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Endogenous Technological Progress and the Macroeconomy: Stagnation, Low Interest Rates and the Productivity Slowdown

Michaela Schmöller

Aalto University

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Abstract

This dissertation consists of an introductory chapter and three self-contained essays which share the common theme of endogenous technological progress in macroeconomic models.

The first essay presents a model of a currency union with nominal rigidities and endogenous growth in which pessimistic expectations can generate permanent slumps. Stagnation evolves as a growth trap under constraints on the central bank's policy rate: Monetary policy cannot restore full employment since weak growth depresses aggregate demand, pushing the policy rate against the constraint. Growth is low in turn as weak demand reduces firm profits and R&D investment. The currency union can settle in a stagnation steady state at the zero lower bound in which stagnation prevails on the monetary union level. A sufficiently small member state can idiosyncratically face stagnation while the rest of the currency union maintains full employment and sound technology growth when the central bank is constrained by its responsibility for the aggregate. Bilaterally implemented R&D subsidies can prevent stagnation in the currency union.

Essay 2 analyses the procyclicality of euro area total factor productivity and its role in business cycle amplification by estimating a medium-scale DSGE model with endogenous technology growth on euro area data. The endogenous TFP mechanism induces a high degree of persistence in the euro area business cycle via a feedback mechanism between overall economic conditions and productivity-enhancing investments. Decelerating innovation due to a fall in R&D efficiency constitutes a key driver of the euro area productivity slowdown pre-crisis. As of 2008, a crisis-induced drop in technology adoption is identified the most important factor. The response of inflation is dampened under endogenous productivity dynamics, helping explain both the negligible fall in euro area inflation during the crises and its sluggish increase in the subsequent recovery.

In the third essay, I propose a two-sector endogenous growth model with heterogeneous sectoral productivity and nonlinear hiring costs to analyse the link between stagnant wages, sectoral resource misallocation and low productivity growth. An upward shift in employment, triggered for instance by a labor market reform, raises long-run growth of technology, productivity and real wages. In the initial phase, however, productivity and real wages stagnate as employment increases disproportionally in the low-productivity sector. Due to the inherent growth externality the competitive equilibrium is not efficient as firms fail to internalize the effect of their individual labor allocation on aggregate growth. Subsidies to high-productivity sector production can alleviate welfare losses along the transition path.

JEL codes: E20, E22, E24, E32, E40, E52, O30, O42

Keywords Stagnation, Monetary Policy, Low Interest Rates, Endogenous Productivity Dynamics, Technology Growth, Productivity Slowdown

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Tekijä
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Endogeeninen teknologinen kehitys ja makrotalous: stagnaatio, matalat korot ja tuottavuuskasvun hidastuminen

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Tiivistelmä

Tämä väitöskirja koostuu johdantoluvusta sekä kolmesta itsenäisestä esseestä, joiden yhteisenä teemana on endogeeninen teknologinen kehitys makrotaloudellisissa malleissa.

Ensimmäinen essee esittelee rahaliittoa koskevan mallin, joka sisältää nimellisiä jäykkyyksiä ja endogeenista kasvua ja jossa pessimistiset odotukset voivat johtaa pysyviin taantumiin. Stagnaatio kehittyy kasvuansaksi, koska keskuspankin ohjauskorolle on olemassa rajoite: Täystyöllisyyttä ei kyetä palauttamaan rahapolitiikan keinoin, sillä kasvun heikkous vaimentaa kokonaiskysyntää ja painaa ohjauskorkoa rajoitetta kohti. Kasvu puolestaan on vaimeaa, koska kysynnän heikkous vähentää yritysten voittoja sekä tutkimus- ja kehitysinvestointeja. Rahaliitto voi nollakorkorajalle ajautuessaan jäädä pitkäaikaiseen stagnaatioon, joka vallitsee rahaliiton tasolla. Kyllin pieni jäsenmaa voi joutua stagnaatioon myös tilanteessa, jossa rahaliitossa on muilta osin täystyöllisyys ja teknologiakasvu on terveellä tasolla, kun vastuu kokonaisuudesta rajoittaa keskuspankin toimintamahdollisuuksia. Kahdenvälisesti toteutetut T&K-tuet voivat ehkäistä stagnaatiota.

