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Herrn Diplom-Volkswirt Mathias Trabandt
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Präsident der Humboldt-Universität zu Berlin:
Prof. Dr. Christoph Markschies

Dekan der Wirtschaftswissenschaftlichen Fakultät:
Prof. Oliver Günther, Ph.D.

Gutachter:

1. Prof. Harald Uhlig, Ph.D.
2. Prof. Michael C. Burda, Ph.D.

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Abstract

This dissertation consists of three essays which investigate the economic implications of monetary and fiscal policies on the macroeconomy. The first essay focuses on the following question: how can we explain the observed behavior of aggregate inflation in response to e.g. monetary policy changes? Mankiw and Reis (2002) have proposed sticky information as an alternative to Calvo sticky prices in order to model three conventional views about the behavior of aggregate inflation. We use a fully-fledged DSGE model with sticky information and compare it to Calvo sticky prices, allowing also for dynamic inflation indexation as in Christiano, Eichenbaum, and Evans (2005). We find that sticky information and sticky prices with dynamic inflation indexation do equally well in our DSGE model in delivering the conventional view. The second essay analyzes the following question: how does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? The Laffer curve provides us with a framework to analyze this question. Using a calibrated neoclassical growth model we show that the US and the EU-15 area are located on the left side of their labor and capital tax Laffer curves, but the EU-15 economy being much closer to the slippery slopes than the US. A dynamic scoring analysis shows that more than one half of a labor tax cut and more than four fifth of a capital tax cut are self-financing in the EU-15 economy. Therefore, we conclude that there are higher incentive effects in the EU-15 compared to the US in response to tax cuts. Finally, the third essay focuses on the following question: should fiscal policy pre-announce tax reforms before their implementation from a welfare point of view? Domeij and Klein (2005) have shown that pre-announcement of an optimal tax reform is costly in terms of welfare. We reexamine their claim by taking two additional features of government spending into account: public goods and public capital. We show that valuable and productive government spending is likely to reduce the welfare costs of pre-announcement. As a further contribution, we show that short-run confiscation and/or subsidy of capital and labor income is not important for the welfare gains of pre-announced reforms with sufficiently long pre-announcement duration. For 4 years pre-announcement, a suboptimal reform without confiscation and subsidy generates similar welfare gains as the baseline optimal reform. The underlying tax structure of both reforms, however, appears to be very different.

Keywords:
Sticky information, sticky prices, inflation indexation, DSGE, Laffer curve, incentives, USA, EU-15, pre-announced optimal tax reform, public goods, public capital, confiscation, subsidy, welfare

Zusammenfassung

Diese Dissertation besteht aus drei Aufsätzen, welche die ökonomischen Implikationen von Geld- und Fiskalpolitiken für die Makroökonomie untersuchen. Der erste Aufsatz konzentriert sich auf die folgende Fragestellung: Wie kann das beobachtete Verhalten der aggregierten Inflation nach z.B. geldpolitischen Veränderungen erklärt werden? Mankiw und Reis (2002) propagieren klebrige Information als eine Alternative zu Calvo klebrigen Preisen, um drei konventionelle Sichtweisen über das Verhalten aggregierter Inflation zu modellieren. Ich verwende ein vollständiges DSGE Modell mit klebriger Information und vergleiche es mit Calvo klebrigen Preisen mit dynamischer Inflationsindexierung wie in Christiano, Eichenbaum und Evans (2005). Es stellt sich heraus, dass klebrige Information und klebrige Preise mit dynamischer Inflationsindexierung in meinem DSGE Modell gleich gut geeignet sind, die konventionellen Sichtweisen zu erklären. Der zweite Aufsatz beschäftigt sich mit der folgenden Frage: Wie passt sich das Verhalten von Haushalten und Firmen in den USA verglichen mit der EU-15 Ökonomie infolge von Steuerveränderungen an? Die Laffer Kurve liefert ein Rahmenwerk, um diese Frage zu analysieren. Unter Verwendung eines kalibrierten neoklassischen Wachstumsmodells zeigt sich, dass die USA und die EU-15 Ökonomie auf der linken Seite der Lohn- und Kapitalsteuer Laffer Kurve liegen. Die EU-15 Ökonomie befindet sich jedoch viel näher an der rutschigen Steigung als die USA. Eine dynamische Scoring-Analyse zeigt, dass mehr als die Hälfte einer Lohnsteuersenkung und mehr als vier Fünftel einer Kaptialsteuersenkung in der EU-15 Ökonomie selbstfinanzierend sind. Hieraus folgt, dass es in der EU-15 Ökonomie grössere Anreizeffekte durch Steuersenkungen als in den USA gibt. Der dritte Aufsatz analysiert die folgende Fragestellung: Soll die Fiskalpolitik Steuerreformen vor deren Implementierung vorankündigen, um die Wohlfahrt zu maximieren? Domeij und Klein (2005) zeigen, dass die Vorankündigung einer optimalen Steuerreform mit Wohlfahrtskosten verbunden ist. Ich prüfe diese Behauptung unter zusätzlicher Berücksichtigung von öffentlichen Gütern und öffentlichem Kapital nach. Es zeigt sich, dass nutzenbringende und produktive Staatsausgaben die Wohlfahrtskosten durch Vorankündigungen höchstwahrscheinlich reduzieren. Als einen weiteren Beitrag zeige ich, dass kurzfristige Konfiszierung und/oder Subvention von Kapital- und Lohneinkommen nicht wichtig für die resultierenden Wohlfahrsgewinne einer hinreichend vorangekündigten Steuerreform sind. Für 4 Jahre Vorankündigung generiert eine sub-optimale Steuerreform ohne Konfiszierung und Subvention gleichartige Wohlfahrtsgewinne wie die zugehörige optimale Reform. Die zugrundeliegende Steuerstruktur beider Reformen ist jedoch sehr unterschiedlich.

Schlagwörter:
Klebrige Information, klebrige Preise, Inflationsindexierung, DSGE, Laffer Kurve, Anreize, USA, EU-15, vorangekündigte optimale Steuerreform, öffentliche Güter, öffentliches Kapital, Konfiszierung, Subvention, Wohlfahrt

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1 Introduction

1.1 Objective of the Study

This dissertation investigates the economic implications of monetary and fiscal policies on the macroeconomy. More precisely, this study attempts to answer three particular questions of macroeconomic interest related to issues in the recent macroeconomic literature. First, how can we explain the observed behavior of aggregate inflation in response to e.g. monetary policy changes? Second, how does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? Third, should fiscal policy pre-announce tax reforms before their implementation from a welfare point of view?

In order to address the first question we follow the recent literature on monetary economics. An important determinant for the behavior of aggregate inflation is the underlying price setting mechanism of firms. Are firms able to set prices optimally in every instance of time? The recent literature believes they are not, see e.g. Walsh (2003) and Woodford (2003). Rather, the decisions of firms which prices to set on the markets are affected by frictions such as costs of acquiring, absorbing and processing information or by inabilities of changing prices.

Mankiw and Reis (2002) argue that the paradigm of short-run information stickiness is better suited than short-run price stickiness to explain the following three conventional views about the behavior and consequences of aggregate inflation: i) inflation reacts with delay and gradually to a monetary policy shock, ii) announced and credible disinflations are contractionary and iii) inflation accelerates with vigorous economic activity. However, Mankiw and Reis (2002) draw their conclusion based on a highly stylized partial equilibrium model. Is that an appropriate description of an economy? In particular, in the presence of information or price rigidities, output is typically demand determined. Mankiw and Reis (2002) assume that this demand is exogenously given. The question that arises is what happens to their results if demand is determined endogenously in an economy? Put differently, how important are general equilibrium forces such as intertemporally optimized goods and money demand for the price setting behavior of firms and hence for aggregate inflation in an economy? One objective of chapter three is to answer this question. To do so, we use a fully-fledged dynamic stochastic general equilibrium (DSGE) framework similar to Woodford (2003) and examine the consequences when firms operate under sticky information as proposed by Mankiw and Reis (2002).

Empirical studies suggest that lagged inflation is an important determinant for the ability of Calvo sticky price models to explain the behavior of aggregate inflation. In order to account for this, Christiano, Eichenbaum, and Evans (2005) employ dynamic inflation indexation as a modification to the standard Calvo sticky price approach. In particular, non-optimizing firms apply a rule of thumb by updating last period's price with yesterday's inflation rate. As a second objective of chapter three, we examine the ability of Calvo sticky prices with dynamic inflation indexation to explain the three conventional facts and compare the results to those when sticky information is assumed instead.

The remaining two chapters of this dissertation focus on the consequences of fiscal policies for the macroeconomy. Chapter four, which is joint work with Harald Uhlig, attempts to answer the second question which focuses on the incentive effects for households and firms in response to changes in taxation.

Given a tax cut, are the incentives to change consumption, hours worked and investment higher or lower in the US compared to the EU-15 economic area? The answer to this question has important consequences for the evolution of e.g. government tax revenues. Put differently, is a tax cut more or less self-financing in the US compared to the EU-15 economy? In order to address these questions of economic interest we use a neoclassical growth model extended to include fiscal policy and calibrate it to each respective economic area.

Interestingly, the model exhibits an inverted U-shape relationship between taxes and tax revenues - the so-called Laffer curve. The Laffer curve provides us with a framework to think about the incentive effects and hence the degree of self-financing of tax cuts. In case an economy is located on the right hand side or slippery slope side of the Laffer curve, then cutting taxes boosts incentives and the tax cut becomes fully self-financing. However, even if an economy is located on the left side of the Laffer curve, one ought to investigate the position on it for at least two reasons. First, the knowledge of the peak is important: if it is close, one should be careful about raising taxes to avoid the slippery slope side. Second, the slope reminds us of the incentive effects of tax changes. How strong are these effects quantitatively?

The goal of chapter four is a quantitative assessment of the positions of the US and EU-15 economies on their respective Laffer curves by employing a simple calibrated neoclassical growth model. Further, we examine how incentives have changed over time by analyzing how the economies have shifted over time on their Laffer curves. In addition, our analysis enables us to explicitly determine the incentive effects expressed as degrees of self-financing of tax cuts in each respective economic area.

Finally, chapter five focuses on the following question: should fiscal policy pre-announce tax reforms before their implementation from a welfare point of view? Domeij and Klein (2005) show that the welfare gains of an optimal capital and labor tax reform decline the longer the reform is pre-announced before its implementation. Hence, pre-announcement is costly in terms of welfare. In line with the classical optimal taxation literature, Domeij and Klein (2005) use a neoclassical growth model in which the fiscal authority collects distortionary taxes. The resulting tax revenues are rebated lump-sum to households or simply represent wasteful government spending. Is that an economically sensible description of the behavior of e.g. US fiscal policy? We believe it is not. Rather, we observe that fiscal policy uses tax revenues also to provide e.g. public goods and public capital. If these valuable and productive elements of government spending adjust endogenously in general equilibrium they are likely to affect the welfare consequences of pre-announced tax reforms. What are these welfare implications quantitatively? Does pre-announcement become more or less costly for a society in terms of welfare when taking public goods and public capital into account? One objective of chapter five is to answer these questions.

Similar to Domeij and Klein (2005), we employ a calibrated neoclassical growth model with distortionary taxation. By contrast to our predecessors, we assume that government consumption is part of a household utility function as well as that productive government capital enters the production function of firms, similar to Baxter and King (1993).

As a second objective of chapter five, our approach allows us to investigate an additional interesting issue. It turns out that the short- and long-run properties of the optimal tax system appear to be quantitatively very different. Put differently, the baseline optimal pre-announced tax reform displays short-run confiscation and/or subsidy of capital and labor income followed by a rather quick transition to the long-run steady states taxes. How important are the short-run properties of the optimal tax system for the resulting welfare gains of the pre-announced tax reform? In other words, is confiscation and/or subsidy quantitatively important for the resulting overall welfare gains of pre-announced tax reforms? Chapter five answers these questions as a second objective.

1.2 Outline of the Study

Before we turn to each respective chapter we want to outline each part of this thesis. The second chapter surveys the literature that is related to this dissertation. It describes the general position of the current research frontier with respect to the three questions of interest outlined in the previous section and relates the present study to each literature. In addition, chapter two also discusses the reasons why particular approaches rather than others have been chosen in this dissertation.

