T grows faster.

Important for chapter 3 of the dissertation at hand, the findings of Tornell and Westermann (2002) and of Ranciere, Tornell and Westermann (2003) contrast my description of the Piton (2019, see also 2021) findings (see chapter 3.1) in the following perspective. Piton (2019, see also 2021) found for selected peripheral European economies that, relatively to the capital costs in non-tradable production, capital costs in tradable production reduce during European (macroeconomic) integration. Precisely, capital costs in non-tradable production grew faster than in tradable production in selected peripheral European economies. Tornell and Westermann (2002) and Ranciere, Tornell and Westermann (2003) indicate that the major benefits of *financial liberalization* (leading to lending booms) to capital accumulation should be in non-tradable production. Because of the recency of the Piton (2019, see also 2021) research, her focus on European (*macroeconomic*) integration, and because of the recent time frame (1995-2015) considered in Piton (2019), I base my theoretical modelling in this chapter 3 at hand on Piton (2019, see also 2021).

Rodrik (2013) analyzes the sectoral labour productivity of up to 118 economies for a time span up to 1965 to 2005. He finds that labour productivity in industries classified as manufacturing, mostly producing tradable goods, converge to global productivity leaders of the sample. The same was not found at economy wide levels, when aggregating over all industries and sectors. Rodrik (2013) traces this back to missing productivity convergence in other sectors, like services, producing mostly non-tradable goods. Rodrik (2013) argues, among other reasons, that international competition forces companies in tradable production to adapt new technologies. This promotes a productivity catch-up.

Martin and Rey (2006) theoretically contribute with a two-economy-model to the question *what should integrate first – capital markets or goods markets?* The two economies (rich and poor) of their model differ in income levels, borne from (labour) productivity differences, defining the poor economy and the rich economy. In one scenario, the two economies' goods markets and capital markets are integrated. Each firm based in each of the two economies realizes revenues and profits in *both* economies, as each firm, regardless of being based in the rich or in the poor economy, exports. As capital markets are also integrated, both economies potentially invest domestically and abroad. When the rich economy invests in the poor economy, this contributes to capital accumulation and growth that particularly the poor economy requires and depends on. In case of an exogeneous adverse shock in the poor economy, firms in the poor economy can export to the rich economy, as goods markets are well integrated. This maintains (trade) profits of the (firms based in the) poor economy. As the firms in the poor economy maintain their profits (by exporting to the rich economy), investors continue investing in the firms based in the poor economy, preserving capital accumulation there. This thus mitigates the adverse effects of the exogeneous adverse shock in the poor economy.

Empirically, Martin and Rey (2006) find for emerging market economies, that an open trade in goods reduces the risk of incurring a crisis, while being financially open increases the risk of incurring a crisis. Martin and Rey (2006) conclude that emerging economies should first open for the trade of goods (goods market integration), and afterwards open for the trade in financial assets (capital market integration). This finding is important to keep in mind when interpreting my results in chapter 3.5 and my policy implications in chapter 3.6.

Alberola and Benigno (2017) investigate *Resource Curses* by extending the Benigno and Fornaro (2014) model by intermediate goods as a second production factor, and a third sector, intermediate goods production. Intermediate goods production represents a commodity extracting industry. An intermediate goods price upswing drags (labour) resources out of tradable production and relocates them into intermediate goods production. The departing of resources out of tradable production depresses a positive technological progress externality, developed in tradable production. Despite one expects a commodity exporting economy to benefit from high commodity prices, Alberola and Benigno (2017) show that the crowding out of technological progress by high intermediate goods prices potentially burdens the economy.

Benigno, Fornaro, and Wolf (2020) analyze the macroeconomic integration of a developing economy with a developed economy. Before macroeconomic integration, households populating the developing economy realize higher savings and thus lower interest rates. For the developed economy, the contrary holds. Households realize higher consumption and thus, higher interest rates. The developed economy is the technological and financial core of the model. It provides technological progress which the developing economy adapts, and financial assets which the developing economy enjoys holding. Should both economies integrate macroeconomically, the new 'global' interest rate balances between the two economies. Thus, the developing economy exogenously experiences an interest rate increase, and the developed economy experiences an interest rate reduction. In the developed economy, this spurs-on consumption, like described in Benigno and Fornaro (2014). Spurred-on consumption in the Benigno, Fornaro, and Wolf (2020) model relocates resources out of tradable production into non-tradable production, impeding learning-by-doing and technological progress in tradable production of the developed economy.

As the developing economy in the Benigno, Fornaro, and Wolf (2020) model adapts technological progress from the developed economy, this also slows technological progress in the developing economy. Potentially, productivity in both economies is injured.

Tornell and Westermann (2003) empirically analyze firm level data of up to 39 middle income economies from 1980 to 1999. From their finding, that non-tradable production firms are on average smaller than tradable production firms, they derive the existence of a borrowing constraint in non-tradable production, as larger firms have easier access to international capital (see also Gopinath et al., 2017). They find that the emergence of lending booms particularly benefits firms who were previously financially constraint. Thus, lending booms benefit particularly non-tradable production. Tornell and Westermann (2003) also find the emergence of a real appreciation during lending booms. Moreover, and interestingly, they found consumption roughly invariant to lending booms.

3.3 Model

This model (chapter 3.3), its description, and its computer code are based on and are borrowed from those of chapter 1.3[30] (see also Hildebrandt, Michaelis, 2022) and of chapter 2.3. Doing so, in their core, my model in chapter 3.3 and its computer code rest on those of Benigno and Fornaro (2014) and on the model of de Cordoba and Kehoe (2000) but build on their derivates. My model (chapter 3.3) and its computer code are a derivate/extension of the model and computer code in chapter 2.3, extended by capital costs premia R_t^{TK} in tradable production (sector T) contingent on macroeconomic integration only, see Eqs. (3.3) and (3.11). My model chapter 3.3 and my/its computer code borrow heavily from those of Benigno and Fornaro (2014), de Cordoba and Kehoe (2000), of chapter 1.3 (see also Hildebrandt, Michaelis, 2022) and of chapter 2.3.

The following models a perfect foresight small open economy.

Households

The economy is populated by a continuum of identical households with population size normalized to unity. The representative household maximizes the utility function:

$$U_t = \sum_{t=0}^{\infty} \beta^t logC_t, \tag{3.1}$$

where $\beta < 1$ is the discount factor, and C_t is a consumption index defined as:

$$C_t = (C_t^T)^{\omega}(C_t^N)^{1-\omega}. \tag{3.2}$$

Here, C_t^T and C_t^N are the consumption of tradable (T) and non-tradable (N) goods, respectively. Parameter ω is the expenditure share for the tradable good. From (3.1) and (3.2), and according to Benigno and Fornaro (2014), the elasticity of substitution between the two available types of goods as well as the intertemporal elasticity of substitution between goods across periods is restricted to unity. The household supplies labour inelastically without a loss of utility. The budget constraint of the household reads:

$$C_t^T + P_t^N C_t^N + \frac{as_{t+1}}{R_t} = W_t L + as_t + q_{t-1} R_t^{TK} K_t^{TD} + \pi_t^T + \pi_t^N + \pi_t^K, \tag{3.3}$$

where

$$as_{t+1} = B_{t+1} + q_t K_{t+1}^{TD} + q_t K_{t+1}^{ND}. \tag{3.4}$$

Like in de Cordoba and Kehoe (2000), the tradable good serves as numeraire, the price is given by the world market and normalized to unity; P_t^N is the relative price of non-tradable goods in the form of tradable goods, and L is the endowment of labour, which receives wage rate W_t (assumed identical across sectors N and T, like in Benigno, Fornaro, 2014). Domestic sector N, T, and K firms are owned by domestic households, profits from sectors N, T, and K, π_t^N, π_t^T, π_t^K, benefit the representative domestic household.

[30] Chapter 1 was written in co-authorship with Jochen Michaelis (joint research project). Thus, the work and its description of Jochen Michaelis contributed to a large extent to (the descriptions in) this chapter (chapter 3.3).

The compensation earned for risk on capital invested in sector T, $0 \leq R_t^{TK} < 1$, enters the household's budget constraint, multiplied by the domestically financed capital stock in sector T, $q_{t-1}K_t^{TD}$ (see below).

The (domestic) household purchases and holds assets in three forms, bonds B_{t+1}, domestic capital invested in sector T, K_{t+1}^{TD}, and domestic capital invested in sector N, K_{t+1}^{ND}. All assets purchased in period t are priced at $1/R_t$, and redeemed in period $t+1$. The price of a capital good in the form of the tradable good, q_t, as well as the gross interest rate, R_t, are given by the world market. Note that capital goods purchased in period t must be put in place one period before they are used, i.e., these goods turn into capital for production in the subsequent period $t+1$ (like in de Cordoba, Kehoe, 2000).

The representative household chooses C_t^T, C_t^N and as_{t+1} to maximize the utility function (3.1) subject to the budget constraint (3.3). From the solution of this problem, the demand function for non-tradable goods is:

$$C_t^N = \frac{1-\omega}{\omega}\frac{1}{P_t^N}C_t^T, \tag{3.5}$$

and

$$C_{t+1}^T = \beta R_t C_t^T, \tag{3.6}$$

as standard Euler equation for the optimal intertemporal allocation of tradable consumption goods (see Benigno, Fornaro, 2014).

Firms

Tradable Sector (T, tradable production). Firms in the tradable sector combine L_t^T workers with K_t^T units of real capital to produce output Y_t^T. The production-technology is Cobb-Douglas with constant returns to scale:

$$Y_t^T = A_t(L_t^T)^{\alpha}(K_t^T)^{1-\alpha}, \tag{3.7}$$

where the stock of technology A_t is a total-factor-productivity shifter. Because of international competition, the tradable sector absorbs foreign technology (Rodrik, 2013, see also Blanchard, Giavazzi, 2002). The expression of Benigno and Fornaro (2014) for the endogenous process of technology accumulation is extended by technology accumulation from the stock of foreign (financed) capital goods, installed in the domestic sector T (machinery/capital goods imported from foreign, installed in domestic sector T, K_t^{TF}), like in chapter 2.3:

$$A_{t+1} = \begin{cases} A_t\left[1 + c_1\, L_t^T\left(1 - \frac{A_t}{A_t^*}\right) + c_2\, K_t^{TF}\left(1 - \frac{A_t}{A_t^*}\right)\right] & \text{for } K_t^{TF} > 0 \\ A_t\left[1 + c_1\, L_t^T\left(1 - \frac{A_t}{A_t^*}\right)\right] & \text{for } K_t^{*TF} > 0 \end{cases} \tag{3.8}$$

Benigno and Fornaro (2014) term it 'knowledge accumulation'. I term it 'technology accumulation', because of the modelling of the Cobb-Douglas production function. There is a world technological leader, whose stock of technology A_t^* grows with an exogenously given yearly rate g^*. The domestic economy is well behind, $A_t < A_t^*$, but catches up. The speed of convergence is determined by the convergence parameter c_1 and by employment in the tradable sector (L_t^T), incorporating learning-by-doing. Further, the speed of convergence is determined by the stock of foreign (financed) capital goods, installed in the domestic sector T (K_t^{TF}), incorporating technology transfers from abroad/'foreign', with convergence parameter c_2 (like in chapter 2).

Conditional on the model calibration, foreign (financed) capital (goods), installed in the domestic sector T, K_t^{TF}, and in the domestic sector N, K_t^{NF}, can numerically turn negative. This (K_t^{TF}<0, K_t^{NF}<0) implies that the domestic capital goods production/provision exceeds sectoral (N and T) capital goods demand, and a crowding out of foreign capital (goods) installed in the domestic economy. Then, the domestic economy builds up a capital stock abroad / in 'foreign' (machinery export). Terminological, I introduce:

$$K_t^{TF} = \begin{cases} K_t^{TF} & for\ K_t^{TF} > 0 \\ -K_t^{*\,TF} & for\ K_t^{TF} < 0 \end{cases} \tag{3.9}$$

and

$$K_t^{NF} = \begin{cases} K_t^{NF} & for\ K_t^{NF} > 0 \\ -K_t^{*\,NF} & for\ K_t^{NF} < 0 \end{cases} \tag{3.10}$$

For a detailed motivation of (3.8), I refer to Benigno and Fornaro (2014), who introduced the learning-by-doing component of (3.8) to describe sector T technology accumulation in their model. I also refer to chapter 2 where I introduced the technology accumulation from foreign (financed) capital (goods) installed in domestic sector T. Like said, the stock of foreign capital goods installed in domestic sector T (K_t^{TF}) is not necessarily positive in each period.

If the domestic capital goods production/provision exceeds the demand for capital goods exerted by sectors N and T, there are no foreign capital goods flowing into the economy. Thus, I incorporate the accumulation of foreign technology from employment in sector T, L_t^T, *and* from the stock of inward foreign capital, K_t^{TF}, in Eq. (3.8), like in chapter 2. Doing so, the (empirical) evidence on the positive impact of inward foreign capital *stocks* on total-factor-productivity (see, e.g., Baltabaev, 2014, on the effect of inward FDI *stocks* on TFP, and Eaton, Kortum, 2001, on technology transfers from foreign capital goods) is captured.