Toisessa esseessä analysoidaan euroalueen kokonaistuottavuuden myötäsyklisyyttä ja sen suhdannevaihtelua voimistavaa vaikutusta estimoimalla euroalueen dataa hyödyntäen dynaaminen stokastinen yleisen tasapainon malli, johon sisältyy endogeeninen teknologian kasvu. Endogeeninen kokonaistuottavuusmekanismi lisää euroalueen suhdannekierron persistenssiä merkittävästi yleisen taloustilanteen ja tuottavuutta parantavien investointien välisen palautemekanismin kautta. T&K-toiminnan tehokkuuden heikentyminen on keskeinen syy euroalueen tuottavuuden kasvun heikkenemiselle ennen kriisejä. Vuoden 2008 jälkeen keskeisin syy tähän on ollut uuden teknologian aiempaa vähäisempi käyttöönotto. Tuottavuusdynamiikka vaimentaa inflaation reaktiota, mikä auttaa selittämään sekä euroalueen inflaation vähäisen hidastumisen kriisien aikana että sen vaimean kiihtymisen kriisejä seuraavan elpymisen aikana.

Kolmannessa esseessä esitellään kahden sektorin endogeenisen kasvun malli, jossa sektoreittainen tuottavuus on heterogeenista. Mallin avulla analysoidaan palkkojen hitaan kasvun, resurssien sektoreittaisen väärinkohdentumisen ja heikon tuottavuuden kasvun yhteyttä. Työllisyyden nousu kiihdyttää teknologian, tuottavuuden ja reaalipalkkojen pitkän aikavälin kasvua. Alkuvaiheessa tuottavuus ja reaalipalkat kuitenkin jähmettyvät, koska työllisyys lisääntyy suhteettoman voimakkaasti heikon tuottavuuden sektorilla. Kasvu-ulkoisvaikutuksen vuoksi kilpailutasapaino ei ole tehokas, sillä yritykset eivät työvoiman kohdentamista koskevissa ratkaisuissaan ota huomioon niiden vaikutusta kokonaiskasvuun. Hyvinvointitappioita on mahdollista vähentää tukemalla korkean tuottavuuden sektorin tuotantoa.

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Michaela Schmöller
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List of essays

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Secular Stagnation in a Currency Union
Unpublished manuscript

Essay 2
Endogenous TFP, Business Cycle Persistence and the Productivity Slowdown, *joint with Martin Spitzer (ECB)*
A version of this essay was published as Bank of Finland Research Discussion Paper 21/2019

Essay 3
Stagnant Wages, Sectoral Misallocation and Slowing Productivity Growth
A version of this essay was published as Bank of Finland Research Discussion Paper 8/2019

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I

Introduction

The pre-crisis macroeconomic paradigm focused on short-term fluctuations around a given, predetermined trend in which technological progress is not explicitly modelled but instead evolves purely exogenously in the form of a technology shock. However, the experience of advanced economies starting from the financial crisis, characterized by a deep and highly persistent recession, slowing productivity growth and subdued inflation in an environment of ultra-low interest rates, challenged existing modelling approaches. This experience highlighted, among others, the need for macroeconomic frameworks capable of making statements about the drivers of technological progress and productivity growth in a macroeconomic general equilibrium setting. This dissertation contributes to this strand of the literature as its essays share the main common theme of endogenous productivity growth in macroeconomic models, designed to explain economic dynamics starting from the Great Recession.