The third chapter focuses on the following question: how can we explain the observed behavior of aggregate inflation in response to e.g. monetary policy changes? In order to address this question, we examine sticky information and Calvo sticky prices with dynamic inflation indexation in a fully-fledged DSGE model similar to Woodford (2003). We analyze the ability of each model to replicate the following three conventional views: i) inflation reacts with delay and gradually to a monetary policy shock, ii) announced and credible disinflations are contractionary and iii) inflation accelerates with vigorous economic activity.

Regarding the sticky information model our results confirm the finding by Mankiw and Reis (2002): all three effects listed above can be replicated in our baseline DSGE model as well. However, general equilibrium features such as forward looking households and interest elastic money demand are nevertheless important. In contrast to Mankiw and Reis (2002), we find that e.g. inflation and the output gap in the sticky information model react already in the announcement periods of an announced disinflation due to consumption smoothing households and interest elastic money demand in general equilibrium. Further, we show that a Calvo sticky price model without indexation can already match the conventional view that announced and credible disinflations are contractionary due to the existence of interest elastic money demand in general equilibrium in our baseline DSGE framework. Further, we allow for dynamic inflation indexation in the Calvo sticky price model and show that in our baseline DSGE framework this works just as well as sticky information in delivering all three effects. Finally, our results appear to be robust to variations in key structural parameters of the model.

We conclude that sticky information as in Mankiw and Reis (2002) as well as sticky prices with dynamic inflation indexation as in Christiano, Eichenbaum, and Evans (2005) are perfectly capable of replicating the conventional wisdom with respect to inflation inertia, announced disinflations and the acceleration phenomenon in the DSGE framework used in chapter three. However, the source of e.g. inflation inertia in both models is different. In the sticky information model, inflation inertia arise due to slow information diffusion. In the sticky price model with dynamic inflation indexation, inflation inertia is hard-wired by assuming that non-optimizing firms index prices to past inflation. Hence, these firms use a very limited outdated information set. Thus, one might want to view information stickiness as providing a micro foundation for the particular choice of dynamic inflation indexation in Calvo sticky price models. Although both models perform equally well with respect to our measures, we believe that sticky information might be better suited to explain the underlying micro behavior of price setting firms.

The fourth chapter of this thesis concentrates on the incentive effects for households and firms in response to changes in taxation in the US and EU-15 economies. In order to address this issue we use a neoclassical growth model with distortionary taxation. The model exhibits a Laffer curve which provides us with a framework to analyze the incentive effects of tax changes.

We show that there exist steady state Laffer curves for labor taxes as well as for capital taxes. This result is robust with respect to variations of preferences of the household. According to the predictions of the model both economies - the US and the EU-15 area - are located on the left side of their Laffer curves, but the EU-15 economy is much closer to the right hand side or slippery slopes than the US. Further, we examine how the US and EU-15 economies have shifted on their Laffer curves over time. We show that the US has moved closer to the peak for labor taxes while it has hardly shifted relative to the peak for capital taxes. By contrast, the EU-15 area has moved considerably closer to the peak for both - labor and capital taxes. An individual country analysis for the EU-15 area reveals that in terms of labor taxes all individual EU-15 countries are closer to the slippery slopes of their Laffer curves than the US. For capital taxes this conclusion holds also for the majority of countries in the EU-15 area. Finally, the long-run slopes of the labor and capital tax Laffer curves are smaller in all individual EU-15 countries compared to the US.

Further, we quantify the short-run dynamic impact of unexpected and announced tax cuts, financed by corresponding cuts in government spending. For both types of tax cuts it turns out that the short-run slopes of the Laffer curves in the EU-15 economy are lower than in the US which documents higher distortions in the EU-15 area. To that end, our analysis indicates that the incentive effects to increase consumption, hours worked and investment due to tax changes are stronger in the EU-15 than in the US. For a given cut in taxes, EU-15 tax revenues fall less than in the US as documented by the lower slope of the Laffer curves in the EU-15. Finally, following Mankiw and Weinzierl (2005), we analyze by how much a tax cut is self-financing quantitatively if we take incentive feedback effects into account. We find that for the US model one fifth of a labor tax cut and half of a capital tax cut are self-financing in the steady state. By contrast, in the EU-15 economy half of a labor tax cut and more than four fifth of a capital tax cut are self-financing. This reflects much higher incentive effects from tax cuts in the EU-15 economy compared to the US. Hence, we conclude, that the efficiency gains from cutting taxes in the EU-15 area are considerably larger than in the US economy.

The fifth chapter of this dissertation focuses on this question: should fiscal policy pre-announce tax reforms before their implementation from a welfare point of view? In particular, we reexamine Domeij and Klein (2005) by taking two additional features of government spending explicitly into account: public goods and public capital. As a further contribution, we analyze how important the short-run properties of the optimal tax system - in other words confiscation and/or subsidy of capital and labor income - are for the resulting overall welfare gains of the pre-announced tax reform.

In our baseline optimal tax reform we find that valuable and productive government spending leads to higher absolute welfare gains and makes pre-announcement less costly in terms of relative welfare gain reductions due to pre-announcement. More precisely, a four years pre-announced reform reduces relative welfare gains compared to an immediate reform by roughly 24 percent in the presence of valuable and productive government spending. By contrast, the relative loss is roughly 36 percent in an economy without valuable and productive government spending. A sensitivity analysis based on empirically reasonable parameter estimates reveals that for the overwhelming majority of parameter combinations pre-announcement is less costly than in an economy without valuable and productive government spending. Therefore, we conclude that public goods and public capital are likely to reduce the welfare losses that are associated with pre-announcement.

Hence, our results show that the welfare costs of pre-announcing an optimal tax reform are likely to be smaller than previously thought. Interestingly, the reduction of welfare costs due to a more realistic description of the spending side of fiscal policy are not dramatic in our baseline reform. Nevertheless, they are economically significant and therefore, the effects of valuable and productive government spending should be taken into account when benefits and costs of an optimal pre-announced tax reform are considered.

The second contribution of chapter five focuses on the following question: are the short-run properties of the optimal pre-announced tax system important for the resulting overall welfare gains? The baseline optimal tax reform is characterized by initial confiscation and/or subsidy of capital and labor income via taxation followed by a rather quick transition to the long-run values of taxes. How important is this short-run deviation from the long-run optimal taxes for the welfare consequences of our pre-announced reform?

In order to answer this question, we design a tax reform in which capital and labor income taxes move - without confiscation and subsidy - directly to their endogenous long-run values from the implementation date of the reform onwards. We argue that this pattern for the path of taxes is more in line with observed behavior of fiscal policy. Interestingly, we show that welfare gains for this "no-confiscation/subsidy" tax reform increase with the pre-announcement horizon as opposed to the decrease observed in the baseline optimal pre-announced reform. In particular, we find that relative welfare gains increase by roughly

35 percent if the tax reform is pre-announced 4 years in advance. Moreover, we show that the level of welfare gains is very different for the baseline optimal and the "no-confiscation/no-subsidy" reform in case of immediate implementation. By contrast, the level of welfare gains becomes very similar for 4 years pre-announcement. Despite this, however, the underlying structure of taxes in both reforms appears still to be very different. For 4 years pre-announcement, the first freely chosen capital tax in the baseline optimal tax reform is still 178 percent. By contrast, the "no-confiscation/no-subsidy" reform moves straight to zero percent capital taxes. The resulting loss of revenues in the "no-confiscation/subsidy" reform is made up for by moving to moderately higher steady state labor taxes of 30 percent compared to 28 percent in the baseline optimal tax reform.

Therefore, our results indicate that confiscation and subsidy of capital and labor income is not important for the level of welfare gains that arise from an optimal tax reform which is sufficiently pre-announced in advance of its implementation. Finally, we show that our results prevail qualitatively even if the government has no access to government debt.

2 Literature Review

The purpose of this chapter is to survey the literature that is related to the contents of this thesis. We aim at describing the general position of the current research frontier with respect to the three questions of interest outlined in the previous chapter. Having done so, this enables us to locate the three main chapters of this dissertation within each literature. Furthermore, this chapter also discusses the reasons why particular approaches rather than others have been chosen in this dissertation.

2.1 Sticky Information vs. Sticky Prices

The third chapter of this dissertation focuses on the question how the observed behavior of aggregate inflation in response to e.g. monetary policy changes can be explained. An important determinant for the behavior of aggregate inflation is the underlying price setting mechanism of firms. In the recent literature on monetary economics, two competing paradigms have been used to model this behavior: firms that face inabilities of changing prices or firms that face costs of acquiring, absorbing and processing information.

A substantial part of the literature attempts to explain the behavior of aggregate inflation in response to monetary policy changes by short-run nominal price rigidities, e.g. inabilities of firms to change prices optimally. A leading framework has been provided by Calvo (1983) and used e.g. by Woodford (1996), Yun (1996), Goodfriend and King (1997), Clarida, Gali, and Gertler (1999) and Gali (2003). Walsh (2003) as well as Woodford (2003) provide excellent, extensive and comprehensive overviews about the sticky price literature respectively the resulting New Keynesian Phillips curve. However, common to this literature is that aggregate inflation in the standard Calvo sticky price model does not react with delay and gradually in response to a monetary policy shock. Empirical studies, see e.g. Gali and Gertler (1999) and Gali, Gertler, and Lopez-Salido (2005), suggest that lagged inflation is an important determinant for the New Keynesian Phillips curve. In order to account for this, Christiano, Eichenbaum, and Evans (2005) employ dynamic inflation indexation as a modification to the standard Calvo sticky price approach. Non-optimizing firms apply a rule of thumb by updating last period's price with yesterday's inflation rate. There are, of course, alternative approaches to indexation in the literature. Yun (1996) assumes indexation to steady state inflation. Although this leads to a vertical long-run Phillips curve the dynamics are still entirely forward looking and hence inflation behaves not inertial. Smets and Wouters (2003) and Giannoni and Woodford (2003) assume partial dynamic inflation indexation, i.e. firms update prices only with a fraction of past inflation. Interestingly, Smets and Wouters (2003) report evidence for partial inflation indexation in European data while Giannoni and Woodford (2003) find evidence for full inflation indexation in US data and thereby confirm Christiano, Eichenbaum, and Evans (2005) choice of full dynamic inflation indexation. To that end, we are most interested in the consequences of full dynamic inflation indexation for the dynamics of aggregate inflation. Therefore, our results can be interpreted as representing an upper bound compared to cases of partial dynamic inflation indexation.

Let's turn to the second paradigm that has been used to analyze the price setting behavior of firms: imperfect information. The economic effects of imperfect information have been a fruitful research area in macroeconomics. Phelps (1970) suggested a parable of an economy consisting of many islands that coexist under informational isolation. He demonstrated that in such an economy an increase in nominal expenditures through, e.g. monetary policy, increases employment and output. In his pioneering work, Lucas (1972, 1973) showed that the implied short-run inflation and unemployment trade-off in the island model is consistent with rational expectations of economic agents. In particular, in his island model, firms have imperfect information about aggregate variables and must solve a signal-extraction problem. As a result, imperfect information has the potential to result in short-run monetary non-neutralities, e.g. leading to short-run output fluctuations. In other words, the island model generates a short-run Phillips curve trade-off despite the presence of rational expectations. In spite of this success, it turns out that the island model cannot replicate the observed persistence of output and inflation fluctuations in the data. Generating persistence in rational expectations models has become a central issue in the recent macroeconomic literature as we will see now.

Sims (2003) explores the implications of rational inattention in an economy. He finds, that if agents face a finite information processing capacity then they may rationally decide to observe available information imperfectly. He concludes, that rational inattention might be an important ingredient for models that attempt to account for observed macroeconomic behavior. Woodford (2002) employs the idea of rational inattention in a model in which firms observe the state of aggregate demand with an idiosyncratic error. He shows that the presence of this idiosyncratic "noisy information channel" leads to persistent effects of inflation and output in response to aggregate nominal disturbances. In a recent paper, Sims (2006) surveys the existing literature on rational inattention. Within this literature, Moscarini (2004) as well as Mackowiak and Wiederholt (2006) analyze the effects of rational inattention for the pricing behavior of firms. These authors find that firms may decide to observe available information imperfectly due to limited information flow capacity and hence, nominal shocks have persistent effects on aggregate inflation and output.