It is important to underline, that capital received from domestic (D) and foreign (F) capital goods production and utilized by sector T firms (and sector N firms) is not necessarily equity financed. Particularly, the interpretation of being debt financed is standing to reason. *Apart* from technology accumulation, domestically financed/produced capital (goods), installed in the domestic sector T (in the following: domestic sector T capital) K_t^{TD}, and foreign financed/produced capital (goods), installed in the domestic sector T (in the following: foreign sector T capital) K_t^{TF}, are perfect substitutes.

To be clear, I do not aim at modelling sophisticated risk in tradable production. Rather, I aim at working out a meaningful theory with sectoral risk, that is capable to explain resource reallocations and a productivity slowdown contingent on macroeconomic integration. I model additional tradable production capital costs R_t^{TK} from risk in tradable production as simple/intuitive as possible. To compensate risk in sector T (tradable production), I introduce additional net capital costs R_t^{TK} on capital installed in domestic sector T.

Risk in sector T disrupts profits in sector T, defined from cash flows (derived from de Cordoba, Kehoe, 2000, extended by additional sector T capital costs R_t^{TK}):

$$\pi_t^T = A_t[L_t^T]^\alpha[K_t^T]^{1-\alpha} - W_t L_t^T - q_t\,[K_{t+1}^T - (1-\delta)K_t^T] + \frac{q_t K_{t+1}^T}{R_t} - q_{t-1}K_t^T - q_{t-1}R_t^{TK}K_t^T \quad (3.11)$$

This definition of profits in tradable production was also used in chapters 1.3 and 2.3 (without the R_t^{TK} term).

My model requires foreign capital (K_t^F) to be invested in tradable production (depicted K_t^{TF}) and in non-tradable production (depicted K_t^{NF}) of the small open economy.

I assume:

$$K_t^T = K_t^{TD} + K_t^{TF}\,. \quad (3.12)$$

The interpretation of (3.11) is as follows. Revenues in sector T are the output of sector T priced at unity. Labour costs are wage payments $W_t L_t^T$. Capital costs are the payments for new machinery purchased, $q_t\,[K_{t+1}^T - (1-\delta)K_t^T]$. Further, the firm in sector T receives new funds from credit raising $\frac{q_t K_{t+1}^T}{R_t}$, but must repay funds from previous credit raising, $q_{t-1}K_t^T$. Additional sector T capital costs $q_{t-1}R_t^{TK}K_t^T$ for risk compensation reduce profits.

Capital depreciates with rate δ, capital accumulation follows $K_{t+1}^{TD} = (1-\delta)K_t^{TD} + I_t^{TD}$ and $K_{t+1}^{TF} = (1-\delta)K_t^{TF} + I_t^{TF}$, where I_t^{TD} and I_t^{TF} is the investment during period *t*. I_t^{TD} is produced by the domestic capital goods sector, I_t^{TF} are capital goods imported from abroad/'foreign'.

Firms in sector T hire workers up to the point where the marginal product of labour equals the wage:

$$W_t = MPL_t^T = \alpha A_t (L_t^T)^{\alpha-1}(K_t^T)^{1-\alpha}. \quad (3.13)$$

In period $t-1$, firms in sector T decide on the optimal capital stock for production in period t:

$$MPK_t^T + (1-\delta)q_t = (R_t^{TK} + R_{t-1})\,q_{t-1}, \quad (3.14)$$

$$MPK_t^{TF} = MPK_t^{TD}. \quad (3.15)$$

Note that firms act on behalf of their owners, domestic households. From the household point of view all three types of assets, bonds B_{t+1} and capital invested in sector T and N are imperfect substitutes, see Eq. (3.4). De Cordoba and Kehoe (2000) motivate that all three types of assets are perfect substitutes (in the absence of sector T capital cost risk premia). See also Funke and Strulik (2000), who use perfect substitutability (in the absence of sector specific capital cost premia, for a one-sector model).

The return of sector T capital exceeds the return of bonds and of sector N capital by R_t^{TK}, modelled to compensate the volatile returns (tradable production risk) in sector T, that I assume in my model/theory. In period $t-1$, capital goods cost q_{t-1}. The marginal yield equals marginal costs, see Eq. (3.14).

The marginal yield has two components: First, the additional output in period t (marginal product of capital MPK_t^T) and second, the value of the depreciated capital good at the end of period t, $(1-\delta)q_t$.

Marginal costs have two components: First, sectoral capital costs risk premia $R_t^{TK}q_{t-1}$ to compensate volatile profit (assumed in my model). Second, the investment of q_{t-1} in a bond yields gross return $R_{t-1}q_{t-1}$, embodying opportunity costs (de Cordoba, Kehoe, 2000, see also Funke, Strulik, 2000, for a one sector case). Firms can import capital goods from abroad/'foreign', Eq. (3.15) is the no-arbitrage condition.

Sector T capital is:

$$K_t^T = L_t^T \left[\frac{(1-\alpha)A_t}{(R_t^{TK} + R_{t-1})q_{t-1} - (1-\delta)q_t}\right]^{\frac{1}{\alpha}} \tag{3.16}$$

As I model risk premia on capital costs in tradable production R_t^{TK} to be invoiced by the bankrollers and paid to them in the identical period when capital stocks in tradable production are installed (K_t^T), I suppose that they (R_t^{TK}) have no impact on the intertemporal allocation of the household (tradable) consumption (C_t^T). To see this more clearly, please compare the time indices of R_t^{TK} and R_{t-1} in (3.16).

Non-Tradable Sector (N, non-tradable production). The output of the non-tradable good, Y_t^N, is produced with the help of labour, L_t^N, and real capital, K_t^N. Again, the production-technology is Cobb-Douglas:

$$Y_t^N = (L_t^N)^{\alpha}(K_t^N)^{1-\alpha}. \tag{3.17}$$

Like in Benigno and Fornaro (2014), total-factor-productivity in sector N is fixed to unity, in the non-tradable sector there is no accumulation of foreign technology and thus no technological progress, in line with the findings of Rodrik (2013) shown in chapter 3.2.

Profits in sector N follow cash flows[31] (derived from de Cordoba, Kehoe, 2000), the interpretation of (3.18) is like the one of (3.11):

$$\pi_t^N = P_t^N[L_t^N]^{\alpha}[K_t^N]^{1-\alpha} - W_t L_t^N - q_t\,[K_{t+1}^N - (1-\delta)K_t^N] + \frac{q_t K_{t+1}^N}{R_t} - q_{t-1}K_t^N \tag{3.18}$$

This definition of profits in non-tradable production was also used in chapters 1.3 and 2.3.

Like Eq. (3.12), I assume a simple aggregation:

[31] With (3.11) and (3.18) I do not intend to imply/model the absence of non-tradable production sector specific risk. Rather, (3.11) and (3.18) are supposed to model that risk (and thus, capital costs) in tradable production has components that is affected by macroeconomic integration, and which are absent in non-tradable production. Thus, (3.11) and (3.18) model that tradable production has risk, compensated by R_t^{TK}, that macroeconomic integration affects *stronger* than it affects non-tradable production risk. R_t^{TK} measures the extend to which macroeconomic integration reduces risk and capital costs in tradable production asymmetrically (see chapter 3.5 for the definition of the macroeconomic integration scenario).

$$K_t^N = K_t^{ND} + K_t^{NF} \tag{3.19}$$

for domestically financed/produced capital (goods), installed in the domestic sector N (in the following: domestic sector N capital) K_t^{ND}, and foreign financed/produced capital (goods), installed in the domestic sector N (in the following: foreign sector N capital) K_t^{NF}.

Capital accumulation follows $K_{t+1}^{ND} = (1-\delta)K_t^{ND} + I_t^{ND}$ and $K_{t+1}^{NF} = (1-\delta)K_t^{NF} + I_t^{NF}$, where the investment I_t^{ND} is produced by the domestic capital goods sector. The investment I_t^{NF} are capital goods imported from abroad/'foreign'.

The first-order conditions of firms in sector N for labour and capital are:

$$W_t = P_t^N \cdot MPL_t^N = P_t^N \cdot \alpha (L_t^N)^{\alpha-1}(K_t^N)^{1-\alpha}, \tag{3.20}$$

$$P_t^N \cdot MPK_t^N + (1-\delta)q_t = R_{t-1}q_{t-1}, \tag{3.21}$$

$$MPK_t^{NF} = MPK_t^{ND}. \tag{3.22}$$

As described, in period $t-1$, firms decide on the optimal capital stock for production in period t. Because of perfect labour mobility across sectors, firms in the non-tradable sector must pay the same wage as firms in the tradable sector. Again, Eqs. (3.21) and (3.22) rest on my assumption that bonds and capital invested in sectors N and T were perfect substitutes *in the absence* of sector T capital cost risk premia (see de Cordoba, Kehoe, 2000, also Funke, Strulik, 2000, for a one sector case). To connect sectoral capital stocks with the budget constraint of the household (3.3) I make use of $K_t^D = K_t^{TD} + K_t^{ND}$ and $K_t^F = K_t^{TF} + K_t^{NF}$.

Sector N capital is:

$$K_t^N = L_t^N \left[\frac{(1-\alpha)P_t^N}{R_{t-1}q_{t-1} - (1-\delta)q_t}\right]^{\frac{1}{\alpha}} \tag{3.23}$$

By combining the optimality conditions, I also get:

$$P_t^N = A_t \left[\frac{K_t^T / L_t^T}{K_t^N / L_t^N}\right]^{1-\alpha} \tag{3.24}$$

Eq. (3.24) is related to the familiar Samuelson-Balassa effect. Total-factor-productivity (A_t) growth in the sector producing tradable goods pushes up labour demand in this sector T. Tradable production increases its wages to attract workers. Non-tradable production has no productivity advances but must pay the same (higher) wage. Thus, non-tradable production faces an increase in the marginal costs of production. This leads to an increase in the relative price (P_t^N) of non-tradable goods. As it will be described in chapter 3.4, total labour supply is calibrated $L_t^T + L_t^N = 1$. Under the temporarily made assumption in chapter 3.5, $R_t^{TK} = 0$, sectoral capital intensities are identical (see also Gopinath et al., 2017), and the share of labour installed in a sector equals the share of capital installed in the sector:

$$L_t^T = \frac{K_t^T}{K_t^N + K_t^T}\,, \tag{3.25}$$

$$L_t^N = \frac{K_t^N}{K_t^N + K_t^T}\,. \tag{3.26}$$

For $R_t^{TK} > 0$, Eqs. (3.25) and (3.26) are complicated by tradable production capital costs risk premia R_t^{TK}. For $R_t^{TK} > 0$, I did not find an expression for L_t^T or L_t^N algebraic, but by computer zero calculation, because of a non-linear expression. Should the computer code calculate/find several zeros, I directed the code to use/take the lowest zero.

If $R_t^{TK} = 0$, capital intensities are identical across sectors (see also Gopinath et al., 2017, who argue similarly in case of a frictionless economy).

Capital goods sector (K, capital goods production). The modelling of the domestic capital goods sector very much follows de Cordoba and Kehoe (2000). Real capital goods are produced by using tradable goods and non-tradable goods as inputs. The production-technology[32] is Cobb-Douglas:

$$I_t^D = (A_t)^{\mu}(Z_t^T)^{\gamma}(Z_t^N)^{1-\gamma}, \tag{3.27}$$

where I_t^D is the domestic output of capital goods, augmenting domestic capital accumulation. Z_t^T is the input of the tradable good into capital goods production, Z_t^N is the input of the non-tradable good into capital goods production. As de Cordoba and Kehoe (2000, p.57) mention, these inputs "…can be thought of loosely as equipment and structures". Following the chapter 1.3, both, sector T and sector K, produce physically tangible goods in an industrial or manufacturing production process. Thus, in chapter 1.3 it is regarded as meaningful, that sector K can use the same technology, A_t, as sector T does. Chapter 1.3 (and 2.3 and 3.3) thus deviates from de Cordoba and Kehoe (2000) and incorporates A_t into (3.27). As technology A_t is built up (developed) in sector T and must diffuse to sector K, chapter 1.3 argues that capital goods sector K absorbs foreign technology (via sector T technology A_t) lesser than sector T firms, meaning that $0 < \mu < 1$.

Maximizing the profit function $\pi_t^K = q_t I_t^D - Z_t^T - P_t^N Z_t^N$ with respect to inputs leads to:

$$\frac{Z_t^T}{Z_t^N} = \frac{\gamma}{1-\gamma} P_t^N\,. \tag{3.28}$$

When the Samuelson-Balassa effect operates, the relative price P_t^N increases period by period. Then, the non-tradable good as a factor of production becomes more expensive period by period, and firms in the capital goods sector adjust the optimal production plan by switching from Z_t^N to Z_t^T. The ratio Z_t^T/Z_t^N rises continuously if P_t^N rises continuously.