Essay 1 analyzes mechanisms and channels of secular stagnation in a currency union by means of an endogenous growth model with nominal wage rigidities and a joint monetary policy. The second essay sheds light into the causes of the drivers behind the severity and persistence of the Great Recession in the euro area and the central contributing forces to the euro area productivity slowdown by estimating a medium-scale DSGE model with an endogenous total factor productivity mechanism on euro area data. Essay 3 investigates the role of sectoral misallocation in explaining decelerating productivity and real wage growth following a large-scale employment shift in a nonlinear two-sector endogenous growth model with heterogeneous productivity.

1 Post-crisis dynamics and novel modeling approaches in macroeconomics

The Great Recession marked a decisive turning point in macroeconomics. Over a prolonged phase preceding the crisis, advanced economies displayed sound growth and low unemployment. Inflation, in turn, could be aligned with central banks' targets by means of conventional monetary policy instruments only and equilibrium real interest rates ranged in positive territory. The Great Recession, however, proved the most severe economic crisis in the post-war period with highly disruptive effects in terms of output loss and unemployment: GDP remained persistently below its pre-crisis levels and unemployment rose to stubbornly high levels for a prolonged period of time. These developments induced a then unprecedented, ultra-accommodative monetary policy stance: Advanced economy central banks lowered their key policy rates towards zero and complemented existing policy options by unconventional monetary policy tools, such as quantitative easing, forward guidance and negative interest rates. As to the supply side, a persistent slowdown in productivity growth, which already set in in the early 2000s, accelerated and started to become increasingly apparent since the Great Recession.

The experience following the Great Recession also raised concerns that advanced economies may not only suffer from the long-lasting effects of a severe crisis but from even more fundamental issues, leading to a revival of the secular stagnation hypothesis. While there is no single definition of "secular stagnation", most views would agree that the term denotes a prolonged period of weak growth, subdued inflation and low interest rates. Alvin Hansen coined the term already in 1938 drawing on the experience of the United States following the Great Depression, which was characterised by a prolonged period of insufficient aggregate demand and underinvestment, depressing the US equilibrium real interest rate and the outlook on long-run growth at that time.

Being designed to analyze pre-2008 economic dynamics and thus to study small-scale, short-run fluctuations around a predetermined trend, standard models in the pre-crisis macroeconomic paradigm proved incapable of matching the economic dynamics observed since the Great Recession. Naturally, the experience of the financial crisis painfully revealed the shortfalls in macroeconomics resulting from the absence of financial frictions in existing macroeconomic modelling approaches. Moreover and crucially in the context of this thesis, standard macroeconomic workhorse models remain silent on the drivers of technological progress and productivity growth. This property stems from the fact that productivity dynamics are not endogenously modelled, but productivity is instead assumed to evolve purely exogenously in the form of a technology shock. Consequently, these models cannot provide explanations on the driving forces behind the productivity

slowdown in advanced economies, highlighting the need for macroeconomic models which feature endogenous productivity dynamics in the post-crisis phase.

Generally, the endogenous analysis of the evolution of aggregate technology and productivity constitutes in itself not a new modelling approach, since endogenous growth models have been prevalent in macroeconomic at the latest since the seminal contributions by Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992). The novelty in recent macroeconomic models with endogenous productivity dynamics lies instead in the combination of insights from frameworks designed to analyze macroeconomic fluctuations, such as Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2007) with elements from endogenous growth theory. As a result, this new class of macroeconomic models with endogenous productivity dynamics, most importantly represented by Anzoategui, Comin, Gertler and Martinez (2018) and Bianchi, Kung and Morales (2019), is capable of generating deep and persistent recessions observed in the aftermaths of the Great Recession, through hysteresis effects in productivity-enhancing investments. More specifically, these models feature a powerful feedback mechanism between the general state of the economy on the one hand and productivity growth on the other hand, inducing a high degree of business cycle amplification and persistence. As a result, these frameworks are capable of generating not only short-run fluctuations but instead deep and long-lasting recessions.