Mankiw and Reis (2002) also assume that firms face costs of acquiring, absorbing and processing information. However, in contrast to the rational inattention literature, they assume that firms receive information updates exogenously and infrequently. In other words, firms have an unlimited information processing capacity at times when they receive information updates and a zero information processing capacity otherwise. Thus, if no new information arrives, firms must use old information and are completely inattentive. This price setting behavior of sticky information firms is equivalent to write an entire plan of prices which in turn is similar to pricing policies described in Fischer (1977), Cespedes, Kumhof, and Parrado (2003), Benassy (2003) and Devereux and Yetman (2003). Interestingly, although their story is different, Benassy (2003) and Devereux and Yetman (2003) arrive at equilibrium equations that are very similar to Mankiw and Reis (2002). However, in both cases, aggregate demand is also static and independent of the nominal interest rate. By contrast, this chapter incorporates sticky information in a DSGE framework that features the so called dynamic "New IS" equation and a real money demand equation that depends on the nominal interest rate, see Clarida, Gali, and Gertler (1999), Gali (2003) or Woodford (2003).

However, Mankiw and Reis (2002) show that their so-called sticky information model performs better than the frequently used Calvo sticky price model in explaining three conventional facts: i) inflation reacts gradually and with delay to a monetary policy shock, ii) announced disinflations are contractionary and iii) inflation accelerates with vigorous economic activity. In a recent paper, Reis (2006) shows that the so called sticky information Phillips curve in Mankiw and

Reis (2002) can be micro-founded in an environment in which firms face fixed and finite costs of acquiring information and thereby moving sticky information as proposed by Mankiw and Reis (2002) closer to the rational inattention literature.

The literature on sticky information *à* la Mankiw and Reis (2002) is a quickly growing research area. In the course of writing this final draft further very recent studies have emerged. Note however, that chapter three was written independently of competing papers and is likely to be intellectually prior to work of many other authors since the chapter has been published already in 2003 as a Humboldt University Berlin SFB 373 discussion paper No. 2003-41. However, competing papers as well as the advances of the literature on sticky information are worth to be highlighted here.

Dupor and Tsuruga (2005) compare the effects of random duration information updating *à* la Calvo with a fixed duration information updating interval *à* la Taylor in an otherwise similar partial equilibrium model setup to Mankiw and Reis (2002). They find that inflation is less inertial and exhibits a rather odd looking hump-shape in response to a monetary policy shock when firms update their information at infrequent but fixed intervals. Collard and Dellas (2006) can be interpreted as an extension of the work by Dupor and Tsuruga (2005). These authors incorporate sticky information with fixed duration information update intervals *à* la Taylor in a DSGE framework. Furthermore, the authors analyze the predictions of their DSGE model when sticky prices *à* la Taylor are assumed instead. Interestingly, and in contrast to Dupor and Tsuruga (2005), Collard and Dellas (2006) find that inflation peaks on impact after a money growth shock in the sticky information model. Moreover, the authors obtain the same qualitative result when sticky prices *à* la Taylor are assumed. The reason for these results are that Collard and Dellas (2006) set up a DSGE model in which pricing decisions of firms are not strategic complements but strategic substitutes instead. In other words, in this case, after e.g. a monetary policy shock, newly informed firms adjust their prices to a larger extend than they would do in a perfectly informed environment. They do so, in order to compensate for those firms who keep setting prices based on outdated information. Hence, due to missing strategic complementarities of firms pricing decisions, inflation peaks on impact - regardless whether sticky information or sticky prices *à* la Taylor are assumed.

Recently, Keen (2005) incorporates sticky information with the original Mankiw and Reis (2002) information updates *à* la Calvo in an alternative DSGE framework compared to the one used in chapter three. Interestingly, Keen (2005) reports that sticky information generates a maximum inflation response at most one quarter after a money growth shock and on impact after a nominal interest rate shock. Similar to Collard and Dellas (2006), the DSGE model in Keen (2005) generates pricing decisions of firms that are strategic substitutes which produce the early peaks of inflation. However, Woodford (2003) reviews and discusses the existing literature at length and concludes that firms pricing decisions ought to be modeled as strategic complements rather than strategic substitutes in order to allow for potential inflation inertia. Therefore, we employ a commonly used DSGE framework which is closely related to the one developed in Woodford (2003). This DSGE framework allows for sufficient strategic complementarities in firms pricing decisions. We believe that this is an interesting DSGE framework since it represents a standard small-scale workhorse DSGE model for the analysis of e.g. monetary policy.

Moreover, Andres, Lopez-Salido, and Nelson (2005) analyze sticky price and sticky information models with respect to the natural rate hypothesis. Their main empirical result indicates that the estimated output gaps of the sticky price model with dynamic indexation and the sticky information model are very similar but different from standard output gap measures.

Mankiw and Reis (2003) examine the consequences of sticky information for wage setters in a partial equilibrium model. The authors find that disinflations and productivity slowdowns cause employment to fall below the level that would prevail under full information. Based on the predictions of the model, they argue that policies such as nominal income or nominal wage targeting lead to more stable employment than targeting prices of goods and services.

Recently, Mankiw and Reis (2006a) set up a macroeconomic general equilibrium model in which prices, wages and consumption are assumed to be set by using old and outdated information. Mankiw and Reis (2006a) show that this model of pervasive information stickiness is able to explain three facts about short-run economic fluctuations jointly: the acceleration phenomenon, real wage smoothness and the gradual response of real variables. Thus, adding sticky information to other markets seems to be important to explain further facts jointly. In a very recent paper, Mankiw and Reis (2006b) develop a medium-scale general equilibrium model with sticky information in price, wage and consumption choices in order to explain five key macroeconomic time series jointly. The authors propose a solution method which allows to estimate sticky information models with e.g. Bayesian model estimation methods. Their estimation results indicate that information rigidities are present for firms and especially important for workers and consumers in order to explain the five macroeconomic time series jointly.

Reis (2004) shows that a gradual and delayed response of consumption to news can be obtained in an environment in which households face costs of acquiring, absorbing and processing information. Coibion (2006a) integrates sticky information for consumers in a DSGE model and finds that this yields a more gradual and delayed adjustment of output which in turn amplifies inflation inertia. Moreover, he argues that the ability of sticky information to deliver inflation inertia depends on the underlying parameters of the model. Further, for sticky information firms, Coibion (2006a) reports that Taylor rules make inflation inertia less likely than money growth rules for random information rigidity durations. Interestingly, in the case that information rigidity has a fixed duration, the choice of the monetary policy rule appears to be of minor importance. However, these issues are beyond the scope of the third chapter. Instead, we employ the original Mankiw and Reis (2002) specification of random information rigidity duration and monetary policy that follows a money growth rule. Moreover, we examine how sticky information performs in general equilibrium and, more importantly, in comparison to Calvo sticky prices with dynamic inflation indexation. In addition, we are not only interested in the relative performance of the models with respect to inflation inertia but focus also on Mankiw and Reis (2002) other two measuring devices: announced and credible disinflations and the acceleration phenomenon.

Recently, a growing body of work attempts to assess the empirical support for the sticky information Phillips curve. Mankiw and Reis (2006a,b), Mankiw, Reis, and Wolfers (2004), Kahn and Zhu (2006), Caroll (2003) and Dovern, Doekpe, Fritsche, and Slacalek (2006) find empirical support for the sticky information Phillips curve. By contrast, Coibion (2006b) largely rejects its existence. Recently, and partly motivated by our work, further work attempts to examine the relative performance of sticky information versus sticky prices from an empirical point of view. Authors such as Korenok (2004), Kiley (2005), Dupor, Kitamura, and Tsuruga (2006), Laforte (2005) and Paustian and Pytlarczyk (2006) claim that sticky prices with dynamic inflation indexation perform empirically better than sticky information. Further, Coibion and Gorodnichenko (2006) report that in

US data the fraction of standard Calvo sticky price firms is three times as large as the fractions of sticky information or sticky price firms with dynamic inflation indexation. In contrast to these studies, Andres, Lopez-Salido, and Nelson (2005) report that a sticky information model yields a higher likelihood than a sticky price model with dynamic inflation indexation. Finally, the empirical results of Korenok and Swanson (2006) suggest that sticky information and sticky prices with dynamic inflation indexation perform equally well for reasonable degrees of information and price stickiness. Hence, their empirical study can be interpreted as delivering empirical evidence for the theoretical predictions of chapter three of this dissertation.

However, it seems that the empirical literature has not yet agreed on whether sticky information matters at all or whether sticky information is outperformed by sticky prices with dynamic inflation indexation. This is an ongoing, lively and interesting debate. Given the variety of conflicting empirical evidence it seems that the results depend on the particular empirical approaches or model specifications. In particular, important issues in the work cited above are whether to test sticky information using aggregate or disaggregate data and even more importantly, how to proxy for inflation expectations of economic agents. Furthermore, the particular choice whether to use e.g. reduced form GMM estimation, minimum distance estimation or structural model estimations using Bayesian methods as provided e.g. by Julliard (2006) (DYNARE) appears to matter for the results. Moreover, model features such as the number of relevant lags of the sticky information Phillips curve, the inclusion of sticky information in other markets, the use of small-scale or medium-scale models with further nominal and real frictions have an impact on the empirical performance of the respective models. These issues together with the variety of conflicting empirical evidence leads us to conclude that the literature is not yet mature enough to conclude whether sticky prices outperform sticky information from an empirical point of view. An own explicit empirical assessment of our theoretical conclusions would require us to address these issues thoroughly and would certainly justify a separate piece of research. This, however, is is beyond the scope of chapter three.

Instead, chapter three is designed as a first step from a theoretical point of view to examine the consequences of sticky information in a small-scale general equilibrium model which we then contrast with sticky prices with dynamic inflation indexation as in Christiano, Eichenbaum, and Evans (2005). More importantly and in line with Mankiw and Reis (2002), we explore the *qualitative* ability of the models to generate the three conventional effects. Put differently, the conventional effects itself are of rather *qualitative* nature and chapter three is designed to analyze the models ability to reflect them qualitatively. In terms of the parameters chosen in the chapter, we rely on standard values that are used in the literature. In addition, we pursue a sensitivity analysis to evaluate the robustness of the qualitative predictions of the sticky information model as well as the sticky price with and without dynamic inflation indexation models.

To sum up, chapter three contributes to the existing literature as follows. We show that sticky information as in Mankiw and Reis (2002) as well as sticky prices with dynamic indexation as in Christiano, Eichenbaum, and Evans (2005) are both able to replicate the conventional wisdom with respect to inflation inertia, announced disinflations and the acceleration phenomenon in a DSGE model. We arrive at this conclusion by comparing the respective models in a parameterized standard small-scale DSGE framework similar to Woodford (2003).

2.2 The Laffer Curve

The fourth chapter attempts to answer the question how the behavior of households and firms in the US compared to the EU-15 economy adjusts if fiscal policy changes taxes. We use a neoclassical growth model to answer this question. In particular, the model exhibits a Laffer curve which provides us with a framework to analyze the question at hand. It turns out that there exists a comparably large literature on the effects of fiscal policy on aggregate fluctuations and growth.

One branch of literature investigates the effects of fiscal policy in endogenous growth models. Ireland (1994) shows that there exists a dynamic Laffer curve in an AK model framework. However, using a similar framework, Bruce and Turnovsky (1999) and Novales and Ruiz (2002) find that an unrealistically high degree of intertemporal substitution is needed to generate the desired result that a tax cut is self-financing. Agell and Persson (2001) argue that the assumption of a constant government share on the economy drives the Bruce and Turnovsky result. Once this share is allowed to vary in response to changes in tax rates then there exist dynamic Laffer curves in AK models for empirically plausible elasticities of intertemporal substitutions. Yanagawa and Uhlig (1996) examine the effects of taxation in an overlapping generations model. They show that it is possible that higher capital income taxes may lead to faster growth as opposed to the conventional economic wisdom. In their model, capital income accrues to the old generation and government spending is a fixed fraction of output. They show that higher capital taxes lead to lower labor taxes which in turn leaves the young generation with more income. This may generate higher net savings which in the end might lead to higher economic growth.

However, chapter four abstracts from features such as heterogenous agents or endogenous growth. Rather, we assume homogenous agents in a standard neoclassical growth model. Hence, it belongs to the branch of literature that focuses on the effects of fiscal policy in an exogenous growth context. Baxter and King (1993) were one of the first authors who analyzed the effects fiscal policy a dynamic general equilibrium neoclassical growth model with productive government capital. The authors analyze the effects of temporary and permanent changes of exogenous government purchases. Garcia-Mila, Marcet, and Ventura (2001) study the welfare impacts of alternative tax schemes on labor and capital in a neoclassical growth model with heterogenous agents. They focus on the redistributional effects of capital tax cuts. However, in their heterogenous agents framework, they show that there exists a static Laffer curve. In contrast to the above papers, our work features a representative agent framework with endogenous government purchases.