[32] I gratefully thank Max Fuchs for his helpful suggestion/comment to improve my/our design of the capital goods production function.

Equilibrium

Our economy consists of four markets, namely two goods markets (tradable and non-tradable goods) and two factor markets (labour and capital goods). A general equilibrium requires that all markets in the economy are simultaneously in equilibrium.

The labour market is in equilibrium when the time inelastic labour supply by households (labour endowment) is equal to labour demand from firms of tradable production (sector T) and non-tradable production (sector N):

$$L = L_t^T + L_t^N. \tag{3.29}$$

The capital goods sector is in equilibrium when the domestic output of capital goods is equal to the demand for domestically produced capital goods from firms of sector T and sector N:

$$I_t^D = I_t^{TD} + I_t^{ND} = K_{t+1}^D - (1-\delta)K_t^D. \tag{3.30}$$

The market clearing condition for the non-tradable good:

$$C_t^N + Z_t^N = Y_t^N, \tag{3.31}$$

implies that sector N output is either consumed by the domestic household or is invested as an input in the domestic production of capital goods (3.27). Depending on the domestic output (Y_t^N and Y_t^T) and consumption (C_t^N and C_t^T), Z_t^N and Z_t^T go to the domestic capital goods production (3.27).

Domestic capital goods production is distributed to sectors N and T and is adding to K_t^{ND} and K_t^{TD}. $K_t^{TD} > K_t^T$ implies following (3.12) $K_t^{*\,TF} > 0$, and the small open economy becoming a (net) exporter of capital goods (the same holds for sector N). Thus, in that case, no foreign capital is flowing into sector T. If $K_t^{*\,TF} > 0$, I assume that the domestic economy does not receive R_t^{TK} from the rest of the world. But, if $K_t^{TF} > 0$, I assume that the domestic economy must pay R_t^{TK} to the rest of the world.

Making use of (3.4), (3.29), (3.31) and firms' profit functions (sectors T, N, K), the household budget constraint (3.3) delivers the market clearing condition for the tradable good:

$$C_t^T + \frac{B_{t+1}}{R_t} - B_t = \begin{cases} Y_t^T - Z_t^T - q_t I_t^F + \frac{q_t K_{t+1}^F}{R_t} - q_{t-1}K_t^F - q_{t-1}R_t^{TK}K_t^{TF} & \text{for } K_t^{TF} > 0 \\ Y_t^T - Z_t^T - q_t I_t^F + \frac{q_t K_{t+1}^F}{R_t} - q_{t-1}K_t^F & \text{for } K_t^{*\,TF} > 0 \end{cases} \tag{3.32}$$

where $I_t^F = I_t^{TF} + I_t^{NF}$ is the (payment for the) importing of capital goods. $q_t K_{t+1}^F/R_t$ is firms' borrowing of funds from abroad/'foreign' in period t. $q_{t-1}K_t^F$ is the repayment of foreign funds raised in period $t-1$.

In a next step, let us turn to the current account of the small open economy. Like in Benigno and Fornaro (2014), an economy's current account is defined as the change in its net foreign assets, $CA_t = NFA_t - NFA_{t-1}$. The value of bonds acquired by the representative household in period t is B_{t+1}/R_t, the value of foreign funds raised by firms equals $q_t K_{t+1}^F/R_t$. Thus, one gets $NFA_t = B_{t+1}/R_t - q_t K_{t+1}^F/R_t$. Backdating yields $NFA_{t-1} = B_t/R_{t-1} - q_{t-1}K_t^F/R_{t-1}$. Using the market clearing condition for the tradable good (3.32), the current account is given by (derived like in Benigno, Fornaro, 2017):

$$CA_t = \begin{cases} Y_t^T - Z_t^T - C_t^T - q_t I_t^F + (B_t - q_{t-1}K_t^F)\left(1 - \frac{1}{R_{t-1}}\right) - R_t^{TK} K_t^{TF} q_{t-1} & \textit{for } K_t^{TF} > 0 \\ Y_t^T - Z_t^T - C_t^T - q_t I_t^F + (B_t - q_{t-1}K_t^F)\left(1 - \frac{1}{R_{t-1}}\right) & \textit{for } K_t^{*TF} > 0 \end{cases} \tag{3.33}$$

Period t current account is given by net exports, $Y_t^T - Z_t^T - C_t^T - q_t I_t^F$, plus the interest earned on net foreign assets acquired in period $t-1$, minus risk premia on sector T foreign capital, should it be invested in the domestic small open economy in that period ($K_t^{TF} > 0$).

The intertemporal resource constraint (Obstfeld, Rogoff, 1996):

$$\sum_{s=t}^{\infty} Q_{t,s} CA_s = -\frac{B_t - q_{t-1}K_t^F}{R_{t-1}}, \tag{3.34}$$

with:

$$Q_{t,s} = \frac{1}{\Pi_{v=t+1}^{s} R_{v-1}}, \tag{3.35}$$

has well-known interpretations/definitions:

An economy with an initial net claim position against foreigners must receive net resources from foreigners, which in present value terms must equal the initial net claim position. An economy with an initial net debt position to foreigners must transfer net resources to foreigners, which in present value terms must equal the initial net debt position (Obstfeld, Rogoff, 1996, p.66, 67).

As Obstfeld and Rogoff (1996, p.76) mention, the market discount factor $Q_{t,s}$ describes the relative price of period s consumption in the form of period t consumption. $Q_{t,t}$ is interpreted as one, $Q_{t,t+1} = \frac{1}{R_t}$, $Q_{t,t+2} = \frac{1}{R_t}\frac{1}{R_{t+1}}$ and so on (Obstfeld, Rogoff, 1996, p.76).

3.4 Calibration

My calibration in chapter 3.4 mostly rests on Benigno and Fornaro (2014) and on de Cordoba and Kehoe (2000). The description of the calibration (chapter 3.4) is borrowed from and is based on chapter 1.4[33] (see also Hildebrandt, Michaelis, 2022) and chapter 2.4.

Both, Benigno and Fornaro (2014) and de Cordoba and Kehoe (2000) parametrize their model to match some data for Spain in the 1990s. Thus, Spain is at the centre of my calibration. To be clear, my analysis is not motivated by the objective to improve the quantitative fit of the model with the Spanish data. Instead, I am interested in the *qualitative* question, if there exist parameter constellations for macroeconomic integration and for the reduction of sectoral capital cost risk premia in tradable production that are capable to explain a (Spanish) productivity slowdown *roughly/qualitatively* (for the late 1990s and early 2000s, like shown empirically in Benigno, Fornaro, 2014. See also Bennett et al., 2008, for a burdened TFP growth rate in Italy and Portugal). To provide comparable results, I use the calibration of Benigno and Fornaro (2014) and of de Cordoba and Kehoe (2000) whenever possible.

Following the approach of Benigno and Fornaro (2014), I assume that the small open economy faces perfect access to international goods and capital markets. For that reason, the price of tradable goods is exogenously given and normalized to unity. The small open economy can borrow and lend at the gross interest rate that is assumed to be R_t = 1.0400, which equals a net interest rate of 4 percent. In contrast to Benigno and Fornaro (2014) and in line with chapter 1, my model allows for an international market for capital goods. The home economy can import and export capital goods, the relative price (q_t) of these capital goods (machinery) is exogenously given by the world market and normalized to q = 1.0000.

To calibrate the parameters of the representative household, I again follow Benigno and Fornaro (2014) and set the discount factor at β = 0.9760. As Euler equation (3.6) indicates, this ensures that in the steady state the growth rate of tradable goods consumption is equal to g^*. The expenditure share of the tradable good is set to ω = 0.4140, the labour supply of the household (labour endowment) is normalized to L = 1.0000.

An important element of the Benigno and Fornaro (2014) model is the process of technology accumulation, see Eq. (3.8). The growth rate of the world technological frontier is set to g^* = 0.0150, matching the average yearly growth rate of total-factor-productivity in the United States between 1960 and 1995. The initial value for the stock of technology of the world technological leader is set at $A_0^* = 6.4405$, which corresponds to the estimation of Benhabib and Spiegel (2005) for the USA in 1995. Adopting the estimation for Spain in 1995, the initial value of the home/domestic small open economy is chosen to be $A_0 = 4.1384$. Similarly, matching the evolution of total-factor-productivity in Spain, Benigno and Fornaro (2014) (and I) set the convergence parameter which captures the ability of the home economy to absorb foreign technology by sector T employment to c_1 = 0.1670. c_1 and c_2 express the relative importance of L_t^T and K_t^{TF} in the process of technology accumulation. Considering K_t^{TF} in (3.8) was introduced in chapter 2.

[33] Chapter 1 was written in co-authorship with Jochen Michaelis (joint research project). Thus, the work and its description of Jochen Michaelis contributed to a large extent to (the descriptions in) this chapter (chapter 2.4).

Variable c_2, the convergence parameter for technology accumulation by foreign capital K_t^{TF}, captures *three* observations:

First, in my model results, foreign capital invested in sector T, K_t^{TF}, responds immediately and unrealistically strong to lower sector T capital cost risk premia R_t^{TK} (see chapter 3.5 for the definitions of sector T capital cost premia scenarios). The reason for this unrealistically strong reaction is that I do not model any frictions in capital accumulation. Benigno and Fornaro (2014) attribute the strong reaction to low interest rates in their model to missing frictions. This contrasts the empirical finding of a slow/distorted capital stock build-up (see, e.g., Gopinath et al., 2017). Thus, I should set c_2 low for a realistic impact on technology accumulation from foreign capital.

Second, L_t^T (influencing technology accumulation *by learning-by-doing*) is standardised and ranges $0 < L_t^T < 1$. Foreign financed capital stocks in tradable production K_t^{TF} (influencing technology accumulation by foreign capital inflows) have no upper limit. As L_t^T and K_t^{TF} compete for technology accumulation, I should again set c_2 low for realistic results and a fair competition between L_t^T and K_t^{TF}.

Third, I suppose that not all forms of foreign capital (K_t^F, in my model K_t^{TF}) that are flowing into an economy transfer foreign technology, but mostly Foreign Direct Investment (Baltabaev, 2014, Amann, Virmani, 2015, Blalock, Gertler, 2008). Foreign Direct Investment would only be a fraction of K_t^F(in my model K_t^{TF}).

The value of $c_2 = 0.0001$ very roughly approximates the development of A_t in Spain from 1960 to 1995. Simulating my model (normal Sector T capital cost premia R_t^{TK} scenario, see below) with the start value of $A_{1960} = 1.8502$ for Spain, and with $A_{1960}^* = 3.7648$ for USA from Benhabib and Spiegel (2005), after 35 periods (years), my model simulates A_{1995} of roughly about 4.39. Reducing c_2 pushes this number closer to the empirical estimation of Benhabib and Spiegel (2005) of roughly about 4.14 for Spain in 1995 and would support the hypothesis of my chapter 3. But a further reduction of c_2 would push c_2 unrealistically low. My approach in calibrating c_2 is like in Benigno and Fornaro (2014) when they calibrate c (c_1).

I thus set[34] $c_2 = 0.0001$. When setting c_2 too high, the vast inflow of foreign capital into sector T (in my low sector T capital cost premia R_t^{TK} scenario, see below) implies that the small open economy unrealistically reaches technology levels of the world technological leader. Regardless of the calibration, A_t is programmed in my code not to exceed A_t^*.

In a next step, let us turn to the production functions for the tradable sector and the non-tradable sector. In line with Benigno and Fornaro (2014), the labour share is assumed to be identical across sectors. I set $\alpha = 0.7011$ which is the arithmetic mean of the values defined in de Cordoba and Kehoe (2000), who assume a labour share of 0.7131 for sector T and of 0.6891 for sector N. Following de Cordoba and Kehoe (2000), I choose the yearly capital stock depreciation rate to be $\delta = 0.0576$.

[34] I admit that a low value of c_2 supports the hypothesis of chapter 3. In chapter 3.5, I also provide results for a higher range of c_2.

The initial sector T capital stock is set to K_0^T = 0.5000. De Cordoba and Kehoe (2000) find that sector N capital stocks are roughly twice[35] as high as in sector T. I set K_0^N = 2.0000 K_0^T, so K_0^N = 1.0000. I assume a symmetric initial distribution of domestically financed/produced and foreign financed/produced capital stocks installed in sectors T and N, meaning K_0^{ND} = 0.5000, K_0^{NF} = 0.5000, K_0^{TD} = 0.2500, and K_0^{TF} = 0.2500.

The production function of the capital goods sector (3.27) remains to be calibrated. As μ influences the productivity of domestic capital goods production, I expect that μ influences the share of capital stocks in sectors N and T made up by domestic versus foreign capital, like described in chapter 1. I expect that a lower level of μ induces a higher share of foreign capital flowing into domestic sectors N and T.