Lastly, standard macroeconomic frameworks were generally linearized around a given trend and were thus not constructed to deal with economic nonlinearities. The zero lower bound on nominal interest rates, which became a relevant obstacle for monetary policy in most countries only starting from the Great Recession, constituted a major obstacle to this modelling approach. Relatedly, providing models addressing the secular stagnation debate, rendered nonlinear models capable of not only explaining fluctuations around a trend, but instead the downward shift in the trend itself a necessity. Among the various approaches to secular stagnation, proposed explanations range from long-term shifts in the economy, such as ageing and inequality, depressing aggregate demand and hence the natural rate of interest (Eggertsson, Mehrotra, Singh and Summers (2016), Eggertsson, Mehrotra and Robbins (2018)) to supply-side arguments, most notably represented by Gordon (2015), pointing out that low growth represents the result of the Third Industrial Revolution having entered a phase of diminishing returns. The most relevant approach to secular stagnation in the context of this thesis, however, constitutes the Keynesian growth model proposed by Benigno and Fornaro (2017) with nominal wage rigidities, monetary policy and endogenous technology growth through research and development in which an economy can enter a secular stagnation episode in the form of a "stagnation trap". The latter results from the joint occurrence of a growth and a liquidity trap and in which a

prolonged phase of deficient aggregate demand can lead to persistently depressed aggregate supply.

In sum, the recent literature on endogenous technological progress in macroeconomic models has contributed various novel insights on the driving forces behind deep and highly persistent downturns as observed following the Great Recession, causes of the productivity slowdown, as well as potential mechanisms capable of generating episodes of secular stagnation. This thesis contributes to this strand of the literature as the central common theme shared by the essays are endogenous productivity dynamics in macroeconomic models.

Essay 1 presents channels and key drivers of secular stagnation in a currency union by means of a two-country endogenous growth model with nominal wage rigidities and a joint monetary policy in which growth results from costly R&D investment. This paper contributes to the growing literature initiated by Benigno and Fornaro (2017), which shows that secular stagnation can be the consequence of weak aggregate demand spilling over to the supply side and vice-versa in the presence of constraints on monetary policy, with the capacity of inducing very long-lasting and yet permanent slumps. My model permits the analysis of open economy and currency union implications of secular stagnation, including the role of international trade and growth spillovers in this context. In doing so, I demonstrate an at this stage unexplored channel capable of generating secular stagnation, in which the central bank's responsibility for the currency union aggregate in the presence of country-specific, asymmetric shocks constitutes the key constraint on monetary policy. My framework moreover allows for the analysis of growth-promoting policies to avoid secular stagnation in a currency union.

Essay 2 analyses the main driving forces behind the depth and persistence of the Great Recession in the euro area, as well as the underlying driving forces of the euro area productivity slowdown by estimating a medium-scale DSGE model with endogenous total factor productivity mechanism on euro area data. The key contribution of this paper constitutes the analysis of both deep recessions and slowing productivity growth in the euro area by means of an estimated DSGE model in which total factor productivity evolves endogenously as a result of R&D and technology adoption as proposed by Anzoategui, Comin, Gertler and Martinez (2018). Consequently, this constitutes the first model-based analysis of the euro area productivity slowdown, which allows for the identification of its key driving shocks and the decomposition of slowing productivity growth in the contribution of respectively diminishing innovation activity and technology adoption. Moreover, based on this model, we can provide an explanation of the depth and persistence of the recent crises in the euro area, namely as a result of hysteresis effects brought about by a procyclical fall in productivity-enhancing investments. Lastly, we explicitly derive policy implications for euro area macroeconomic policy based on the insights from our estimated