Schmitt-Grohe and Uribe (1997) show that there exists a Laffer curve in a neoclassical growth model with endogenous labor taxes. However, these authors focus on the effects of endogenous labor and capital taxes and a balanced government budget rule and show that indeterminacy can occur in such a setup. Chapter four by contrast features exogenous tax rates which implies that indeterminacy will not occur. Moreover, we concentrate on a rigorous characterization and comparison of the capital and labor tax Laffer curves for the US and EU-15.

Floden and Linde (2001) examine the effects of government redistribution schemes in the presence of uninsurable idiosyncratic productivity risk in a parameterized model of the US and Sweden. According to their results, for labor taxes the US is located on the left side whereas Sweden is on the slippery slope side of the Laffer curve. Jonsson and Klein (2003) analyze the welfare costs of distortionary taxation in the US and Sweden. They report that Sweden is on the slippery slope side for several tax instruments while the US is on the left side.

These papers however do not focus on the Laffer curve as such but rather briefly mention the implications of their models with respect to it. By contrast, chapter four provides a clear cut and fully-fledged analysis of the shape of the Laffer curve for the US and EU-15 economy.

Braun and Uhlig (2006) examine the economic implications of tax increases. In particular, they demonstrate that increasing taxes and wasting the resulting tax revenues may improve welfare. The authors explore a model with incomplete insurance markets, borrowing constraints, a nonlinear capital income tax schedule and idiosyncratic income shocks. Further, a selfish government taxes capital above a given threshold and simply wastes the revenues. Braun and Uhlig (2006) show that this policy raises the before-tax real return on capital which in turn increases the self-insurance possibilities of agents. Hence, agents prefer the selfish government that wastes capital tax revenues to an environment without a government at all. By contrast, chapter four examines a standard neoclassical growth model without the features employed in Braun and Uhlig (2006). However, we assume that government consumption is valued by households and adjusts endogenously in response to changes in taxation. Therefore, depending on the degree of valuation, increases of tax rates might increase welfare in our model as well. However, we leave an explicit welfare analysis in chapter four to future research.

Prescott (2002, 2004) raised the issue of the incentive effects of taxes by comparing the effects of labor taxes on labor supply for the US and European countries. He finds that Europeans turned to work less than Americans since labor taxes have risen more in European countries compared to the US. Our work is in line with Prescott's findings. However, for his main result Prescott (2002, 2004) investigates only the labor market relation of his model and based on this he analyzes the implied incentive effects for labor supply due to labor tax changes.

The fourth chapter analyzes the incentive effects of changes in labor, capital and consumption taxes in a general equilibrium framework with endogenous government consumption.

Recently, Ljungqvist and Sargent (2006) show that the model of Prescott (2002, 2004) fails to explain the observed employment outcome as soon as government benefits are taken into account. The authors show that due to the existence of generous European government benefits hours worked implode in the model. In order to account for the differences in hours worked in the Europe and the US, Ljungqvist and Sargent (2006) propose to include additional ingredients such as a lower disutility of labor than chosen in Prescott (2002, 2004), government supplied inactivity benefits, tax revenues that are used to finance public goods and/or inactivity benefits and other features like unemployment, disability, and old-age retirement in addition to labor and leisure. Furthermore, and in contrast to the work of Prescott (2002, 2004), authors such as Blanchard (2004) as well as Alesina, Glaeser, and Sacerdote (2005) argue that changes in preferences respectively labor market regulations and union policies rather than different fiscal policies are the driving forces for the observation that hours worked have fallen in Europe compared to the US. In particular, these authors argue that preferences in Europe have shifted over time towards more leisure and thus lower hours worked. By contrast to these alternative explanations for the differences in hours worked between the US and Europe, chapter four employs a model similar to Prescott (2002, 2004) and analyzes the incentive effects of changes in taxation by investigating the Laffer curve.

Chapter four of this thesis analyzes the short-run slopes of the US and EU-15 Laffer curves for immediate and pre-announced labor and capital tax cuts. We show that the short-run dynamics and hence the short-run slopes of the Laffer curves can be very different depending on the timing of tax cuts. In particular, an anticipated future capital income tax cut leads to a short-run investment boom and higher tax revenues while an immediate tax cut delivers the opposite result. In related work, Judd (1985b) shows that anticipated future investment tax credits may reduce current investment. In addition, an immediate income tax cut that is financed by future cuts in government expenditures also depresses current investment. Further, Judd (1987a,b) analyzes the welfare costs of delayed or anticipated tax changes. He reports that delay increases the excess burden of capital taxation while it reduces the excess burden for wage taxation. Moreover, an investment tax credit in the future always dominates a capital income tax cut at that time. Recently, House and Shapiro (2006) investigate the aggregate effects of the timing of tax rate changes in a case study for the 2001 and 2003 US tax law changes. They find that economic growth increased by 0.9 percent once the 2003 law eliminated the pre-announcement structure of the 2001 law. Chapter four departs from this existing work in several dimensions. First, in line with the concept of the Laffer curve, government spending adjusts endogenously to balance the government budget in our model as opposed to lump-sum transfers in the above papers. Moreover, we examine the dynamic effects of immediate and pre-announced labor and capital tax cuts for different steady state tax rates. In particular, we show e.g. that irrespective of the underlying steady state tax rate a pre-announced capital tax cut leads to an investment boom respectively higher tax revenues in the announcement period. When policy is implemented, however, it turns out that we observe a dynamic Laffer effect, i.e. higher or lower revenues depending on the underlying steady state tax rate.

Mankiw and Weinzierl (2005) pursue a dynamic scoring exercise in a neoclassical growth model for the US economy. Dynamic scoring accounts for the feedback effect from lower taxes to growth via increased incentives to participate on the markets. They find that in the US half of a capital tax cut is self-financing compared to a static scoring exercise. The present chapter extends their work in two dimensions. First, we set up a model that has alternative features such as consumption taxes and endogenous government consumption. Second, we calculate the dynamic scoring effect for the EU-15 economic area and compare it to the US economy.

Recently, Leeper and Yang (2005) argue that Mankiw and Weinzierl's result that static scoring overestimates the revenue loss hinges on the assumption that lump-sum transfers adjust to balance the government budget. In particular, Leeper and Yang show that a bond-financed tax cut can have adverse effects on growth. Interestingly, they show that when the government consumption to GDP ratio is adjusted to rising debt in response to a labor tax cut then static scoring underestimates the revenue loss as opposed to Mankiw and Weinzierl. By contrast, in our experiments government debt is fixed and the level of government consumption adjusts. As already indicated above, we find that static scoring overestimates the revenue loss for labor and capital tax cuts and thereby confirm Mankiw and Weinzierl (2005).

In chapter four, we examine the shape of the Laffer curve in a calibrated neoclassical growth model for three different types of preferences. Our results depend of course on our parameter choices for these preferences. In principle, there are two possibilities to proceed. One is to estimate each parameter specification with e.g. DYNARE as provided by Julliard (2006) and then parameterize each model separately. The different preference specifications, each with their own specific parameter choices, then deliver potentially rather different results for the impact of tax changes on tax revenues. In such a comparison, it is hard to evaluate, how much of the differences are due to specific features of the preferences, and how much are due to implicit and possibly unintended variations across preference specifications, due to the preference-specific parameter choices. A comparison along these lines provides only limited information, in particular as there is considerable disagreement regarding key parameters in the literature.

We therefore choose to proceed differently. We select a baseline calibration for our favorite Cobb-Douglas preference specification and calculate the local marginal impact on total tax revenues from a change in labor taxation along the steady state Laffer curve. We then choose the parameters for the other two preference types (Power utility, GHH utility) to keep this quantity the same for the US economy. Put differently, the change of government tax revenues after changing the steady state labor income tax is identical across all three preference specifications at our baseline calibration. We take the resulting baseline calibration for the Power and GHH preferences seriously, since the resulting parameters are within the range of values suggested in the literature. Finally, we also provide a sensitivity analysis to examine the robustness of our results.

To sum up, chapter four of this dissertation contributes to the literature by analyzing the shape of the Laffer curve quantitatively in a simple neoclassical growth model calibrated to the US as well as to the EU-15 economy. We locate the US and the EU-15 area on their respective Laffer curves and examine how they have moved over time on them. We find that the slopes of the Laffer curves in the EU-15 economy are lower than in the US which documents a higher degree of distortions in the EU-15 area. Moreover, tax cuts in the EU-15 area are much more self-financing and hence, we conclude that there are higher incentive effects in the EU-15 compared to the US in response to tax cuts.

2.3 Pre-Announced Tax Reforms

The fifth chapter of this dissertation is concerned with the question whether fiscal policy should pre-announce tax reforms before their implementation from a welfare point of view. By contrast to chapter four which pursued a positive analysis of the effects of fiscal policy, chapter five turns to a normative perspective. In particular, we analyze optimal pre-announced Ramsey tax reforms when government spending consists also of valuable and productive elements which adjust endogenously in general equilibrium.

Optimal taxation in a standard neoclassical growth model using a normative approach proposed by Ramsey (1927) is studied by many authors, see e.g. Chamley (1986), Judd (1985a), Lucas (1990), Chari, Christiano, and Kehoe (1994), Atkeson, Chari, and Kehoe (1999), Chari and Kehoe (1999) and Erosa and Gervais (2001). Typical results of this literature are the optimal zero steady state capital income tax as well as sizable welfare gains from the tax reform. However, common to this literature is that it analyzes optimal taxation with immediate implementation only and therefore abstracts from pre-announcement effects.

By contrast, Domeij and Klein (2005) investigate an optimal pre-announced labor and capital income tax reform in a standard neoclassical growth model. The authors show that the welfare gains of an optimal capital and labor tax reform decline the longer the reform is pre-announced before its implementation. Hence, pre-announcement is costly in terms of welfare. Domeij and Klein (2005) argue that the incentive effects of the future anticipated tax reform are dominated by the time delay effect and therefore fiscal policy should not pre-announce this type of tax reform. In line with the classical optimal taxation literature, Domeij and Klein (2005) use a neoclassical growth model in which the fiscal authority collects distortionary taxes. However, Domeij and Klein (2005) assume that government consumption is constant and not valued by households and there does not exist a variable and productive government capital stock. By contrast, we examine the importance of valuable and productive government spending for the resulting welfare gains of pre-announced tax reforms.

Aiyagari (1995) examines optimal capital income taxation in an economy with incomplete insurance markets and borrowing constraints. He shows that in such an environment the optimal capital income tax rate is positive in the short- and long-run. Due to uninsurable, idiosyncratic risk, individuals accumulate too much capital because of precautionary savings motives. A positive capital income tax reduces the capital stock to its optimal level. By contrast, chapter five assumes homogenous agents that face no borrowing constraints as in Domeij and Klein (2005) and therefore, the optimal long-run capital income tax will be zero in our model.

Lansing (1998) studies optimal fiscal policy in a business cycle model that features utility providing public consumption and public capital. He employs a stochastic model in order to analyze optimal fiscal policy responses to technology and preference shocks. Lansing (1998) analyzes approximated local dynamics but does not consider transitional dynamics of the underlying optimal tax reform. Cassou and Lansing (2006) study the effects of tax reforms with useful public expenditures in an endogenous growth model. In their model, public expenditures contribute to human capital formation as well provide utility. The authors compare the effects of optimal tax reforms with sub-optimal revenue-neutral tax reforms. However, both papers assume that fiscal policies are implemented immediately and do not consider effects from pre-announcement.

Baxter and King (1993) are one of the first authors who analyze the effects of fiscal policy in a neoclassical growth model with productive government capital and utility providing government consumption. McGrattan (1994) analyzes the macroeconomic effects of distortionary taxation in a neoclassical growth model in which household utility depends on government spending. Further, Christiano and Eichenbaum (1992) assume that government consumption affects household utility and show that this has important consequences for aggregate labor market fluctuations. However, these papers make no reference to pre-announcement.