In line with chapter 1, I expect[36] that a (too) high level of μ induces domestic capital goods production above sectoral (N and T) demand for capital goods. This implies a total crowding out of foreign capital in both sectors N and T, and the small open economy becoming a (net) exporter of capital goods (mathematically $K_t^{*\,TF} > 0$ and $K_t^{*\,NF} > 0$, i.e., $K_t^{TF} < 0$ and $K_t^{NF} < 0$). Investigating the economic evolution of a catching up / emerging economy, the latter is for the initial periods of simulation not meaningful (Eaton, Kortum, 2001).

Investigating the impact of inward foreign capital installed in the domestic sector T on technology accumulation, it requires foreign capital (goods) to flow into the (domestic) small open economy ($K_t^{TF} > 0$). A level of μ = 0.5000 ensures in the numerical experiment (see chapter 3.5) that both sector T capital cost risk premia scenarios realize a positive stock of K_t^{TF} in at least the first ten periods of simulation, which make up the treatment period of macroeconomic integration (see chapter 3.5). I set μ = 0.5000.

Regarding the share of tradable goods used as input in the production of the capital good, I follow de Cordoba and Kehoe (2000) and set γ = 0.3802.

Now, let us turn to calibrating R_t^{TK}, the risk premia on tradable production capital costs.

As indicated in chapter 1 by using OECD data, in the early 1980s, the yield spread on Spanish 10-year government bonds, relative to 10-year government bonds of Germany, was roughly around 8 percent (see panel 1.2d, figure 1.2 in chapter 1). This yield spread vanished during/by European (macroeconomic) integration until the mid-2000s (see also Sinn, 2012, 2015).

I use this as a first rough hint on the effect of European (macroeconomic) integration. I calibrate that sectoral risk in tradable production makes capital lenders in tradable production to require a risk premium on interest rates (capital costs) of $R_t^{TK} = 0.0800$ (‘before’ European macroeconomic integration). I admit this is to an extend arbitrary. As I am interested in a theoretical assessment, this should suffice for now. This implies that I calibrate the risk premia on tradable production capital costs R_t^{TK} roughly around 8%. I admit that this is relatively high and supports the hypothesis of my chapter 3. In chapter 3.5, I also provide some results for a lower range of R_t^{TK}.

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[35] In de Cordoba and Kehoe (2000) I find an indication that K_O^N is *roughly* 1.84 times higher than K_O^T (suggesting $K_O^N = 1.8400\ K_O^T$). To solve my model, I had to set $K_O^N = 2.0000 K_0^T$.

[36] In chapter 1, it is mentioned that some parameter constellations confirmed the expectation of a higher μ inducing a lower K_t^F (also K_t^{NF} and K_t^{TF}) in selected periods. For transparency, there were also found parameter constellations where a higher μ induced a higher K_t^F (also K_t^{NF} and K_t^{TF}) in selected periods.

Finally, I set the initial bond holding to $B_0 = 0.0000$, in line with Benigno and Fornaro (2014).

As my model is made up by more complexity compared to the model of Benigno and Fornaro (2014), I regard it as meaningful to expand the period (years) to transit to steady state to T=225. This improves the accuracy of my results, compared with T=200 in the Benigno and Fornaro (2014) model.

I calibrate as follows:

Parameter	Value	Description
g^*	0.0150	Total-factor-productivity growth rate of the world technological leader
R	1.0400	Interest rate
q	1.0000	Relative price of capital goods
β	0.9760	Discount factor
ω	0.4140	Share of tradable goods in consumption
L	1.0000	Total endowment of labour
A_0^*	6.4405	Initial total-factor-productivity of the world technological leader
A_0	4.1384	Initial total-factor-productivity of the domestic economy
c_1	0.1670	Conv. parameter in the technology accumulation process by sector T employment
c_2	0.0001	Conv. parameter in the technology accumulation process by sector T foreign capital
R_t^{TK}	0.0800	Capital cost risk premium in sector T, normal sector T capital cost premia scenario
$R_t^{TK}\_low$	0.0000	Capital cost risk premium in sector T, low sector T capital cost premia scenario
α	0.7011	Labour share in the production of tradable goods and non-tradable goods
δ	0.0576	Capital stock depreciation rate
μ	0.5000	Degree of the international technology spillover across sectors K and T
γ	0.3802	Share of tradable goods in the production of capital goods
K_0^T	0.5000	Initial capital stock in sector T
K_0^{TD}	0.2500	Initial domestically financed/produced capital stock in sector T
K_0^{TF}	0.2500	Initial foreign financed/produced capital stock in sector T
K_0^N	1.0000	Initial capital stock in sector N
K_0^{ND}	0.5000	Initial domestically financed/produced capital stock in sector N
K_0^{NF}	0.5000	Initial foreign financed/produced capital stock in sector N
B_0	0.0000	Initial bond holdings of the small open (domestic) economy
T	225	Number of periods (years) to transition to steady state
t		Periods are years

Table 3.1: Calibration of numerical simulations.

3.5 Results

This chapter provides the results[37] of a macroeconomically integrating economy in figures 3.3 and 3.4. There are similarities with the results and their description in chapter 1.5 and 2.5 (see also Hildebrandt, Michaelis, 2022).

Solid lines simulate the 'normal sector T capital cost risk premia' scenario (norm), by simulating a not macroeconomically integrated benchmark economy.

Dashed lines simulate the 'low sector T capital cost risk premia' scenario (low), by simulating a macroeconomically integrating economy, with temporarily low risk premia on capital costs in tradable production. Resting on similar models, many results are like in chapter 1 (see Hildebrandt, Michaelis, 2022) and chapter 2. The experiment is a temporary reduction of sectoral capital cost risk premia in tradable production R_t^{TK} contingent on macroeconomic integration. I follow Benigno and Fornaro (2014) in defining two sector T capital cost risk premia *scenarios* (see figure 3.1), which I simulate numerically (see next page).

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[37] I use the standard shooting algorithm code that Benigno and Fornaro (2014) introduced and extend it by sectoral (T and N) differences in capital costs contingent on macroeconomic integration. Doing so, my code rests on the code of chapter 2 (precisely chapter 2.3), extended by sectoral capital costs premia in tradable production contingent on macroeconomic integration, according to chapter 3.3. The code of chapter 2 (precisely chapter 2.3) rests on the code of Benigno and Fornaro (2014) and of the code of chapter 1 (precisely chapter 1.3). The shooting algorithm starts solving the simultaneous system of equations by using an initial assumption for tradable consumption C_t^T in period 0. This allows to solve the simultaneous system for the introduced endogenous variables, for the whole T=225 periods. Finally, the algorithm checks the deviation from the intertemporal resource constraint Eq. (3.34). This implies that the present value of total tradable goods consumption must be equal to the present value of total tradable goods production. Should the deviation from the intertemporal resource constraint exceed a predefined tolerance parameter, using the initial (t=0) assumption for tradable goods consumption C_0^T, the algorithm updates its initial assumption for tradable goods consumption and checks again the fulfilment of the intertemporal resource constraint Eq. (3.34). I set the tolerance parameter to 2e-9, compared with 2e-8 in Benigno and Fornaro (2014) to improve accuracy of my (extended) model. As soon as the deviation from the intertemporal resource constraint undercuts / falls short of the tolerance parameter, the algorithm stops and provides the results. The simultaneous system / shooting algorithm code runs in Matlab, figures are made in Microsoft Excel. My computer code assumes that the domestically financed/produced capital goods are distributed over sectors N and T in the same ratio as total capital (financed/produced from 'domestic' *and* 'foreign') goods are distributed over sectors N and T.

To maintain a stable sectoral employment in the steady state, like in chapter 1 and chapter 2, the code *assumes* that current (= in a current period 't') sectoral employment will equal future (= in the next period 't+1') sectoral employment in domestic and foreign investment decisions, *in the absence of changes* in sector T capital cost risk premia. This approach is mirrored in the calculation of future (= for next period 't+1') sectoral capital stocks (K_{t+1}^T and K_{t+1}^N) in the current period (= in current period 't'). This maintains stable sectoral employment (L_t^T and L_t^N) over time and in steady state. My interpretation of the original Benigno and Fornaro (2014) model is that, by using a Cobb-Douglas consumption index, Benigno and Fornaro (2014, p.67, 75) also require a stable sectoral employment in steady state to ensure a 'balanced growth path'. From the theoretical findings of chapter 1 and of chapter 2, sectoral labour allocation is invariant to interest rate reductions, and constant, if and as capital stocks in both sectors (T and N) benefit *simultaneously* from capital accumulation (and low interest rates) (I refer to chapter 1 and 2 for technical interpretation).

In the current chapter (chapter 3, precisely chapter 3.5):

Normal sector T capital cost premia scenario ('norm', no macroeconomic integration) (see panel 3.1b in figure 3.1)
In the absence of *changes* in sector T capital costs premia R_t^{TK}, sectoral labour supply is *assumed* to be constant over time, from the findings and motivation in chapter 1 and chapter 2, from the beginning of the simulations in t=0 on. Thus, when calculating future (= for next period 't+1') sectoral capital stocks (K_{t+1}^T and K_{t+1}^N) in the current period (in current period 't'), the code assumes that future (in next period 't+1') sectoral employment will equal current sectoral employment (L_t^T and L_t^N). In other words, as tradable production capital cost risk premia R_t^{TK} are assumed constant over time, sectoral employment (L_t^T and L_t^N) is *assumed* constant over time. At the end of the simulations in t=T=225, I/the code confirm(s) the continued validity of the sectoral labour allocation by using its continued determinants at t=T=225.

Low sector T capital cost premia scenario ('low', macroeconomic integration) (see panel 3.1b in figure 3.1)
Initial (t=0) sectoral labour allocation (L_t^T and L_t^N) in t=0 is calculated following Eq. (3.25) and again remains constant for the first ten periods (i.e., from t=0 to and including t=9) (from the findings of chapter 1), until tradable production capital cost premia R_t^{TK} set in from period t=10 on. In period t=10 (from period t=10 on), sectoral labour resource allocation (L_t^T and L_t^N) faces tradable production capital cost premia R_t^{TK}, and the code directs sectoral labour resources (L_t^T and L_t^N) in period t=10 to the level that had initially (t=0) been realized, if the economy *had initially* (in t=0) faced tradable production capital cost premia R_t^{TK}. In the absence of further changes in tradable production capital cost premia R_t^{TK} from period t=11 on, the code keeps the sectoral labour resource allocation constant from t=11 until t=T=225. At the end of the simulations in t=T=225, I/the code confirm(s) the continued validity of sectoral labour allocation by using its continued determinants at t=T=225.

Normal sector T capital costs premia scenario ('norm', no macroeconomic integration)

The 'normal sector T capital cost premia' scenario depicts a not macroeconomically integrated benchmark economy ('norm', solid lines). Chapter 3 motivates for a not integrated economy that, exchange risk, transportation risk, and contract risk when importing intermediates and exporting goods disrupts profits in tradable production. In non-tradable production, such risk is assumed minor/absent. Thus, as the small open economy does not integrate macroeconomically in the '*Normal sector T capital costs premia scenario*', tradable production must pay a risk premium of $R_t^{TK} = 0.0800$ to capital lenders over the whole period of simulation.

Benigno and Fornaro (2014) simulated a temporary reduction of the interest rate *R* (see figure 3.1, panel 3.1a). As a result, they found a depressed (growth rate of) productivity and potentially a depressed welfare. Extending the Benigno and Fornaro (2014) model by capital as a production factor (chapter 1 of the dissertation at hand) and by technology accumulation from foreign capital (chapter 2 of the dissertation at hand) theoretically proved that a temporary reduction of interest rates R_t *does not* sufficiently explain a depressed (growth rate of) productivity and a potentially depressed welfare, for most of the parameter constellations which chapter 1 and chapter 2 checked.

The hypothesis of chapter 3 is that a (temporary) *sectoral* reduction of capital cost risk premia in sector T *does* explain a depressed (growth rate of) (total-factor) productivity and potentially a depressed welfare. Thus, I design a 'Low sector T capital costs premia scenario'.

Low sector T capital costs premia scenario ('low', macroeconomic integration)

The 'low sector T capital cost premia' scenario investigates macroeconomic integration ('low', dashed lines). Macroeconomic integration unites currencies, improves infrastructure, and harmonizes product standards (Baldwin, Wyplosz, 2015, Blanchard, Giavazzi, 2002, Griffith, Harrison, Simpson, 2010). The harmonization of product standards might also improve contract reliability in international trade. Thus, when importing intermediates and exporting goods, tradable production benefits overproportionate from risk lowering (European) macroeconomic integration. I thus set the (risk) premia on sector T capital costs R_t^{TK} to $R_t^{TK}\_low = 0.0000$ for the first ten periods of simulation (from t=0 to and including t=9). Macroeconomic integration vanishes tradable production capital cost risk premia. To provide comparable results with Benigno and Fornaro (2014) (see panel 3.1a in figure 3.1), from period t=10 on, the risk premia on tradable production capital costs return to $R_t^{TK} = 0.0800$ for the rest of the simulation. The first ten periods of simulation are a 'treatment period' of macroeconomic integration relative to a benchmark economy, showing the effect of macroeconomic integration.