model.
Essay 3 explores channels of misallocation on the sectoral level in explaining decelerating productivity and stagnant wage growth following a substantial employment expansion by example of the German experience following its large-scale labor market reforms from 2003 to 2005. The theoretical model underlying this analysis is a nonlinear two-sector endogenous growth model with heterogeneous productivity in which technology evolves endogenously in the form of a learning-by-doing externality in the high-productivity sector. Importantly, my framework allows to disentangle short-run to medium-term effects from long-run effects following a pronounced employment shift: While in the long-run technology growth increases as a result of higher resources for innovation given increased employment in the high-growth sector, the economy experiences a slowdown in real wage and productivity growth resulting from sectoral labor misallocation in the immediate phase after the employment shock. My model thus features a novel, misallocation-based channel capable of explaining the empirically observable deceleration of both real wages and productivity following a pronounced employment expansion. Moreover, I conduct a model-based welfare analysis, which permits me to derive optimal policies to accompany the employment shift in order to alleviate welfare losses alongside the transition path.

2 Essay 1: Secular stagnation in a currency union

In this essay, I propose a two-country endogenous growth model of a currency union with nominal wage rigidities and a jointly conducted monetary policy. The monetary union consists of a small member state with negligible impact on the monetary policy stance, as well as a large country. As to trade, there is perfect specialization in goods production, while each good is available in a continuum of varieties. The growth engine in this model constitutes investment in research and development through which firms can capture monopoly profits by becoming the quality leader in a given industry. As the economy is subject to nominal wage rigidities, there is a role for monetary policy, which is conduced by the monetary union's single central bank.

On the basis of this model, I derive economic outcomes the monetary union can settle in with regards to equilibrium interest rates, employment and technology growth across countries by taking into account the possibility that monetary policy may in this setup be restricted by the standard zero lower bound constraint and in addition by its responsibility for a set of countries in the presence of asymmetric, country-specific shocks. I demonstrate that in addition to a full employment steady state in which the currency union operates at full employment and generates high technology growth, the model entails also the possibility of a symmetric unemployment steady state in which the entire

monetary union experiences a "stagnation trap" (Benigno and Fornaro (2017)). Under this constellation, the currency union is at a liquidity trap at the zero lower bound on nominal interest rates, each of the union members operate below capacity and technology growth is weak across the currency union. In addition, I show that the framework entails the possibility of an asymmetric stagnation steady state. In this asymmetric stagnation trap, only the small currency union member state enters stagnation, while the rest of the union, by contrast, operates at full capacity. The binding constraint restricting monetary policy in this case is the central bank's responsibility for the monetary union aggregate, which imposes an implicit lower bound for economic stabilization of a small member state with correspondingly lower policy weight. In the asymmetric stagnation steady state, the small currency union member faces unemployment and subdued technology growth, whereas the remaining currency union operates at full employment levels and, as a result of lower interest rates favoring investment, achieves higher technology growth vis-à-vis the full employment equilibrium in which both countries operate at full capacity.

Secular stagnation in this model evolves in the form of an "inverse Say's law": A prolonged period of low aggregate demand creates a sustained slowdown in aggregate supply. The main mechanism generating persistent stagnation can be described as a self-reinforcing downward spiral of a shortfall in aggregate demand, triggered by pessimistic expectations about future economic outcomes, and reduced firm profits inducing weak R&D investment. I develop growth-promoting policies and show that innovation subsidies constitute effective policy tools in preventing stagnation in the currency union. This is the case since in the presence of R&D subsidies growth-enhancing innovation cannot fall below the level of the subsidies and thus prevents the downward spiral of weak demand, reduced firm profits and thus subdued R&D investment to unfold in the currency union. As to policy design, it is essential that the subsidies constitute a "big push", meaning that subsidies have to be of sufficiently high magnitude to be effective. Innovation subsidies only constitute adequate policy tools if they are implemented by both countries, rendering policy coordination across the currency union crucial.