Judd (1985b) shows in a representative agent model that anticipated future investment tax credits may depress current investment. Further, he shows that an immediate income tax cut that is financed by future cuts in government expenditures also depresses current investment. Judd (1987a,b) analyzes the welfare costs of unanticipated and anticipated tax changes. He finds that delay increases the excess burden of capital taxation while it reduces the excess burden for wage taxation. Further, an investment tax credit at a future point in time always dominates a capital income tax cut at that time. However, these papers do not analyze optimally chosen tax rates in the presence of delay. Further, Judd abstracts from valuable and productive government spending.

Chapter four of this dissertation analyzes the short-run slopes of the US and EU-15 Laffer curves for immediate and pre-announced labor and capital tax cuts. It is shown that the short-run dynamics can be very different depending on the timing of tax cuts. House and Shapiro (2006) investigate the aggregate effects of the timing of tax rate changes in a case study for the 2001 and 2003 US tax law changes. They find that economic growth increased by 0.9 percent once the 2003 law eliminated the pre-announcement structure of the 2001 law. However, these two contributions do not derive optimal tax reforms nor they consider welfare issues. House and Shapiro (2006), however, conjecture in footnote 1 that "Because it is often optimal to tax the initial capital stock heavily, the optimal tax rate on capital income should be phased-in". In terms of welfare, Domeij and Klein (2005) as well as chapter five show that the baseline optimal tax reform with immediate implementation (no phase-in) generates the highest gains. Hence, the optimal baseline tax reform should not be phased-in. However, our "no confiscation/subsidy" reform shows indeed that optimal tax rates should be implemented with pre-announcement (or should be phased-in) since for this type of reform welfare gains increase with pre-announcement.

Recently, Klein, Krusell, and Rios-Rull (2004) study the optimal choice of utility providing government expenditures when the government cannot commit to future policies. By contrast, the present chapter assumes that the government can commit to future government expenditures. In addition, the paper by Klein, Krusell, and Rios-Rull (2004) considers immediately implemented reforms only.

Hassler, Krusell, Storesletten, and Zilibotti (2004) analyze the optimal timing of capital income taxes when capital depreciation is not constant. The authors find that under commitment the optimal time pattern of capital taxes is oscillating whereas optimal capital taxes are smooth without commitment. However, although the paper considers a one period implementation lag of optimal capital taxes, pre-announcement of more periods is not considered. In addition, the paper abstracts from utility providing government consumption as well as from productive government capital.

Dominguez (2006a) analyzes the time-inconsistency of optimal capital income taxes in an economy without full commitment. She studies optimal capital and labor income taxation in a neoclassical growth model with debt restructuring and an institutional delay of capital tax changes of one year. Referring to the terminology that is used in the chapter five, the institutional delay can also be interpreted as a one year pre-announcement of a capital tax change. Dominguez (2006a) finds that debt restructuring together with the institutional delay enforces commitment of the government to the optimal tax reform. Put differently, without full commitment, debt restructuring and institutional delay can improve welfare. The author concludes that the time-inconsistency problem of optimal capital taxes is not as severe as previously thought since decision making in democratic societies is characterized by institutional delays. However, chapter five abstracts from debt restructuring policies and assumes that the Ramsey planner can commit to future policies.

Klein and Rios-Rull (2003) examine optimal fiscal policy when the government has no access to commitment. The authors study the properties of Markov perfect equilibria in an economy with a one period implementation lag for capital taxes but without government debt. Klein and Rios-Rull (2003) show that optimal time-consistent capital taxes are different from zero. Benhabib and Rustichini (1997) explore optimal capital taxes in an environment without commitment, without government debt and without implementation lags. They find that capital taxes are likely to be different from zero in the long-run. Phelan and Stacchetti (2001) analyze the set of sustainable equilibria in an economy without commitment and without government debt and report that optimal capital taxes may be different from zero in the steady state. Recently, Dominguez (2006b) has shown that these results are sensitive to whether the government has access to government debt. In particular, as soon as the government can issue debt and smooth taxes over time, it appears that optimal long-run capital taxes are zero.

Eichengreen (1990) analyzes confiscation of capital income in theory and practice. Using a highly stylized theoretical model, he argues that a capital levy which is subject to an institutional delay induces capital owners to move their assets abroad. Due to the capital flight the capital levy as such is likely to be abolished at the date of implementation. Eichengreen (1990) examines historical cross-country evidence with respect to capital levies and concludes that capital flight in conjunction with institutional delays are the reasons for unsuccessful capital levies in practice. By contrast, chapter five of this dissertation examines pre-announced capital levies in a closed economy. In line with Domeij and Klein (2005), we find that the size of the optimal initial capital levy decreases with the pre-announcement horizon. Capital cannot move abroad in our model as it is the case in Eichengreen (1990). However, we observe nevertheless a similar effect. In our model, individuals decide to accumulate less capital if they expect a levy in the future which in turn induces the Ramsey planner to choose a lower levy. In addition, and more importantly, our "no confiscation/subsidy" reform shows that capital levies as such are not important for the resulting welfare gains of an optimal pre-announced reform.

Our "no confiscation/subsidy" reform shares one dimension of one of the reform experiments in Chari, Christiano, and Kehoe (1994), Domeij and Klein (2005) and Dominguez (2006a). These authors analyze the case when the government imposes a constant zero capital income tax over time in case of an immediate reform.[1] We depart from this work in two dimensions. First, we analyze the effects of pre-announcement for the resulting welfare gains of this type of tax reform. Second, we analyze the effects when the government moves capital and labor taxes to their endogenous long-run values at the implementation date of the reform.

Chapter five of this dissertation employs the normative approach proposed by Ramsey (1927) in order to determine optimal fiscal policy. The Ramsey planner is assumed to be able to choose linear distortionary taxes optimally but cannot choose lump-sum taxes. Moreover, most of the literature assumes that there is no heterogeneity across individuals. The Ramsey literature arrives at the result that savings decisions shall not be distorted in the long-run and hence capital income taxes are zero in the steady state. By contrast, Mirrlees (1971) proposed an alternative approach. He explores a model in which agents have private information about their stochastic individual skills. The Mirrlees approach aims

[1]Dominguez (2006a) assumes a one period implementation lag. However, she does not discuss welfare implications in the presence of the zero capital income tax policy.

at designing a tax system that provides insurance for skill risk on the one hand and incentives for more production of high skilled agents on the other hand. The resulting optimal tax schedule is non-linear in the sense that there are no distortions for high skilled agents but distortionary taxes for low skilled agents. Insurance is then provided via lump-sum redistribution.

Recently, the New Dynamic Public Finance literature puts the Mirrlees approach into a dynamic context. Golosov, Tsyvinski, and Werning (2006) as well as Kocherlakota (2006) provide excellent and comprehensive surveys that summarize the growing body of work of that literature. Outstanding papers by Albanesi and Sleet (2006), Golosov, Kocherlakota, and Tsyvinsky (2003) as well as Golosov and Tsyvinski (2006) have shown that it is optimal to distort the savings decisions of individuals if skills change stochastically over time. Kocherlakota (2005) shows that in an environment with idiosyncratic and aggregate shocks the expected individual wealth tax rate is zero. More importantly, he shows that the government never collects net revenues from wealth taxes. In other words, the dynamic Mirrlees approach in Kocherlakota (2005) generates an optimal aggregate capital income tax rate that is zero in all periods. Interestingly, this result is similar to the long-run zero aggregate capital income tax result suggested by the Ramsey approach.

However, we are not aware of work that has been done in the New Dynamic Public Finance literature which examines the effects of pre-announcement respectively the effects of valuable and productive government spending. Examining these features within this literature would certainly be a useful next step on the research agenda. To that end, however, we rely on the Ramsey approach in chapter five since it is particulary useful for our question. First, the chapter represents an extension to the work of Domeij and Klein (2005) who themselves apply the Ramsey approach in their analysis. Hence, in order to facilitate comparison, we also choose the Ramsey approach. Second, we aim to assess the importance of short-run confiscation and subsidy of capital and labor income in the presence of pre-announcement in the Ramsey approach.

In chapter five, the benevolent Ramsey planner undertakes an optimal pre-announced tax reform in which he also chooses optimal levels of valuable and productive government spending. Hence, the Ramsey planner determines the optimal size of the government in our economy given preferences and technology. By contrast, Krusell and Rios-Rull (1999) explore a model with heterogenous agents in which majority voting determines policies. The political economy paradigm enables the authors to analyze how different policy selection procedures and collective choice mechanisms affect taxes and the size of the government. As a result, their political economy model predicts e.g. a size of transfers that is consistent with US data. For further prominent contributions on political economy implications for economic policies, see e.g. Alesina and Rodik (1994), Persson and Tabellini (1994), Krusell and Rios-Rull (1996), Krusell, Quadrini, and Rios-Rull (1996, 1997), Hassler, Krusell, Storesletten, and Zilibotti (2005) and Hassler, Storesletten, and Zilibotti (2003, 2006). However, political economy considerations are beyond the scope of chapter five. Instead, we regard our work as an extension to Domeij and Klein (2005) by examining the welfare effects of pre-announced tax reforms when the Ramsey planner chooses optimal levels of valuable and productive government spending that are consistent with preferences and technology. We believe, that reexamining our work from a political economy perspective might be an interesting next step. However, we leave this issue to future research.

In our analysis, we employ a calibrated neoclassical growth model. Hence, our results depend on our parameter choices. In principle, there are two possibilities to proceed. First, estimate the model and use the estimation results to calibrate and parameterize the model. This, however, is a thorny issue. Similar to Domeij and Klein (2005), we have chosen a deterministic model. Hence, in order to estimate it with e.g. recent Bayesian model estimation procedures (see e.g. DYNARE as provided by Julliard (2006)) we would need to put the economy into a stochastic environment with many shocks or by mechanically integrating measurement errors. Further, we use a small-scale model without any nominal or real rigidities. Estimating the model would potentially deliver biased or non-identified parameter estimates since Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003), Mankiw and Reis (2006b) and others have shown that additional features such as sticky prices, sticky wages, sticky information, investment and capacity utilization costs, limited participation etc. are important ingredients for a model in order to explain macroeconomic time series behavior. These features, however, would complicate the model considerably and simultaneously fog up the key issues this chapter attempts to address. Finally, in order to estimate the model, we would need to specify fiscal policy rules, e.g. how taxes or transfers adjust to changes in debt or other types of government expenditures in the competitive equilibrium. We believe, that the particular choice of fiscal policy rules as well as their dynamic lead/lag pattern has important effects for the resulting parameter estimates of the model. Due to these reasons, we do not estimate the model in chapter five. However, addressing these issues thoroughly would be a useful next step on the research agenda and would certainly justify a separate piece of research. Instead, and in line with Domeij and Klein (2005), we calibrate the model to historical averages of data respectively parameterize the model using standard parameter values used in the literature. Later on, we perform a sensitivity analysis with respect to key parameters of the model.

To sum up, the contribution of the fifth chapter to the literature is twofold. First, we reexamine Domeij and Klein (2005) by taking two additional features of government spending explicitly into account: public goods and public capital. In other words, we examine the welfare consequences of utility providing government consumption and productive government capital in a pre-announced optimal tax reform. Second, we analyze how important the short-run properties of the optimal tax system - in other words confiscation and/or subsidy of capital and labor income - are for the resulting overall welfare gains of the pre-announced tax reform.

3 Sticky Information vs. Sticky Prices: A Horse Race in a DSGE Framework

How can we explain the observed behavior of aggregate inflation in response to e.g. monetary policy changes? Mankiw and Reis (2002) have proposed sticky information as an alternative to Calvo sticky prices in order to model the conventional view that i) inflation reacts with delay and gradually to a monetary policy shock, ii) announced and credible disinflations are contractionary and iii) inflation accelerates with vigorous economic activity. We use a fully-fledged DSGE model with sticky information and compare it to Calvo sticky prices, allowing also for dynamic inflation indexation as in Christiano, Eichenbaum, and Evans (2005). We find that sticky information and sticky prices with dynamic inflation indexation do equally well in our DSGE model in delivering the conventional view.