The following figure summarizes the stylized policy setups:

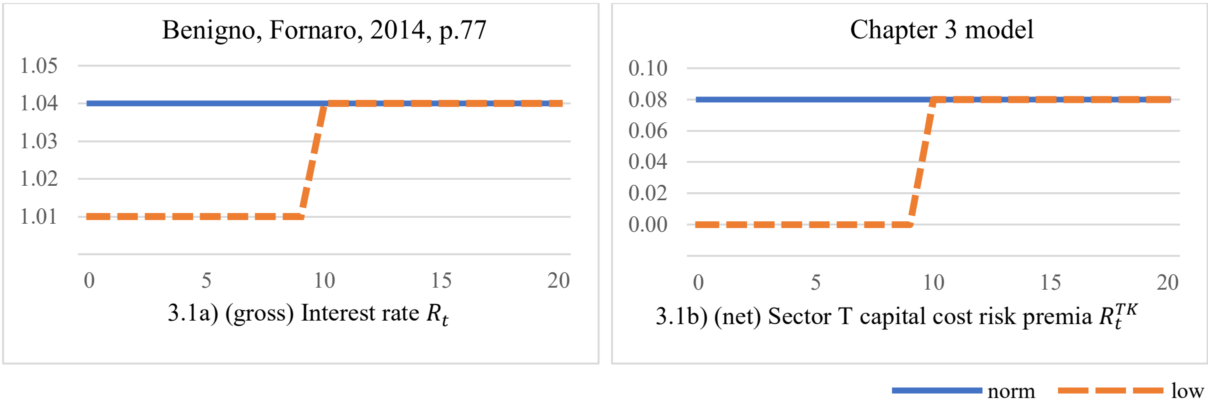

Figure 3.1: Policy setups. Horizontal/longitudinal axes are periods/years.

Benigno, Fornaro, 2014:
'norm': normal interest rates scenario, no financial integration, benchmark economy.
'low': low interest rates scenario, financial integration, treatment economy.

Chapter 3 model:
'norm': normal sector T capital cost premia scenario, no macroeconomic integration, benchmark economy.
'low': low sector T capital cost premia scenario, macroeconomic integration, treatment economy.

Panel 3.1b in figure 3.1 shows the policy setup for my numerical simulations.

To be clear, in chapter 3 I do *not* simulate a temporary reduction of the interest rate R_t like Benigno and Fornaro (2014) simulated (panel 3.1a, figure 3.1). In chapter 3, I simulate a temporary reduction of sector T capital cost risk premia R_t^{TK} *only* (panel 3.1b, figure 3.1). The interest rate R_t is constantly at 1.04 in both of my scenarios ('norm' and 'low'), over the whole simulation period.

A main driver of the reaction of my model and of the small open economy to macroeconomic integration is the change of relative input prices (ratio 'capital costs to labour costs') between sectors N and T, induced by macroeconomic integration. The reason is that the change in relative input prices (ratio 'capital costs to labour costs') induced by macroeconomic integration, makes tradable production to substitute labour against capital.

The ratio 'capital costs to labour costs' in tradable production is: $\frac{Capital\ costs\ (sector\ T)}{Wages}$

The ratio 'capital costs to labour costs' in non-tradable production is: $\frac{Capital\ costs\ (sector\ N)}{Wages}$

When comparing both ratios (and their reaction to macroeconomic integration) with each other, labour costs (wages) cancel out, as they are assumed to be identical across sectors (like in Benigno, Fornaro, 2014). Thus, to compare the 'capital costs to labour costs' ratio across sectors (T and N) and their response to macroeconomic integration, it suffices to compare capital costs across sectors. The following figure 3.2 compares stylized/proxied (net) capital costs in tradable production and non-tradable production:

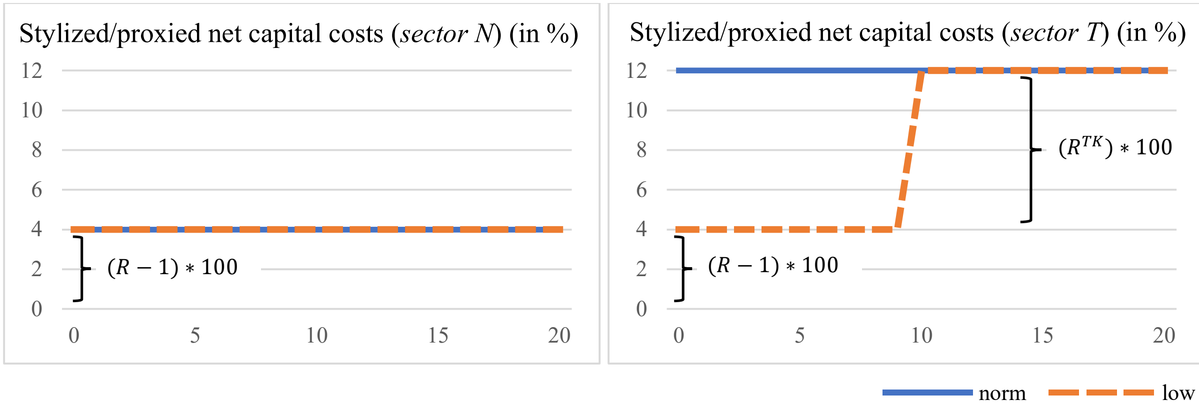

Figure 3.2: Stylized / proxied net capital costs in percent, sectors N and T.
Horizontal/longitudinal axes are periods/years.

'norm': normal sector T capital cost premia scenario, no macroeconomic integration, benchmark economy.
'low': low sector T capital cost premia scenario, macroeconomic integration, treatment economy.

Scenario 'norm'

Without macroeconomic integration (scenario 'norm'), tradable production constantly has a higher 'capital costs to labour costs' ratio than non-tradable production (from sectoral labour costs equality, but capital costs risk premia in tradable production). This augments labour demand in tradable production (capital is relatively expensive), simulated in scenario 'norm'.

Scenario 'low'

Macroeconomic integration (simulated in the first ten periods in scenario 'low') reduces the ratio 'capital costs to labour costs' in tradable production. The ratio 'capital costs to labour costs' in tradable production reduces to the one in non-tradable production, making tradable production to demand less labour and more capital during the first ten periods in scenario 'low' (compared to scenario 'norm'). Tradable production substitutes labour against capital in this period (see results starting on the next page).

Results

Macroeconomic integration (simulated in the first ten periods of scenario ‘low’) has the following effects, *compared to a not macroeconomically integrated benchmark economy*:

By asymmetrically reducing risk in tradable production, tradable production capital costs risk premia vanish. The ratio ‘capital costs to labour costs’ in tradable production reduces. Thus, given the tradable production output, tradable production demands less labour L_t^T (panel 3.3a) and more capital K_t^T (panel 3.3i). As relative input prices in tradable production change, tradable production substitutes labour against capital.

As I do not simulate an overall interest rate R_t reduction, there is no boom of non-tradable C_t^N and tradable C_t^T consumption[38] (panels 3.3b, 3.3c). The overall interest rate R_t affects household consumption decision like in Benigno and Fronaro (2014) as bonds B_{t+1} (equipped with interest rate R_t) are used by the household for the intertemporal consumption allocation.

Relative prices of non-tradable goods P_t^N increase (panel 3.3d), and this reduces non-tradable consumption. Tradable production costs are lower (lower tradable production capital costs R_t^{TK}), reducing the prices for tradable goods. Relatively to non-tradable goods, macroeconomic integration thus lowers tradable goods prices, and thus increases P_t^N (see also Piton, 2019). This like in Mian, Sufi, and Verner (2020), who theorize that the relative price of non-tradable goods will rise, if an economy faces a credit supply expansion, that is centred on asymmetrically improving credit availability (and thus capital accumulation) in tradable production. This contributes to explaining the real appreciation in peripheral Europe when integrating macroeconomically shown in Sinn (2012, 2015) and in Zemanek (2010). As (the growth rate of) technology accumulation is lower (panel 3.3f), tradable consumption suffers (panel 3.3c).

Foreign capital K_t^{TF} flows into tradable production (panel 3.3e). Technology A_t accumulation is promoted from inflowing foreign capital K_t^{TF} (panel 3.3e) and weakened by reduced labour demand L_t^T (panel 3.3a). For technology A_t accumulation, in the current calibration, the negative effect of a reduced learning-by-doing by lower L_t^T dominates over the positive effect of technology transfers from foreign capital inflows. For that reason, the ‘growth rate’ of technology A_t is lower (panel 3.3f). The promotion of capital accumulation (by reduced R_t^{TK}) particularly benefits tradable production. In the current calibration, this burdens total-factor-productivity there. In the next subchapter, I also test if this finding is robust for other parameter constellations.

The investment of tradable goods into capital goods production responds positively. Tradable goods invested in capital goods production (Z_t^T) are partly imported, also reflected in a negative response of B_t (panel 3.3g).

Capital stocks in both sectors respond positively (panels 3.3h and 3.3i). Sector T capital responds positively, reflecting the reduction of capital costs in tradable production (reduced risk premia) (panel 3.3i). Sector N

[38] For transparency, I also experimented with a temporal interest rate R_t reduction parallel to the temporal sectoral capital cost R_t^{TK} reduction in the scenario of macroeconomic integration (not illustrated in chapter 3). Still, my model failed to predict booming consumption. I assume that this comes from the relative size of the overall temporary interest rate reduction R_t and the temporal sectoral capital cost R_t^{TK} reduction. In chapter 1 and in chapter 2, temporal sectoral capital cost R_t^{TK} reductions were small (=absent), and overall temporal interest rate reductions R_t were significant. As result, chapters 1 and 2 found initially booming consumption in the scenarios of temporary low interest rates (macroeconomic integration) (like shown in the original model of Benigno, Fornaro, 2014).

capital responds positively, as labour moves into sector N, requiring a capital endowment (equipment) (panel 3.3h). The additional demand for capital goods is partly serviced by domestic capital goods production.

Promoting sectoral capital stocks K_t^N and K_t^T, sectoral output Y_t^N and Y_t^T, and GDP ($GDP_t = Y_t^N P_t^N + Y_t^T$) respond positively (panels 3.4c, 3.4d, 3.4e). For tradable production Y_t^T (panel 3.4d) an interesting pattern emerges. Despite macroeconomic integration burdens (the growth rate of) total factor productivity A_t (panel 3.3f) in tradable production, and despite macroeconomic integration drags labour resources out of tradable production (panel 3.3a), the promotion of capital stocks K_t^T in tradable production (panel 3.3i) pushes tradable production output Y_t^T (panel 3.4d).

The temporary promotion of sectoral output Y_t^N and Y_t^T (panel 3.4c, 3.4d) is reflected in a temporary promotion of non-tradable goods invested in capital goods production, Z_t^N, and of tradable goods invested in capital goods production, Z_t^T (panel 3.4a and 3.4b). As domestic demand for capital goods rises (panel 3.4j), this is partly satisfied from domestic capital goods production, promoting the demand that capital goods production exerts, namely Z_t^N and Z_t^T.

Economic growth, in the sense of GDP_t growth, shows an even more interesting response to macroeconomic integration (panel 3.4e). It is shown that GDP_t responds positively to macroeconomic integration, as sectoral output levels (Y_t^N and Y_t^T) benefit from a spurred-on capital accumulation. Nevertheless, the positive response of GDP_t to macroeconomic integration is an interesting pattern, as macroeconomic integration reduces the growth rate of technology accumulation (panel 3.3f), and macroeconomic integration relocates labour resources out of tradable production (utilizing productivity level A_t), into non-tradable production (utilizing no productivity level).

The Current account to GDP ratio $\frac{CA_t}{GDP_t}$ responds negatively (panel 3.4f), reflecting the import of capital goods from abroad/'foreign' when the economy integrates macroeconomically. Summarizing the previous current account deficits, net foreign assets to GDP $\left(\frac{NFA_t}{GDP_t}\right)$ respond negatively (panel 3.4g). Promoting the import of capital goods, macroeconomic integration is reflected in the increased ratio of foreign capital installed in the domestic economy to GDP, $\frac{K_t^F}{GDP_t}$ (panel 3.4h). Reflecting lower tradable production capital costs, foreign financed (produced) and domestically financed (produced) capital goods, installed in the domestic economy, K_t^F and K_t^D, respond positively (panels 3.4i and 3.4j).

As one can see, the foreign financed/produced capital stock, installed in the domestic economy K_t^F turns negative after some periods (panel 3.4i). Like mentioned in chapter 1, this implies that the domestic production/provision of capital goods by the domestic sector producing capital goods is higher than the domestic sectoral (N and T) demand for capital goods. Then, foreign financed/produced capital, installed in the domestic economy, is crowded out ($K_t^F < 0$). The extend, to which K_t^F turns negative, measures (net) machinery exports. If $K_t^F < 0$, this mirrors that in period t, there is no foreign capital invested, neither in domestic tradable production, nor in domestic non-tradable production.