3 Essay 2: Endogenous TFP, business cycle persistence and the productivity slowdown

In the second essay, which is co-authored with Martin Spitzer, we estimate a medium-scale DSGE model with endogenous total factor productivity mechanism, as initially proposed by Anzoategui, Comin, Gertler and Martinez (2018) on euro area data to investigate the causes of the depth and persistence of the Great Recession in the euro area and the drivers

of the euro area productivity slowdown. We show that accounting for endogenous total factor productivity dynamics through productivity-enhancing investments in R&D and technology adoption considerably increases the persistence of the euro area business cycle relative to standard macroeconomic frameworks in which TFP evolves purely exogenously.

Moreover, we demonstrate that the endogenous part of total factor productivity is empirically of substantial magnitude and accounts for a large share of overall TFP in the euro area. Our findings point out that euro area TFP evolves clearly procyclically. As to the development of euro area TFP over time, we show that the productivity slowdown has commenced already before the Great Recession. Starting from the Great Recession, we document a pronounced further deceleration of productivity growth. Regarding the central factors driving the euro area productivity slowdown, we demonstrate that in the pre-crisis phase, a drop in R&D efficiency constitutes a main driving force. Since the Great Recession, the liquidity demand shock, which depresses consumption relative to safe asset holdings and the resulting fall in firms' technology adoption represents the most important influencing factor. In sharp contrast to standard macroeconomic models in which the supply side evolves strictly distinct from demand-side fluctuations, this result underlines the relevance of demand shocks in explaining the evolution of the supply side in the euro area. We observe starting from 2015 a gradual improvement in the endogenous part of total factor productivity as a consequence of generally improving economic conditions in the euro area. The observed reduced efficiency of R&D investment in producing new innovations, however, still represents a drag on euro area TFP.

Lastly, accounting for endogenous productivity dynamics features crucial implications for euro area inflation as the endogenous TFP mechanism alleviates the inflation response over the business cycle. More concretely, total factor productivity decreases in a downturn, providing a potential explanation for the only negligible drop in inflation during the Great Recession vis-à-vis a marked fall in output. In an upswing, in turn, productivity increases and these procyclical productivity gains dampen the inflation increase in an expansion. Hence, our findings also help in explaining the sluggish pickup in euro area inflation in the recent expansion.

4 Essay 3: Stagnant wages, sectoral misallocation and slowing productivity growth

Several advanced economies have in recent years experienced a persistent slowdown in productivity and a stagnation in real wages, while employment shifted upwards as a result of labor market reforms. In this paper, I propose based on these observations a mechanism, which shows that stagnant real wages and decelerating productivity growth can represent the results of a misallocation of the production factor labor to low-productivity sectors in the economy in the initial phase after a pronounced employment increase. I develop a nonlinear two-sector model, which features endogenous growth and heterogeneous productivity across sectors. The high-productivity sector constitutes the growth engine in the economy and technology growth is concentrated to this sector. The framework features an endogenous growth mechanism in total factor productivity, which evolves in the form of learning-by-doing, where technology growth is increasing in high-productivity sector employment. Labor is homogeneous and in principle mobile across sectors. The presence of nonlinear adjustment costs, however, constitutes a constraint to the movement of labor to the high-productivity sector.

I show by means of this framework that the upward shift in employment has the desirable effect in the long-run that it increases both technology and productivity growth, while also raising real wages. Over the short- to medium-term, however, real wage and productivity growth exhibit a period of stagnation. I show that due to the presence of the learning-by-doing growth externality in the high-productivity sector, the allocation in the competitive equilibrium is not efficient since high-productivity sector firms do not internalize the effect of their own labor allocation choice on aggregate performance and welfare.

Furthermore, given the inefficiencies in the competitive equilibrium, there is a call for macroeconomic policies in this context: I demonstrate that subsidies to production in the high-productivity sector constitute an adequate policy measure to reduce the extent of misallocation following the employment shock. These subsidies reduce the welfare losses during the transition to the new high-employment - high-growth equilibrium, which also demonstrates the importance of not only the quantity but also the quality of employment in the economy, when assessing the drivers of the productivity slowdown and stagnant real wages.

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