3.1 Introduction

How can we explain the observed behavior of aggregate inflation in response to e.g. monetary policy changes? An important determinant for the behavior of aggregate inflation is the underlying price setting mechanism of firms. Are firms able to set prices optimally in every instance of time? The recent literature believes they are not, see e.g. Walsh (2003) and Woodford (2003). Rather, the decisions of firms which prices to set on the markets are affected by frictions such as costs of acquiring, absorbing and processing information or by inabilities of changing prices. What are the consequences of these frictions for the behavior of aggregate inflation in response to e.g. changes in monetary policy? In particular, this chapter focuses on the question whether aggregate inflation behavior can be better explained by the price setting behavior of firms that face imperfect information or by firms that face inabilities of resetting prices. A substantial part of the literature attempts to explain the behavior of aggregate inflation in response to monetary policy changes by short-run nominal price rigidities. A leading framework has been provided by Calvo (1983) and used e.g. by Woodford (1996), Yun (1996), Goodfriend and King (1997), Clarida, Gali, and Gertler (1999), Gali (2003) and Woodford (2003). Mankiw and Reis (2002) have proposed random information arrival and slow information diffusion as an alternative paradigm. They argue that models based on sticky information can more easily reproduce the following conventional views:

1. Inflation inertia: inflation reacts with delay and gradually to a shock in monetary policy (see e.g. Christiano, Eichenbaum, and Evans (2005)).
2. Announced and credible disinflations are contractionary (see Ball (1994)).
3. Acceleration phenomenon: the change in inflation is positively correlated with output (see e.g. Abel and Bernanke (1998)).

However, Mankiw and Reis (2002) draw their conclusion based on a highly stylized partial equilibrium model. Is that an appropriate description of an economy? In the presence of information or price rigidities, output is typically demand determined. Mankiw and Reis (2002) assume, however, that demand is exogenously given. The question that arises is: what happens to their results if demand is endogenously determined in an economy? Put differently, how important are general equilibrium forces such as intertemporally optimized goods and money demand for the price setting behavior of firms and hence for aggregate inflation in an economy? One objective of the present chapter is to answer these questions. To that end, we use a fully-fledged dynamic stochastic general equilibrium (DSGE) framework similar to Woodford (2003). We believe that this is an interesting framework since it represents a standard small-scale workhorse DSGE model for the analysis of e.g. monetary policy. We integrate sticky information into this DSGE framework and compare the results to those, when Calvo sticky prices are assumed instead. This modifies the comparison envisioned by Mankiw and Reis (2002) in two important dimensions. First, by employing a DSGE model, aggregate demand now arises from an intertemporal household maximization problem rather than from an exogenously assumed static demand curve as in Mankiw and Reis (2002). Second, as a variation to standard Calvo sticky prices, we allow also for dynamic inflation indexation in the Calvo sticky price model as it has been proposed in the recent literature, see Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003).

Regarding the sticky information model our results confirm the finding by Mankiw and Reis (2002): all three effects listed above can be replicated in our baseline DSGE model as well. A sensitivity analysis reveals that our result is robust with respect to parameter variations. However, general equilibrium features such as forward looking households and interest elastic money demand are nevertheless important. In particular, we find that e.g. inflation and the output gap in the sticky information model react already in the announcement periods to an announced disinflation due to consumption smoothing households and interest elastic money demand in general equilibrium.[1] Further, we show that a Calvo sticky price model without inflation indexation can already match the conventional view that announced and credible disinflations are contractionary due to the existence of interest elastic money demand in general equilibrium in our baseline DSGE model.[2] This result appears also to be robust within our DSGE framework. Finally, we allow for dynamic inflation indexation in the Calvo sticky price model and show that in our baseline DSGE model this works just as well as sticky information *à* la Mankiw and Reis (2002) in delivering all three effects. Again, result appears also to be robust to variations in key structural parameters of the model.[3]

We conclude that sticky information as in Mankiw and Reis (2002) as well as sticky prices with dynamic inflation indexation as in Christiano, Eichenbaum, and Evans (2005) are perfectly capable of replicating the conventional wisdom with respect to inflation inertia, announced disinflations and the acceleration

[1] Mankiw and Reis (2002) find in their partial equilibrium model that for sticky information there is absolutely no reaction of inflation in response to the announcement and variables react only when policy is implemented.

[2] Due to their partial equilibrium model, Mankiw and Reis (2002) find that announced and credible disinflations are expansionary in the standard Calvo sticky price model.

[3] An alternative way to verify our conclusions respectively to evaluate the robustness of our results would be to estimate the model. This however, turns out to be a thorny issue. Our models belong to the class of small-scale DSGE models. That is, they contain only a single friction e.g. sticky information or sticky prices. We know ever since Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003) as well as Mankiw and Reis (2006b) that further nominal and real frictions such as sticky wages, habit persistence, capacity and investment adjustment costs, limited participation or sticky information in other markets are necessary to obtain a reasonably good fit of the model to the data. Hence, estimating our small-scale DSGE models would probably result in biased results since the data would assign all these frictions to either sticky prices or sticky information. Enriching our model by these additional frictions would certainly be a useful step. However, this would also fog up the key questions raised in this chapter. More precisely, each enriched model then would potentially assign different weights to various frictions and hence it would be difficult to evaluate how much of the differences between sticky information and sticky prices are due to these additional frictions. Addressing these issues thoroughly would be a useful next step on the research agenda and would certainly justify a separate piece of research. Instead, and in the light of Mankiw and Reis (2002), we evaluate the *qualitative* ability of the models to deliver the three conventional effects. In other words, the conventional effects itself are of rather *qualitative* nature and we examine the models ability to reflect them qualitatively. In terms of parameters we rely on standard values used in the literature and pursue a sensitivity analysis to evaluate the robustness of the qualitative predictions of the models.

phenomenon in the DSGE model used in this chapter. However, the source of e.g. inflation inertia in both models is different. In the sticky information model, inflation inertia arise due to slow information diffusion. In the sticky price model with dynamic inflation indexation, inflation inertia is hard-wired by assuming that non-optimizing firms index prices to past inflation. Hence, these firms use a very limited outdated information set. Thus, one might want to view information stickiness as providing a micro foundation for the particular choice of dynamic inflation indexation in Calvo sticky price models. Although both models perform equally well with respect to our measures, we believe that sticky information might be better suited to explain the underlying micro behavior of price setting firms.

The chapter is organized as follows. Section two lays out the DSGE model. Results are discussed in section three and finally section four concludes.

3.2 The DSGE Model

In the following section we lay out a fully-fledged DSGE model similar to Woodford (2003) with intertemporally optimizing households, a government and either sticky information firms or Calvo sticky price firms.

3.2.1 Households

The representative agent maximizes the discounted sum of life-time utility,

$$\max_{C_t, M_t, N_t(i), D_{t+1}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma} - 1}{1-\sigma} + \frac{\chi}{1-\nu} \left[\left(\frac{M_t}{P_t} \right)^{1-\nu} - 1 \right] - \delta \int_0^1 \frac{N_t(i)^{1+\phi}}{1+\phi} di \right]$$

subject to

$$\int_0^1 P_t(i)C_t(i)di + M_t^d + E_t\left[Q_{t,t+1}D_{t+1}\right] \leq$$
$$\int_0^1 W_t(i)N_t(i)di - T_t + M_{t-1}^d + D_t + \int_0^1 \Pi_t(i)di$$

where C_t denotes a composite consumption index which is defined as $C_t \equiv \left[\int_0^1 C_t(i)^{\frac{\theta-1}{\theta}}di\right]^{\frac{\theta}{\theta-1}}$. This in turn implies the following for the aggregate price level: $P_t \equiv \left[\int_0^1 P_t(i)^{1-\theta}di\right]^{\frac{1}{1-\theta}}$. M_t denotes nominal money. We assume that each categorized good i is produced by using specialized labor $N_t(i)$ which is supplied by the representative household. $W_t(i)$ is the wage that is payed from firm i to the household. As in Woodford (2003), the assumption of specific labor markets generates strategic complementarities in firm's pricing decisions. D_{t+1} is a nominally denominated state contingent private bond that pays D_{t+1} in period $t+1$. $Q_{t,t+k}$ is the stochastic discount factor from period t to $t+k$ for nominal claims. T_t denotes a lump-sum tax of the government. Finally, the household receives profits $\Pi_t(i)$ of the firms. The household is endowed with one unit of time (normalized) to be allocated between hours of work and leisure. Information is complete for the agent.

3.2.2 Government

The government issues nominal money M_t and nominal bonds B_t and collects lump sum taxes T_t to finance its expenditures G_t,

$$P_tG_t = T_t + B_t - R_{t-1}B_{t-1} + S_t \tag{3.1}$$

where $S_t = M_{t-1}(\xi_t - 1)$. P_t is the aggregate price level, R_{t-1} denotes the nominal interest rate from period $t-1$ to period t and $\xi_t = \frac{M_t}{M_{t-1}}$ is nominal money growth. We assume ξ_t and G_t to follow exogenous AR(1) processes.

3.2.3 Firms

Following Woodford (2003), we assume a continuum of firms $i \in [0,1]$ in monopolistic competition each producing a differentiated good according to $Y_t(i) = Z_t N_t^{\alpha}(i)$. $Y_t(i)$ denotes the differentiated good and $N_t(i)$ is specific labor input of firm i. Z_t denotes technology which is assumed to follow an exogenous AR(1) process. With price $P_t(i)$ for firm i and P_t as the aggregate price level, firm demand is given by $Y^d(P_t(i); P_t, C_t, G_t) = Y_t^d(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta}(C_t + G_t)$. As in Woodford (2003), we assume that firms are wage-takers.[4] Finally, labor input for firm i is given by $N(P_t(i); Y_t^d, Z_t) = N_t(i) = \left(\frac{Y_t^d(i)}{Z_t}\right)^{\frac{1}{\alpha}}$. Now, we consider four different variants for the price setting behavior by firms.

Flexible Price - Full Information Firms

In the absence of any nominal and informational frictions firms choose prices each period to maximize profits,

$$\max_{P_t(i)} P_t(i) Y_t^d(i) - W_t(i) \left(\frac{Y_t^d(i)}{Z_t}\right)^{\frac{1}{\alpha}} \tag{3.2}$$

subject to

$$Y_t^d(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\theta} (C_t + G_t)\,. \tag{3.3}$$

We denote $P_t^*(i)$ as a solution of the above maximization problem.

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[4]Woodford (2003, ch. 3, p. 148) points out: *"Here I assume that the producer is a wagetaker, even though I have supposed that the supplier of each differentiated good uses a different type of labor with its own market. But an assumption of differentiated labor inputs need not imply that each producer is a monopsonist in its labor market. The only assumption that is important for the subsequent results is that producers that change their prices at different times also hire labor inputs from distinct markets. I might, for example, assume a double continuum of differentiated goods, indexed by (I, j), with an elasticity of substitution of θ between any two goods, as previously. It might then be assumed that all goods with the same index I (goods in the same "industry") change their prices at the same time (and so always charge the same price), and are also all produced using the same type of labor (type I labor). The degree of market power of each producer in its product market would then be as assumed here, but the fact that a continuum of producers all bid for type I labor would eliminate any market power in their labor market..."*.

Sticky Information Firms

Following Mankiw and Reis (2002), firms obtain new information with probability $1-\lambda_1$. These firms are able to find the profit maximizing price $P_t^*(i)$. With probability λ_1 firms do not obtain new information. These firms use the information set they updated k periods ago to compute optimal prices. Formally, these firms solve

$$\max_{P_{t+j}(i)} \sum_{j=0}^{\infty} \lambda_1^j E_{t-k} \left[Q_{t,t+j} \left(P_{t+j}(i) Y_{t+j}^d(i) - W_{t+j}(i) \left(\frac{Y_{t+j}^d(i)}{Z_{t+j}} \right)^{\frac{1}{\alpha}} \right) \right] \tag{3.4}$$

subject to

$$Y_{t+j}^d(i) = \left(\frac{P_{t+j}(i)}{P_{t+j}} \right)^{-\theta} \left(C_{t+j} + G_{t+j} \right). \tag{3.5}$$

The optimal log-linear pricing rule for sticky information firms can be written as follows[5]

$$\hat{p}_{t+j}(i) = E_{t-k} \left[\hat{w}_{t+j}(i) - \frac{1}{\alpha} \hat{z}_{t+j} + \left(\frac{1}{\alpha} - 1 \right) \hat{y}_{t+j}^d(i) \right] \quad \forall j \geq 0. \tag{3.6}$$

Note that the right hand side of this equation is the conditional expectation of the log-linearized version of $P_{t+j}^*(i)$ which is the profit maximizing price in the absence of any nominal and informational frictions. After some tedious manipulations we arrive at $\hat{p}_{t+j}(i) = E_{t-k}\left[\hat{p}_{t+j} + \zeta \hat{x}_{t+j}\right]$ for $\forall j \geq 0$ with $\zeta = \frac{\omega + \sigma s_c^{-1}}{1+\theta\omega}$ and $\omega = \frac{\phi}{\alpha} + \frac{1}{\alpha} - 1$. $\hat{x}_t$ denotes the output gap, defined as the difference between the distorted and the flexible price - full information output. Thus, in period t, a firm that updated its information set k periods ago sets the adjustment price

$$\hat{p}_{k,t}^{adj}(i) = E_{t-k}[\hat{p}_t + \zeta \hat{x}_t]. \tag{3.7}$$

[5]Hat-variables denote percentage deviations from steady state.