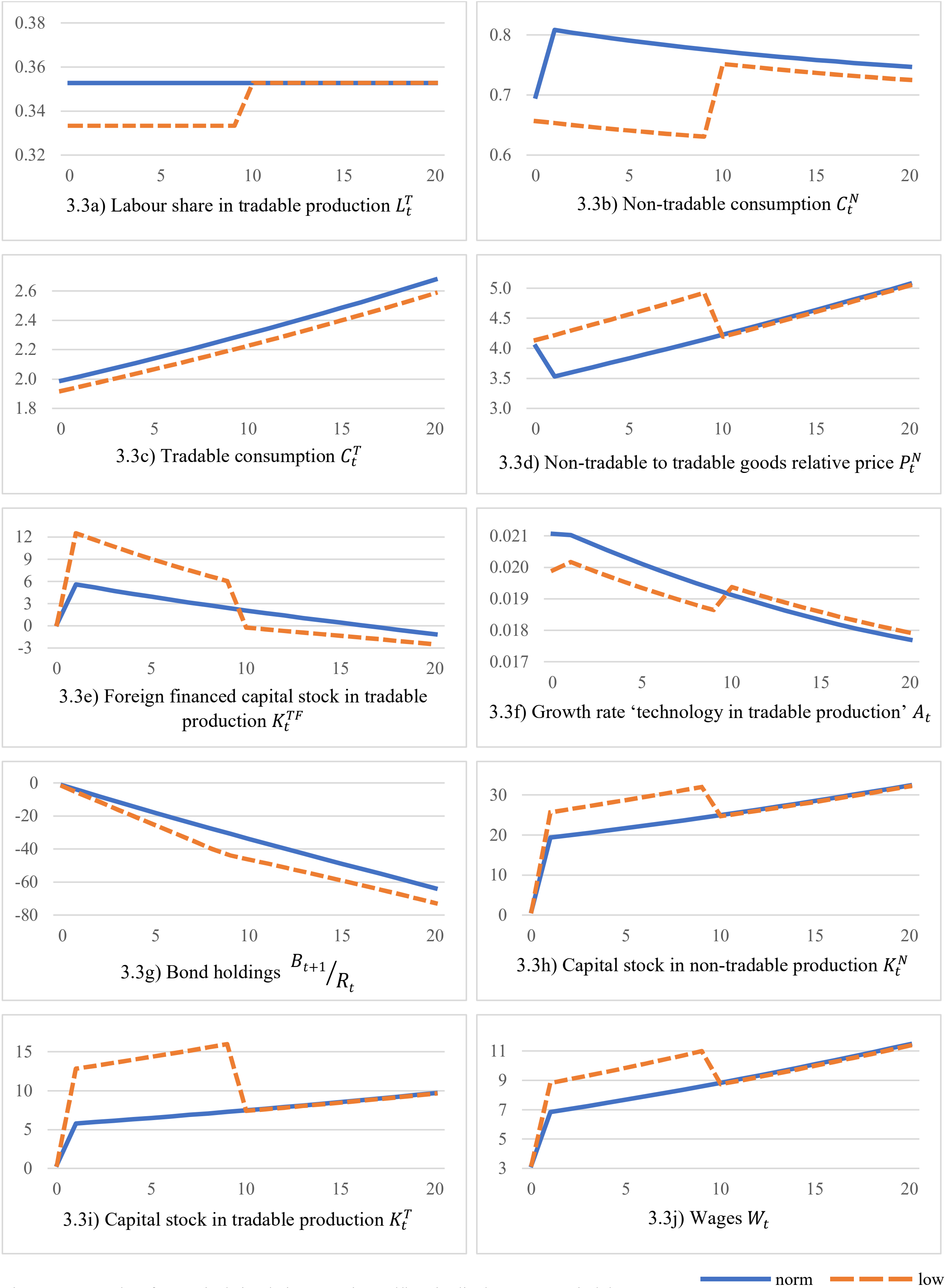

Figure 3.3: Results of numerical simulations. Horizontal/longitudinal axes are periods/years.

'norm': normal sector T capital cost premia scenario, no macroeconomic integration, benchmark economy.
'low': low sector T capital cost premia scenario, macroeconomic integration, treatment economy.

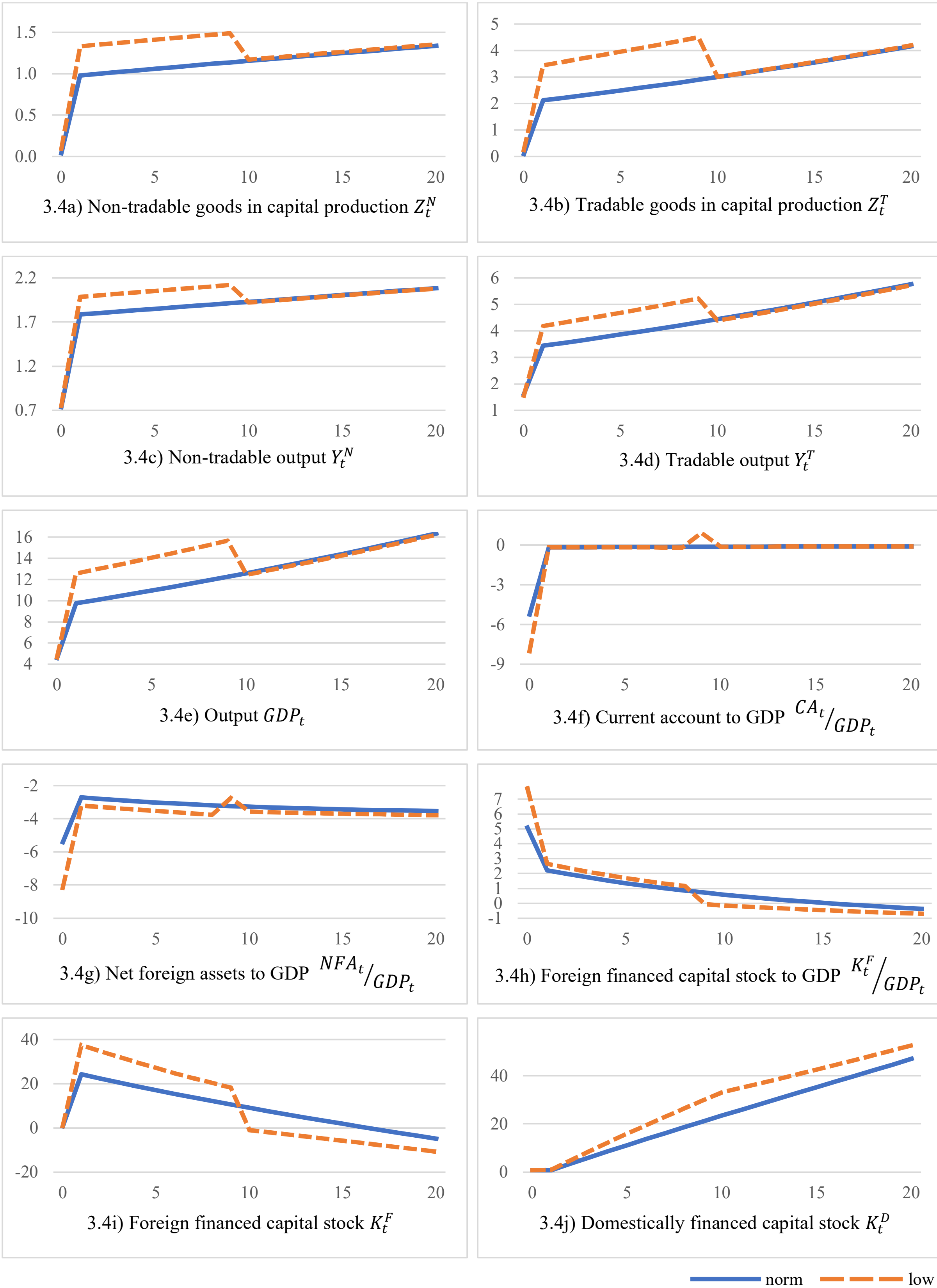

Figure 3.4: Results of numerical simulations. Horizontal/longitudinal axes are periods/years.

‘norm’: normal sector T capital cost premia scenario, no macroeconomic integration, benchmark economy.
‘low’: low sector T capital cost premia scenario, macroeconomic integration, treatment economy.

Technology accumulation

My model, with a tradable production capital cost premia R_t^{TK} reduction contingent on / in case of macroeconomic integration, matches some selected observations of peripheral European integration:

1) Increased private (or public) indebtedness,
   (Sinn, 2012, 2015, Sinn, Wollmershäuser, 2012, Benigno, Fornaro, 2014, Zemanek, 2010)

2) Current account deficits,
   (Sinn, 2012, 2015, Sinn, Wollmershäuser, 2012, Benigno, Fornaro, 2014, Zemanek, 2010)

3) Sectoral reallocation of resources into non-tradable production (out of tradable production),
   (Benigno, Fornaro, 2014, see also Sinn, 2015)

4) Slowdown of (the growth rate of) total-factor-productivity,
   (Benigno, Fornaro, 2014, for Spain. Bennett et al., 2008, for Portugal and Italy)

5) Real appreciation (in my model found in increasing non-tradable relative prices, like a Balassa Samuelson effect),
   (Zemanek, 2010, see also Sinn, 2012, 2015)

should the economy integrate macroeconomically. This can result in depressed welfare (see below). Another key characteristic of (peripheral European) macroeconomic integration, *booming (private or public) consumption* from increased (private or public) indebtedness (Sinn, 2012, 2015, Benigno, Fornaro, 2014), my model fails to predict (see above).

The question arises, how robust the 'slowdown of productivity' (growth rate of A_t) remains towards parameter variations. Investigating this, variable ψ measures the technological advantage of the normal sector T capital cost premia scenario ('norm', no macroeconomic integration), compared to the low sector T capital cost premia scenario ('low', macroeconomic integration):

$$\psi_t = A_t^{norm} - A_t^{low} \tag{3.36}$$

The following figure 3.5 shows the evolution of ψ_t, for ranges of R_t^{TK}. In the low sector T capital cost premia scenario (macroeconomic integration) $R_t^{TK}\_low$ remains at $R_t^{TK}\_low = 0.0000$ for the first ten periods, and then recovers to (the different ranges of) R_t^{TK}.

The lower the calibration of the starting point for R_t^{TK} (the closer R_t^{TK} gets to $R_t^{TK}\_low$), the smaller is the simulated effect of macroeconomic integration on R_t^{TK}, and thus on K_t^{TF} and L_t^{T} (both influence technology accumulation according to Eq. (3.8)). The lower R_t^{TK} (vanished by macroeconomic integration), the smaller the negative effect of macroeconomic integration on learning-by-doing, confirmed by the following figure 3.5.

Macroeconomic integration *in my model* shows two effects on technology accumulation:

1) *Negative effect of macroeconomic integration on technology accumulation.*
   Macroeconomic integration reduces capital costs particularly in tradable production (modelled by reduced R_t^{TK} in case of macroeconomic integration), making tradable production to substitute labour against capital (see figure 3.3, panel 3.3a). This reduces learning-by-doing and technology accumulation (like in Benigno and Fornaro, 2014). The negativity of this effect is augmented if learning-by-doing of the labour force in tradable production is a strong driver of technology accumulation (high values of c_1) (like in Benigno and Fornaro, 2014) (see Eq. (3.8)).

2) *Positive effect of macroeconomic integration on technology accumulation.*
   Macroeconomic integration reduces capital costs particularly in tradable production, making tradable production to demand more capital (K_t^T), which is partly made up by foreign capital K_t^{TF} (see figure 3.3, panel 3.3e). This promotes technology accumulation from inflowing foreign capital. The positive effect is based on the findings of, e.g., Eaton and Kortum (2001) and Baltabaev (2014) and was modelled in chapter 2. The positivity of this effect is augmented if foreign capital, installed in tradable production, is a strong driver of technology accumulation (high values of c_2) (see Eq. (3.8)).

In figure 3.5, even if macroeconomic integration reduces risk in tradable production just slightly more than in non-tradable production (modelled by a lower calibration of R_t^{TK}), the (slight) movement of labour resources out of tradable production explains a productivity slowdown, resulting from the calibration of c_1 and c_2. If macroeconomic integration reduces capital costs in tradable production just slightly (modelled by a low calibration of R_t^{TK}), I suppose that foreign capital invested in tradable production is also K_t^{TF} pushed just slightly from macroeconomic integration. Then, the benefit on technology accumulation from foreign capital K_t^{TF} is not strong.

Lower capital cost risk premia in tradable production R_t^{TK} promote foreign capital flowing into domestic tradable production K_t^{TF} (see panel 3.3e in figure 3.3). Thus, another key parameter for the validity of the 5 matched selected observations of macroeconomic integration (list see above) is c_2, the convergence parameter for sector T technology accumulation from foreign capital (see Eq. (3.8)). For high levels of c_2, the positive effect of macroeconomic integration on technology accumulation (promoted inflowing foreign capital K_t^{TF}) potentially outweighs/overcompensates the negative effect of macroeconomic integration on technology accumulation (reduced employment in tradable production L_t^T, reducing learning-by-doing, mechanism like modelled by Benigno, Fornaro, 2014). Figure 3.6 depicts how macroeconomic integration affects technology accumulation, depicted by ψ_t for ranges of c_2.

As one can see, for higher levels of c_2, technology accumulation benefits from macroeconomic integration and thus from low tradable production capital cost risk premia. In figure 3.6, for *approximated* levels of $c_2 \geq 0.0006$, macroeconomic integration, simulated in the first ten periods of scenario 'low', benefits technology accumulation.

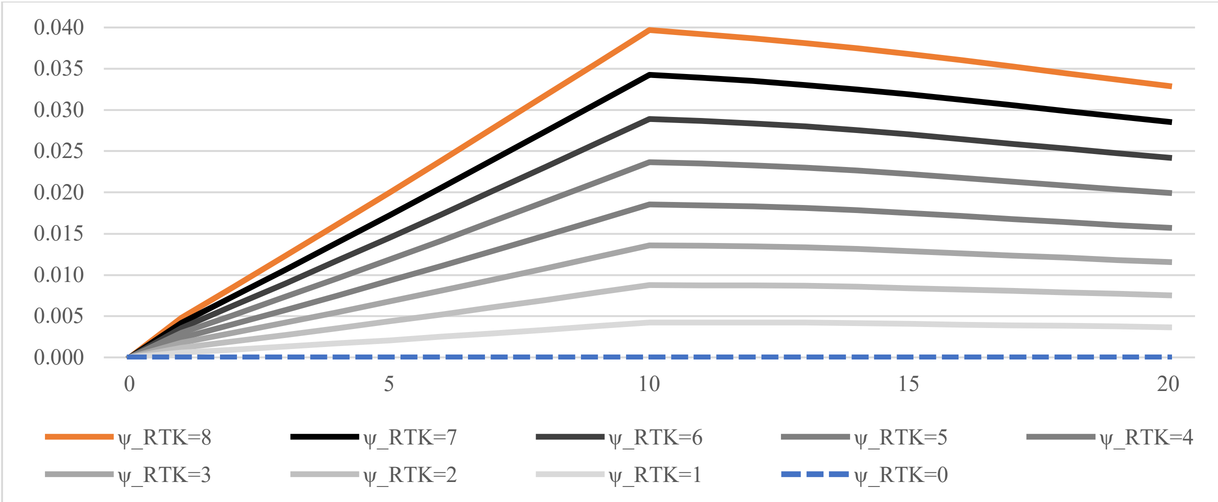

Figure 3.5: Technological advantage (ψ) of normal sector T capital cost risk premia for a range of R_t^{TK}. RTK=2 depicts $R_t^{TK} = 0.02$ (i.e., 2%), RTK=8 depicts $R_t^{TK} = 0.08$ (i.e., 8%), and so on. Horizontal/longitudinal axis are periods/years.

For the results of $R_t^{TK} = 0.04$, I had to run both scenarios (low sector T capital cost premia scenario and normal sector T capital cost premia scenario) at $R_t^{TK} = 0.04000001$.

For the results of $R_t^{TK} = 0.05$, I had to run both scenarios (low sector T capital cost premia scenario and normal sector T capital cost premia scenario) at $R_t^{TK} = 0.05000001$.

For the results of $R_t^{TK} = 0.07$, I had to run both scenarios (low sector T capital cost premia scenario and normal sector T capital cost premia scenario) at $R_t^{TK} = 0.07000001$.

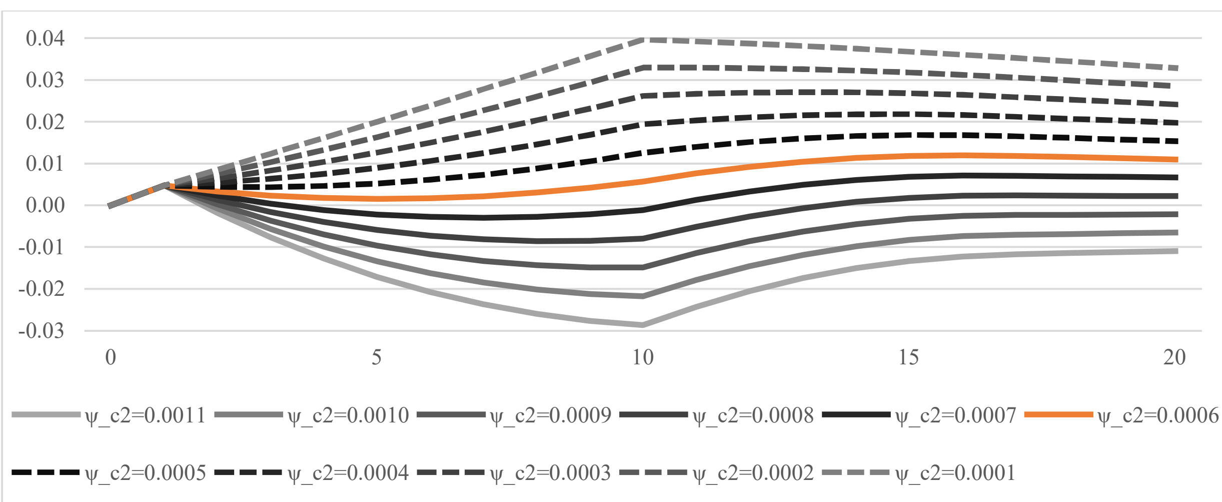

Figure 3.6: Technological advantage (ψ) of normal sector T capital cost risk premia for a range of c_2. Horizontal/longitudinal axis are periods/years.

For the results of $c_2 = 0.0006$, I had to run both scenarios (low sector T capital cost premia scenario and normal sector T capital cost premia scenario) at $c_2 = 0.0006000001$.

Welfare

Knowing the evolution of consumption allows to compare the household's welfare, as the present value of household lifetime utility. For my standard calibration, macroeconomic integration slows (the growth rates of) technology accumulation and productivity, depressing the consumption in the 'low sector T capital cost risk premia' scenario, and welfare. For my standard calibration, the welfare level in the 'normal sector T capital cost risk premia scenario' (15.2, no macroeconomic integration) is higher than in the 'low sector T capital cost risk premia scenario' (13.0, macroeconomic integration).

Lower capital cost risk premia in tradable production R_t^{TK} also spur-on foreign capital flowing into tradable production (panel 3.3e in figure 3.3), contributing to technology accumulation. Thus, one can ask the question, if the results hold for a higher calibration of c_2? Capable to investigate this, Benigno and Fornaro (2014) introduced variable η, the consumption equivalent handed over to the household living in their normal interest rates scenario ('norm'), making him as well off as a household living in their low interest rates scenario ('low'):

$$\sum_{t=0}^{\infty} \beta^t \log\ [\,(1+\eta)\ C_t^{norm}\,] = \sum_{t=0}^{\infty} \beta^t \log\ \left[\,C_t^{low}\,\right] \tag{3.37}$$

I use the Benigno and Fornaro (2014) measure (see Eq. (3.37) from their paper) to compare the 'normal sector T capital costs premia scenario' ('norm') with the 'low sector T capital costs premia scenario' ('low'), stylized in figure 3.2. The following figure 3.7 shows the evolution of the consumption equivalent η for a range of c_2.

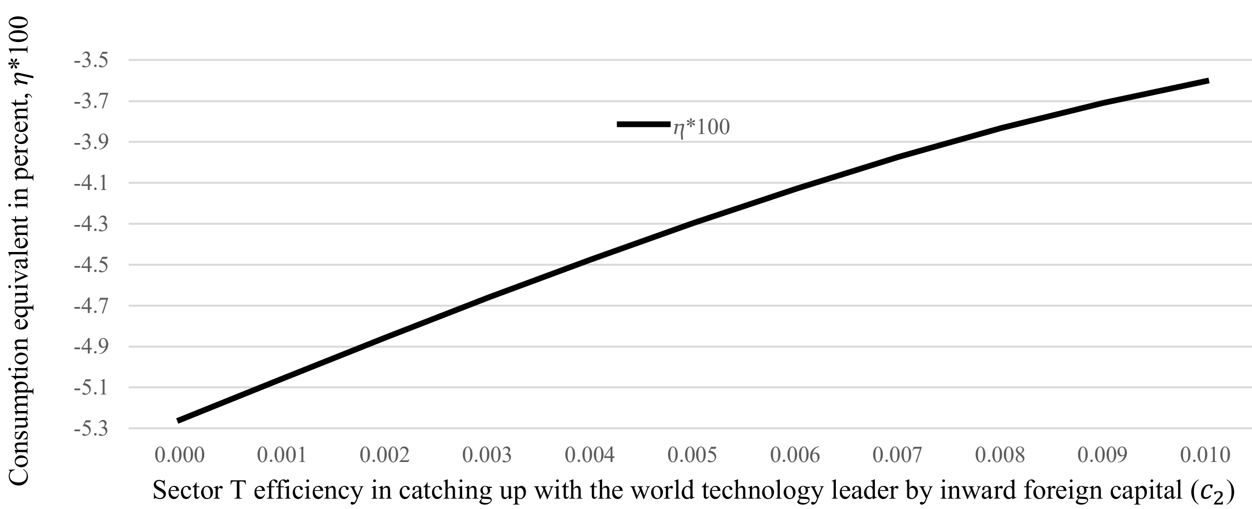

Figure 3.7: Consumption equivalent η*100 of low sector T capital cost risk premia for ranges of c_2. For $c_2 = 0.002$, I had to run both scenarios (low and normal sector T capital cost premia) at $c_2 = 0.002000001$. For $c_2 = 0.005$, I had to run both scenarios (low and normal sector T capital cost premia) at $c_2 = 0.005000001$. For $c_2 = 0.007$, I had to run both scenarios (low and normal sector T capital cost premia) at $c_2 = 0.007000001$. For $c_2 = 0.009$, I had to run both scenarios (low and normal sector T capital cost premia) at $c_2 = 0.009000001$. Outside the range of $0.000 \leq c_2 \leq 0.010$ there seems to be no model solution.

As figure 3.7 shows, even if the domestic economy manages to adapt technology from foreign capital import more sufficiently (higher levels of c_2), the negative effect of lower sector T capital cost premia and of macroeconomic integration on welfare remains.

3.6 Policy

The simplicity of my model and of my calibration, as well as the missing consideration of (financial) frictions (like shown in, for example, Gopinath et al., 2017, or in de Cordoba, Kehoe, 2000) require caution in deriving policy implications. Nevertheless, a try shall be made.

Do my results imply that economies should not integrate macroeconomically, to preserve (the growth rate of) technology accumulation, and to preserve productivity and welfare? This would be impatiently concluded, as one must consider earlier insights of chapter 1 and chapter 2 of the dissertation at hand. Macroeconomic integration exerts *two* effects, according to this dissertation (chapters 1, 2, 3):

1) *First*, macroeconomic integration reduces overall interest rates R_t, shown by Sinn (2012, 2015) and by Benigno and Fornaro (2014). This effect, shown in chapter 1 and in chapter 2 benefits welfare for most of the parameter constellations tested for. This *first* effect pushes productivity (TFP) (see chapter 2).

2) *Second*, macroeconomic integration should exert an asymmetric effect by reducing capital costs in tradable production relatively to capital costs in non-tradable production in the integrating economy. This effect was shown above (chapter 3.5) to potentially threaten productivity and welfare, motivated above and by the finding of Piton (2019, see also 2021).

The *first* effect of macroeconomic integration particularly materializes from the benefit of foreign capital import on domestic productivity and technology accumulation (see, e.g., Baltabaev, 2014, Eaton, Kortum, 2001, Amann, Virmani, 2015). Thus, the (political) promotion of foreign financed capital stocks, installed in the domestic economy, can potentially outweigh the negative (*second*) effect that macroeconomic integration has on technology accumulation. If the technology levels of the integrating economy benefit stronger from inflowing foreign capital, macroeconomic integration can have a positive effect on technology accumulation (mirrored also in figure 3.6) (see also chapter 2).

This underlines the importance of a vivid investment environment, to ensure the build-up of particularly foreign financed/produced capital stocks during macroeconomic integration. A sound environment for foreign capital invested in the buildup of domestic capital stocks might outweigh the negative effect that a resource reallocation out of tradable production has on technology accumulation and welfare when integrating macroeconomically (chapter 3) (see also Yu, Chang, Fan, 2007, who motivate subsidies for inward Foreign Direct Investment). A requirement is that the domestic economy sufficiently learns and accumulates foreign technology from inward foreign investment (higher c_2).

Remember the experience of southern European macroeconomic integration, where an *overall interest rate R_t reduction* spurred-on private (or public) consumption (Benigno, Fornaro, 2014, Sinn, 2012, 2015), with the adverse effects shown in Benigno and Fornaro (2014) and in Sinn (2012, 2015).