Finally, the aggregate price level is the average of all adjustment prices in t

$$\hat{p}_t = (1-\lambda_1) \sum_{k=0}^{\infty} \lambda_1^k \, \hat{p}_{k,t}^{adj}(i). \tag{3.8}$$

Sticky Price Firms

According to Calvo (1983), sticky price firms can set their profit maximizing price $\tilde{P}_t(i)$ with probability $1-\lambda_2$. With probability λ_2 firms cannot set their optimal price. These firms have to keep last period's price and set $P_t(i) = P_{t-1}(i)$. Formally, these firms solve

$$\max_{P_t(i)} \sum_{j=0}^{\infty} \lambda_2^j E_t \left[Q_{t,t+j} \left(P_t(i) Y_{t+j}^d(i) - W_{t+j}(i) \left(\frac{Y_{t+j}^d(i)}{Z_{t+j}} \right)^{\frac{1}{\alpha}} \right) \right] \tag{3.9}$$

subject to

$$Y_{t+j}^d(i) = \left(\frac{P_t(i)}{P_{t+j}} \right)^{-\theta} \left(C_{t+j} + G_{t+j} \right). \tag{3.10}$$

The aggregate price level in case of Calvo sticky prices can be written as

$$P_t = \left[(1-\lambda_2) \tilde{P}_t^{1-\theta} + \lambda_2 P_{t-1}^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{3.11}$$

with $\tilde{P}_t$ as the solution to the above maximization problem.

Sticky Price Firms With Dynamic Inflation Indexation

Empirical studies, see e.g. Gali and Gertler (1999) and Gali, Gertler, and Lopez-Salido (2005), suggest that lagged inflation is an important determinant for the New Keynesian Phillips curve. In order to account for this, Christiano, Eichenbaum, and Evans (2005) employ dynamic inflation indexation as a modification to the standard Calvo sticky price approach. With probability $1-\lambda_3$ firms can set their optimal price $\tilde{P}_t^*(i)$. With probability λ_3 firms cannot set their optimal price. Following Christiano, Eichenbaum, and Evans (2005), these firms set the price $P_t(i) = \Pi_{t-1}P_{t-1}(i)$. The non-optimizers apply a rule of thumb by updating last period's price $P_{t-1}(i)$ with yesterday's gross inflation rate Π_{t-1}.[6] Formally, these firms solve

$$\max_{P_t(i)} \sum_{j=0}^{\infty} \lambda_3^j E_t \left[Q_{t,t+j} \left(U_{t,j} P_t(i) \check{Y}_{t+j}^d(i) - W_{t+j}(i) \left(\frac{\check{Y}_{t+j}^d(i)}{Z_{t+j}} \right)^{\frac{1}{\alpha}} \right) \right] \tag{3.12}$$

subject to

$$\check{Y}_{t+j}^d(i) = \left(\frac{U_{t,j} P_t(i)}{P_{t+j}} \right)^{-\theta} \left(C_{t+j} + G_{t+j} \right) \tag{3.13}$$

with $U_{t,j} = \Pi_t \times \Pi_{t+1} \times ... \times \Pi_{t+j-1}$ for $j \geq 1$ and $U_{t,j} = 1$ for $j = 0$. The aggregate price level in the presence of sticky prices and dynamic inflation indexation can be written as

$$P_t = \left[(1 - \lambda_3)(\tilde{P}_t^*)^{1-\theta} + \lambda_3 (\Pi_{t-1} P_{t-1})^{1-\theta} \right]^{\frac{1}{1-\theta}} \tag{3.14}$$

with $\tilde{P}_t^*$ as the solution to the above dynamic programming problem.

[6] There are, of course, alternative approaches to indexation in the literature. Yun (1996) assumes indexation to steady state inflation, e.g. $P_t(i) = \bar{\Pi} P_{t-1}(i)$. Although this leads to a vertical long-run Phillips curve the dynamics are still entirely forward looking and hence inflation is not inertial. Smets and Wouters (2003) and Giannoni and Woodford (2003) assume partial dynamic inflation indexation, e.g. $P_t(i) = \Pi_{t-1}^{\gamma} P_{t-1}(i)$ with $0 \leq \gamma \leq 1$. Smets and Wouters (2003) estimate γ to be roughly 0.65 for European data. Gali, Gertler, and Lopez-Salido (2001) estimate γ to be equal to 0.6 for European and US data. By contrast, Giannoni and Woodford (2003) find that $\gamma = 1$ delivers the best fitting value for US data and thereby confirm Christiano, Eichenbaum, and Evans (2005) choice of full dynamic indexation. To that end, we are most interested in the consequences of full dynamic indexation for the dynamics of inflation. Therefore, our results can be interpreted as representing an upper bound compared to cases of partial dynamic inflation indexation.

3.2.4 Equilibrium

In equilibrium all markets clear. We log-linearize our equilibrium conditions. Hat-variables denote percentage deviations from steady state. The DSGE framework can be characterized by the following set of equations: an intertemporal IS equation, a real money demand equation, a real money supply equation, an equation for the flexible price - full information real interest rate and the equations for the exogenous AR(1) processes for technology, money growth and government expenditures. See appendix A.1 for a formal description.

Into this DSGE framework, we throw in either one of the following three Phillips curves:

1. Under sticky information we derive the so-called Sticky Information Phillips curve[7]

$$\hat{\pi}_t = \frac{1-\lambda_1}{\lambda_1}\zeta\hat{x}_t + (1-\lambda_1)\sum_{k=0}^{\infty}\lambda_1^k E_{t-k-1}[\hat{\pi}_t + \zeta\triangle\hat{x}_t]. \tag{3.15}$$

   with $\zeta = \frac{\omega+\sigma s_c^{-1}}{1+\theta\omega}$ and $\omega = \frac{\phi}{\alpha} + \frac{1}{\alpha} - 1$ as before. $\hat{\pi}_t$ is the gross inflation rate and $\hat{x}_t$ denotes the output gap, defined as the difference between the distorted and the flexible price - full information output.[8] Note that for $\zeta < 1$ firms pricing decisions are strategic complements which allows for potential inflation inertia as discussed extensively in Woodford (2003).

[7]Similar to the derivation steps described in Mankiw and Reis (2002), we substitute equation (3.7) into equation (3.8). After taking first differences and some tedious manipulations, we arrive at equation (3.15).

[8]In order to derive the Sticky Information Phillips curve we needed three assumptions: i) firms use outdated information and obtain new information infrequently, ii) firms set prices rather than quantities and iii) the information arrival follows a Poisson process. Reis (2006) develops a model where firms just face costs of acquiring, absorbing or processing information and shows that this inattentiveness model provides mirco-foundations for the three assumptions listed above.

2. Under standard Calvo sticky prices we derive the so-called New Keynesian Phillips curve[9]

$$\hat{\pi}_t = \beta E_t[\hat{\pi}_{t+1}] + \kappa \hat{x}_t \tag{3.16}$$

with $\kappa = \frac{(1-\lambda_2)(1-\lambda_2\beta)}{\lambda_2}\zeta$.

3. Finally, under Calvo sticky prices with indexation we arrive at the so-called New Keynesian Phillips curve with dynamic inflation indexation or hybrid New Keynesian Phillips curve[10]

$$\hat{\pi}_t = \frac{1}{1+\beta}\hat{\pi}_{t-1} + \frac{\beta}{1+\beta}E_t[\hat{\pi}_{t+1}] + \frac{\kappa'}{1+\beta}\hat{x}_t \tag{3.17}$$

with $\kappa' = \frac{(1-\lambda_3)(1-\lambda_3\beta)}{\lambda_3}\zeta$.

According to the Sticky Information Phillips curve, inflation is determined by current economic activity and by past expectations about current inflation and current economic activity. If new information arrives only some firms will be informed and change prices accordingly whereas most firms still set prices based on outdated information. As time elapses the fraction of firms that set prices based on new information increases and therefore, it is likely that inflation behaves inertial in response to new information.

By contrast, in the New Keynesian Phillips curve inflation is determined by current expectations about future inflation and by current economic activity. Thus, the New Keynesian Phillips curve is entirely forward looking and therefore in-

[9]To do so, we combine the log-linearized solution of equation (3.9) with the log-linearized version of equation (3.11). After some tedious manipulations, we arrive at equation (3.16).

[10]Similar to the derivations for the Calvo sticky price model, we combine the log-linearized solution of (3.12) with the log-linearized version of equation (3.14) and arrive at equation (3.17) after some further tedious manipulations.

flation will immediately jump on impact rather than reacting with delay in response to new information.

The New Keynesian Phillips curve with dynamic indexation shows that inflation is determined by past inflation, by current expectations about future inflation and by current economic activity. It is the backward looking inflation component due to dynamic inflation indexation which makes it likely that inflation behaves inertial in response to new information.

3.2.5 Microfoundation for Inflation Indexation

Based on the analysis of the previous section, it is the backward looking rule of thumb behavior of non-optimizing Calvo sticky price firms that potentially produces the desired inertial reaction of inflation. But which rule of thumb should be applied? Christiano, Eichenbaum, and Evans (2005) assume that last period's inflation is used to update prices of non-optimizing firms. Thus, these firms use inflation information that is outdated by one period. Clearly, one could assume instead that non-optimizers use inflation observed two periods ago to update their prices. It is also conceivable that they could use even older information to update their prices. Hence, the particular choice how old the information regarding inflation is that firms use to update their prices is ad-hoc in the Calvo sticky price model with dynamic inflation indexation.

By contrast, the sticky information model implies that the choice of inflation indexation depends on the particular information sets that are available to heterogenous firms. Some firms may be forced to use past period's information set including e.g. past period's inflation rate, output etc. Other firms may be forced to use even older information sets also including even older e.g inflation rates, output etc. All these firms use their individually outdated information sets to update prices. Due to this, it takes time in the sticky information model until a sufficiently large fraction of firms has received news and changes prices accordingly and thus inflation inertia are likely to occur. By contrast, in the sticky price model with dynamic inflation indexation as in Christiano, Eichenbaum, and Evans (2005), inflation inertia is hard-wired by assuming indexation to past inflation for all non-optimizing firms. Hence, these firms use a very limited outdated information set only.

Put differently, these firms face costs of acquiring, absorbing and processing information about current e.g. inflation and output but have free access to past period's inflation rate and therefore choose to update their prices using this information. From that perspective, one might want to view information stickiness as providing a micro foundation for the particular choice of dynamic inflation indexation in Calvo sticky price models.[11]

However, the present chapter aims at a comparison of the consequences of the three existing alternative pricing assumptions and their resulting Phillips curves in a DSGE framework taking the conventional wisdom as a measuring instrument.

3.2.6 Parameterization

In order to analyze the implications of the model, we need to parameterize it. In principle, there are two ways to proceed. First, one could estimate the model and use the estimated parameters to parameterize the model. This however, turns out to be a thorny issue. Our models belong to the class of small-scale DSGE models. That is, they contain only a single friction e.g. sticky informa-

[11] Recently, Dupor, Kitamura, and Tsuruga (2006) derive a model of dual stickiness. They assume that only a fraction of firms may reset prices and simultaneously receives new information. All remaining firms keep setting prices based on old and outdated information. In a highly stylized economic environment, they show that the dual stickiness model and a sticky price model with dynamic inflation indexation deliver similar, though not identical, responses of inflation after a money growth shock. Hence, they confirm our reasoning that information stickiness may provide a micro foundation for indexation in sticky price models.

tion or sticky prices. We know ever since Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003) as well as Mankiw and Reis (2006b) that further nominal and real frictions such as sticky wages, habit persistence, capacity and investment adjustment costs, limited participation or sticky information in other markets are necessary to obtain a reasonably good fit of the model to the data and hence reasonable parameter estimates. Hence, estimating our small-scale DSGE models would probably result in biased results since the data would assign all these frictions to either sticky prices or sticky information. Enriching our model by these additional frictions would certainly be a useful step. However, this would also fog up the key questions raised in this chapter. More precisely, each enriched model would potentially assign different weights to various frictions and hence it would be difficult to evaluate how much of the differences between sticky information and sticky prices are due to these additional frictions.