Thus, one possibility for policy to alleviate the potentially adverse effects of macroeconomic integration (shown in chapter 3, see also Benigno, Fornaro, 2014) and to promote technology accumulation mentioned above might be a symmetric tax on household's tradable and non-tradable consumption, to finance subsidies on foreign capital invested in the domestic (integrating) economy.[39]

Particularly, subsidies should target foreign capital invested in tradable production. Taking the need of democratic support for this policy suggestion into account (voters work in both sectors, N and T), it might be difficult to limit subsidies on one sector. Thus, one might subsidize foreign capital inflows into tradable *and* non-tradable production.

A tax on interest rates R_t (Benigno, Fornaro, 2014, model this as capital controls) I regard misleading. Taking capital accumulation into account, a tax on interest rates hinders capital accumulation. Chapter 1 proved the beneficial impact of promoted capital accumulation on welfare (for most of the parameter constellations checked).

My results add to the question
'*What should integrate first: Goods markets or capital markets?' (See, e.g., Martin, Rey, 2006):*

Goods market integration, in my model I see connected to the reduction of R_t^{TK} in tradable production. Goods market integration makes tradable export and intermediates import safer, as it improves infrastructure, and harmonizes product standards (Baldwin, Wyplosz, 2015, Blanchard, Giavazzi, 2002, Griffith, Harrison, Simpson, 2010). Like mentioned above, the harmonization of product standards might also lead to a higher contract reliability in international trade. Idiosyncratically, this reduces uncertainty and risk particularly in (export oriented) tradable production, lowering tradable production capital cost risk premia R_t^{TK}. According to the mechanics described above (chapter 3.5), this makes firms in tradable production hiring less workers, and to substitute them by capital. Hiring less workers reduces learning-by-doing and technology accumulation in tradable production, burdening productivity (see figure 3.3, panels 3.3a and 3.3f) (this mechanism is like in Benigno, Fornaro, 2014). My assumption, that goods market integration idiosyncratically mostly affects tradable production, is supported by the recourse on Griffith, Harrison, and Simpson (2010), mentioned in chapter 3.1.

Capital market integration I see connected to an overall reduction of R_t (not simulated in chapter 3), based on the findings of Sinn (2012, 2015) and of Benigno and Fornaro (2014). Capital controls reduce, political support mitigates default risk, banking unions form, and this reduces the overall country risk, and thus overall interest rates R_t (Sinn, 2012, 2015, Gopinath et al., 2017. See also Benigno, Fornaro, 2014, on integration by Euro introduction). Shown in chapter 2, this pushes technology accumulation in tradable production and stimulates productivity, as it promotes the inflow of foreign capital into tradable production, carrying foreign technology (Baltabaev, 2014, Eaton, Kortum, 2001, Amann, Virmani, 2015, see also Blanchard, Giavazzi, 2002, see also chapter 2).

[39] Yu, Chang, and Fan (2007) find a beneficial effect of subsidizing inward foreign direct investment on the host economy. See also Blalock and Gertler (2008).

One sub-category of capital market integration needs an isolated consideration, namely the forming of a currency union. Besides lowering overall interest rates R_t (Sinn, 2012, 2015, Benigno, Fornaro, 2014), and in contrast to other sub-categories of capital market integration, I assume that 'forming a currency union' asymmetrically exerts a strong effect particularly on tradable production, by reducing exchange risk. Exchange risk materializes in (export oriented) tradable production, while it is presumably smaller in non-tradable production. Thus, 'forming a currency union' should be mirrored in the asymmetrical reduction of capital cost risk premia in tradable production (R_t^{TK}), like it was shown above for 'goods market integration'.

Should goods markets integrate first, without integrating capital markets, the integrating economy might see a negative impact on productivity (and welfare) from a reduced R_t^{TK} (shown in figures 3.5 and 3.7) but miss a sufficiently beneficial impact from promoted K_t^{TF} (shown in chapter 2) on productivity. My/this policy implication contrasts with a finding of Martin and Rey (2006). They conclude, to reduce the risk of a crisis in emerging market economies, goods markets should integrate first (and financial markets afterwards).

My finding also contrasts with Griffith, Harrison, and Simpson (2010). They found that the European Single Market Programme (SMP), a generic example of European (goods market) integration, did empirically promote total-factor-productivity in the economies analysed, as it promoted competition.[40] A reason for different findings of my dissertation and the Griffith, Harrison, and Simpson (2010) study might be that Griffith, Harrison, and Simpson (2010) included the following economies in their empirical analysis: Belgium, Denmark, France, United Kingdom, Netherlands, Canada, Finland, Norway, USA. The economies in peripheral Europe which suffered the most from European (macroeconomic) integration were according to Sinn (2012, 2015): Greece, Italy, Portugal, Spain, Ireland, Cyprus.

[40] Blanchard and Giavazzi (2002) predicted that European capital market integration and goods market integration will promote total-factor-productivity in poorer countries, by promoting competition.

3.7 Conclusion

Chapter 3 suggests why macroeconomic integration depressed (the growth rate of) productivity, and potentially welfare, in peripheral Europe in the late 1990s and early 2000s (like shown in Benigno, Fornaro, 2014, for Spain, and regarding total-factor-productivity, in Bennett et al., 2008, for Italy and Portugal). The meaningful assumption, that macroeconomic integration reduces tradable production risk more than non-tradable production risk, lowers capital costs asymmetrically in tradable production (motivated by the finding of Piton, 2019, see above). Lowering the ‘capital costs to labour costs’ ratio in tradable production, tradable production demands more capital and less labour when integrating macroeconomically (tradable production substitutes labour against capital). Lower labour demand in tradable production impedes learning-by-doing and technology accumulation, depressing (the growth rate of) productivity (like shown in Benigno, Fornaro, 2014). Conditional on the calibration, this negative effect on technology accumulation can overshadow the positive effect that macroeconomic integration has on productivity by promoting inward foreign investment (import of foreign capital goods), transferring foreign technology (see figure 3.6) (the positive effect was modelled in chapter 2, motivated by, e.g., Baltabaev, 2014, Amann, Virmani, 2015, Eaton, Kortum, 2001).

Chapter 3 helps understanding the depressed productivity, and potentially welfare, in peripheral Europe, like shown for Spain by Benigno and Fornaro (2014) (see also Bennett et al., 2008, for TFP in Italy and Portugal). This literature strand (Benigno, Fornaro, 2014, see also Sinn, 2012, 2015) started by theorizing that low interest rates from European (macroeconomic) integration push consumption and crowd out tradable production. This, following Benigno and Fornaro (2014), depresses (the growth rate of) productivity, and potentially welfare.

Subsequent theory (chapter 1, see also Hildebrandt, Michaelis, 2022) opposed that a tradable production crowding out from low interest rates does not necessarily happen if capital stocks in both sectors (N and T) benefit simultaneously from low interest rates and capital accumulation (see also Mian, Sufi, Verner, 2020). Moreover, low interest rates were found to push inward (inflows of) foreign investment and thus technology accumulation and productivity (chapter 2) (see also, e.g., Baltabaev, 2014, Amann, Virmani, 2015).

Thus, there emerged a gap between

- *Empirics*
  Macroeconomic integration was accompanied/followed by burdened (total-factor) productivity
  (Benigno, Fornaro, 2014, researching Spain. See also Bennett et al., 2008, for Italy and Portugal).

- And latest economic *theory*
  Macroeconomic integration should benefit (total-factor) productivity
  (chapter 2 of the dissertation at hand, see also, Blanchard, Giavazzi, 2002).

Chapter 3 of this dissertation at hand contributes to closing this gap. Theoretically, macroeconomic integration affects risk and capital cost in both sectors (tradable and non-tradable production) asymmetrically (see also Piton, 2019, 2021, on asymmetric empirical effects on sectoral capital costs). The unification of currencies, the harmonization of product standards and the improvement of infrastructure, induced by (European) macroeconomic integration (Baldwin, Wyplosz, 2015, Blanchard, Giavazzi, 2002, Griffith, Harrison, Simpson, 2010), should reduce risk particularly in (export oriented) tradable production.

The same may happen when product standard harmonization improves contract reliability in international trade. This should reduce capital costs particularly in tradable production, asymmetrically promoting capital accumulation in tradable production.

This chapter showed parameter constellations, where an asymmetrically strong promotion of capital accumulation in tradable production (sector T) can burden (the growth rate of) total-factor-productivity in tradable production. If European macroeconomic integration lowers risk and capital costs particularly in tradable production, it may induce a reallocation of (labour) resources, potentially depressing (the growth rate of) productivity in tradable production, and welfare (similar like shown in Benigno, Fornaro, 2014).

Economic growth, in the sense of GDP growth, reveals an interesting pattern. GDP responds positively to my simulation of macroeconomic integration, as capital stocks / capital accumulation benefits from lower capital costs (risk premia) in tradable production. Nevertheless, the positive response of GDP to macroeconomic integration is an interesting observation, as macroeconomic integration burdens (the growth rate of) technology accumulation (like shown in Benigno, Fornaro, 2014), and as macroeconomic integration relocates labour resources out of tradable production into the less productive non-tradable production.

For policy, my findings underline the importance of enabling technology accumulation (when integrating macroeconomically) from inward foreign investment by:

1) Stimulating it (Yu, Chang, Fan, 2007, find beneficial effects of subsidizing inward FDI, see also Blalock, Gertler, 2008) and

2) Learning from it (Keller, 1996, underlines the importance of domestically produced human capital for accumulating foreign technology). A higher ability to learn from inward FDI results in a higher c_2.

To preserve productivity, the ease that overall low interest rates from macroeconomic integration (Benigno, Fornaro, 2014, Sinn, 2012, 2015) bring should not only be utilized to expand consumption, but also be utilized push productivity. This can be achieved by taxing consumption, to subsidize inward foreign investment (see, e.g., Yu, Chang, Fan, 2007), and subsidizing education to enable learning from inward foreign investment (derived from Keller, 1996, see above).

Another policy implication arises for the timing of macroeconomic integration (goods market integration and capital market integration) under the following *two* assumptions:

1) First, one can assume that the asymmetrical reduction of tradable production capital costs risk premia (R_t^{TK}) reflects goods market integration, making tradable production to substitute labour against capital (see above) (Griffith, Harrison, Simpson, 2010, argue that goods market integration by the European Single Market Programme particularly affects manufacturing sectors).

2) Second, one can assume that overall interest rate (R_t) reductions (not simulated in chapter 3) reflect capital market integration (Sinn, 2012, 2015. See also Benigno, Fornaro, 2014, on macroeconomic integration by Euro introduction).

Under these *two* assumptions, goods market integration threatens productivity, as it relocates labour resources out of tradable production, impeding learning-by-doing and (the growth rate of) technology accumulation. Capital markets integration promotes technology accumulation, as it opens the economy for foreign capital inflows, carrying foreign technology in it (see, e.g., Eaton, Kortum, 2001, Amann, Virmani, 2015, Baltabaev, 2014).

Thus, when an economy integrates goods markets (with other economies) only, and does not *further* integrate capital markets, this threatens productivity. To prevent this threat, a relaxation for foreign capital inflows and a sound environment for foreign investment is crucial to preserve technology accumulation from inward foreign capital.

Limitations and further research

I admit assuming keen tradable production capital cost risk premia and macroeconomic integration effects (calibrated by R_t^{TK}), to find the effects that I report. Qualitatively, a sectoral reallocation and the consequences for technology accumulation and welfare hold if macroeconomic integration reduces risk in tradable production *stronger* than in non-tradable production (this reduces sector T employment), *and* employment in tradable production (T) was a strong(er) driver for technology accumulation (learning-by-doing). Nevertheless, further research must consider a more detailed calibration of my model, for example with firm level data.

Another major limitation is my assumption that the sectoral allocation of labour resources does not change over time *if* tradable production capital cost risk premia do not change over time. Moreover, my model fails to predict booming (private or public) consumption as a response to macroeconomic integration (Sinn, 2012, 2015, Benigno, Fornaro, 2014).

Finally, my results indicate that macroeconomic integration burdens welfare, regardless of how well the domestic economy performs in accumulating foreign technology from inflowing foreign capital (parameter c_2) (see figure 3.7). This finding can be challenged.

In my numerical simulations, tradable production labour resources react poorly to macroeconomic integration, despite simulating a strong reduction of tradable production capital costs premia R_t^{TK} (sectoral capital cost risk premia). From previous research, I would expect a stronger reaction (Sinn, 2015, Benigno, Fornaro, 2014).

Further research must also consider frictions in the response of capital stocks to (European) macroeconomic integration (here modelled by lower sector T capital costs risk premia), like motivated by Gopinath et al. (2017). Moreover, in the definition of profits in tradable production, additional capital cost risk premia in tradable production R_t^{TK} to compensate volatile profits in tradable production before macroeconomic integration are highly simplified. They (R_t^{TK}) are invoiced by the bankrollers and to be paid to the bankrollers in the same period when capital stocks are installed. A more sophisticated definition of the additional capital cost risk premia in tradable production, as well as 'payment in advance', and a 'payment in arrear' of additional tradable production capital costs risk premia R_t^{TK} might change my result. I lend a further investigation to further research.

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