Instead, and in the light of Mankiw and Reis (2002), we evaluate the *qualitative* ability of the models to deliver the three conventional effects. In other words, the conventional effects itself are of rather *qualitative* nature and we examine the models ability to reflect them qualitatively. In terms of parameters, we therefore rely on standard values used in the literature and pursue a sensitivity analysis to evaluate the robustness of the qualitative predictions of the models. Table 3.1 summarizes the parameterization of our models. Time is taken to be quarters. The subjective discount factor β is set to 0.99. Similar to Woodford (2003), steady state inflation is set to zero, i.e. $\bar{\Pi} = 1 + \bar{\pi} = 1$.[12] The inverse Frisch elasticity of labor supply ϕ is set to 1.5. The coefficient of relative risk aversion of consump-

[12] See Ascari (2004) for an analysis of the effects of positive steady state inflation. In particular, he shows that trend inflation affects the dynamics of inflation and output in the standard Calvo sticky price model. However, as soon as either steady state or dynamic inflation indexation are assumed, the dynamics of the models are not affected by positive steady state inflation.

tion σ and the elasticity of utility with respect to real money holdings ν are set to 2. Real money demand in our model is given by

$$\log m_t = \frac{1}{\nu}\log\chi + \frac{\sigma}{\nu}\log c_t - \frac{1}{\nu}\log\frac{R_t - 1}{R_t}. \tag{3.18}$$

Thus, our choice implies a unit consumption elasticity of real money demand ($\partial \log m_t / \partial \log c_t = \sigma/\nu = 1$) which is in line with most empirical evidence on money demand. Further, our choice also implies the following semi interest rate elasticity $\partial \log m_t / \partial r_t = -\frac{1}{\nu(\bar{R}-1)\bar{R}} = -49.5$.[13] The labor share α in the production function is assumed to be $\frac{2}{3}$. As in Mankiw and Reis (2002), the degree of information rigidity (λ_1) respectively the degree of price stickiness (λ_2, λ_3) is set to 0.75. Thus, in case of the Calvo sticky price model, firms set optimal prices on average once a year. In the case of the sticky information model, firms obtain new information on average once a year.[14] We assume a markup over marginal costs of 20 percent, i.e. $\frac{\theta}{\theta-1} = 1.2$ as in Gali and Monacelli (2005). The steady state consumption to output ratio s_c is set to 0.7, a value that corresponds to the US average for the period from 1960:1 to 2001:4. The AR(1) process for technology is calibrated to standard values with an autocorrelation of $\rho_z = 0.95$ and a standard deviation of $\sigma_z = 0.71$ percent. The AR(1) process for money growth is specified with a persistence parameter of $\rho_\xi = 0.5$ and a standard deviation of $\sigma_\xi = 0.8$ percent, similar to Mankiw and Reis (2002) calibration. Finally, as in Backus, Kehoe, and Kydland (1995) the autocorrelation

[13]Note that Chari, Kehoe, and Mcgrattan (2000) estimate ν to be approximately 2.5 which is roughly in line with our choice of 2. Empirical evidence in Lucas (2000), Chari, Kehoe, and Mcgrattan (2000), Woodford (2003) and Walsh (2003) (who provides an excellent survey) suggest values for the semi interest rate elasticity ranging from -10 to -100. Hence, our implied choice of -49.5 is well within that range. Further, we set $\chi = 0.05$ which is also in line with many of the references cited above. However, note that χ is irrelevant for the dynamics of the model. Another parameter that does not affect the dynamics is the disutility of labor δ. However, we set δ such that the individual chooses to work one third of total time in steady state.

[14]Note that this is in line with empirical studies by Kahn and Zhu (2006), Caroll (2003) and Mankiw, Reis, and Wolfers (2004).

and standard deviation of the AR(1) process for government expenditures is set to $\rho_g = 0.95$ and $\sigma_g = 0.6$ percent. However, in order to access the robustness of our results with respect to our parameter choices we undertake sensitivity checks when discussing the results.

3.2.7 Solution Method

We solve the Calvo sticky price models with and without dynamic inflation indexation using the linear solution algorithm developed in Uhlig (1999). The sticky information model, however, cannot be solved as easily as our other two models. The Sticky Information Phillips curve (see equation (3.15)) consists of an infinite number of lagged expectations. Therefore, the state space of the sticky information model is infinite. In their original model, Mankiw and Reis (2002) guessed that the solution for e.g. inflation takes a $MA(\infty)$ representation and then solved for the MA coefficients recursively. They were able to do so, because aggregate demand was assumed to be exogenous and static. This solution method, however, does not work as soon as aggregate demand is endogenous and more importantly consists of a dynamic relationship such as the "New IS" curve.

The following question arises: how can we solve or approximate the sticky information model in general equilibrium? We proceed as follows. First, observe that the weight of lagged expectations decreases geometrically in the Sticky Information Phillips curve. That is, expectations that are formed recently have a larger impact on present inflation than similar expectations formed many periods ago. Therefore, it might be that expectations formed very far in the past do not change inflation significantly due to the very low weight that is attached to them. Hence, we ask how many lagged expectations are necessary to approximate the Sticky Information Phillips curve reasonably well. In particular, we rewrite the Sticky Information Phillips curve as

$$\hat{\pi}_t = \frac{1-\lambda_1}{\lambda_1}\zeta\hat{x}_t + (1-\lambda_1)\sum_{k=0}^{N}\lambda_1^k E_{t-k-1}[\hat{\pi}_t + \zeta\triangle\hat{x}_t]. \qquad (3.19)$$

Clearly, as $N \rightarrow \infty$ we obtain the original equation (3.15). What is the N for which the path of the model variables does not change anymore by a specified tolerance if we add a further lagged expectation, e.g. setting $N = N + 1$. We will pursue the following strategy to answer this question:

1. Set $N = 0$. That is, use the Sticky Information Phillips curve with only the first lagged expectation E_{t-1} and compute the recursive equilibrium law of motion (RELOM).
2. Set $N = N + 1$. Put differently, add the second lagged expectation E_{t-2} to the Sticky Information Phillips curve from above and compute the new RELOM.
3. Proceed adding lagged expectations by setting $N = N + 1$ as long as the coefficients of the RELOM change by more than a specified tolerance.

Figure 3.1 illustrates the solution algorithm. It shows the impulse responses of inflation to a one percent shock in money growth for a stepwise inclusion of lagged expectations in the Sticky Information Phillips curve. The first plot in the top row shows the response of inflation if the model uses $N = 0$, e.g. $\hat{\pi}_t = \frac{1-\lambda_1}{\lambda_1}\zeta\hat{x}_t + (1-\lambda_1)E_{t-1}[\hat{\pi}_t + \zeta\triangle\hat{x}_t]$. The second plot in the top row shows the response of inflation if the model takes an additional lagged expectation into account by setting $N = N + 1 = 1$ which yields $\hat{\pi}_t = \frac{1-\lambda_1}{\lambda_1}\zeta\hat{x}_t + (1-\lambda_1)E_{t-1}[\hat{\pi}_t + \zeta\triangle\hat{x}_t] + (1-\lambda_1)\lambda_1 E_{t-2}[\hat{\pi}_t + \zeta\triangle\hat{x}_t]$. Thus, the last plot in the bottom row shows the response of inflation if the sticky information model uses $N = 11$ which delivers $\hat{\pi}_t = \frac{1-\lambda_1}{\lambda_1}\zeta\hat{x}_t + (1-\lambda_1)\sum_{k=0}^{11}\lambda_1^k E_{t-k-1}[\hat{\pi}_t + \zeta\triangle\hat{x}_t]$. Obviously, figure 3.1 illustrates that the shape of the response of inflation converges to a smooth hump-shaped pattern as N becomes larger and larger. As an approximation, we look for that N where the recursive law of motion for all model variables does not change by more than a specified tolerance/critical value when setting $N = N + 1$.

Technically, we apply the QZ-decomposition to obtain the recursive law of motion. Following the notation in Uhlig (1999), the model coefficient matrices Δ and Ξ can be decomposed into unitary matrices Y and Z and uppertriangular matrices Σ and Φ such that $Y'\Sigma Z = \Delta$ and $Y'\Phi Z = \Xi$. The recursive law of motion coefficient matrix P which is needed to solve for the other recursive law of motion coefficient matrices, can be obtained by $P = -Z_{21}^{-1}Z_{22}$ where Z_{21} and Z_{22} are partitions of matrix Z, defined as in Uhlig (1999). P, Z_{21} and Z_{22} increase in their dimensions as N - the number of included lagged expectations - increases. Additionally P and Z_{22} are singular. Therefore, to check for convergence of the recursive law of motion we look for that N when the determinant of Z_{21}^{-1} does not change by more than a critical value compared to setting $N = N + 1$.

For our problem we choose the tolerance/critical value to be 1e-25 units. This algorithm appears to be robust. We achieve convergence of the recursive equilibrium law of motion after including the 20th lagged expectation, i.e. by setting $N = 19$. This result is also intuitively reasonable. As mentioned earlier, the Sticky Information Phillips curve can be interpreted as a geometric sum of past expectations with weights $(1-\lambda)\lambda^k$. For our parametrization these weights cumulate to around 99.5 percent after including the 20th lagged expectation.[15]

[15]Recently, Mankiw and Reis (2006b) propose an alternative solution method. They guess that the solution of e.g. the price level can be represented as a $MA(\infty)$ process. They show that the undetermined coefficients of the MA process solve an infinite dimensional second order difference equation with boundary conditions. Mankiw and Reis (2006b) approximate this infinite dimensional difference equation with a finite system of linear equations and a terminal condi-

As a remark, it should be mentioned that one could derive a Sticky Information Phillips curve with a finite number of lagged expectations. We decide not to follow this strategy since it departs too much from Mankiw and Reis (2002) original specification of the Sticky Information Phillips curve. Instead, we developed a fairly accurate algorithm to approximate the originally infinite geometric sum of lagged expectations of the Sticky Information Phillips curve with a finite number of lagged expectations.

Hence, as a further contribution to the literature, we show that a standard linear solution algorithm as e.g. Uhlig (1999) can be used to solve models with lagged expectations like Mankiw and Reis (2002) sticky information model.

3.3 Results

In this section we discuss the results by examining the models ability to deliver the three conventional views stated in the introduction.

3.3.1 Inflation Inertia

First, we analyze the models capability to generate inertial responses of inflation. We focus on the delayed and gradual response of inflation after a mone-

tion. In other words, they approximate the $MA(\infty)$ representation of the solution with a $MA(n)$ representation and choose a sufficiently large n. The authors report that for $n = 1000$ their algorithm takes approximately 5 seconds to solve for the process of the price level. By contrast, our algorithm approximates directly the number of relevant states, i.e. lagged expectations. It takes approximately three minutes on an up-to-date unix machine to solve the model with $N = 19$. However, Mankiw and Reis (2006b) algorithm appears to be constructed for the particular model they wish to solve and adaption to other models seems to involve tedious manual algebraic manipulations. By contrast, our algorithm employs a ready-to-use linear solution algorithm such as Uhlig (1999). In a recent paper, Wang and Wen (2006) propose a solution algorithm for linear difference systems with a finite number of lagged expectations. Thus, the nature of approximation - similar to our algorithm - is that only a finite number of lagged expectations of the Sticky Information Phillips curve are considered. However, the algorithm as such differs from ours. Their key idea is to convert lagged expectations into n-step ahead prediction errors which in turn can be represented as a finite $MA(n)$ process. Wang and Wen (2006) convert the finite MA representation into a standard linear difference system. They claim that a $MA(20)$ process delivers very precise results and thereby include 20 lags of the Sticky Information Phillips curve. Note that our solution method arrives at the same conclusion. Unfortunately, Wang and Wen (2006) do not report how fast their algorithm is in terms of CPU time.

tary policy shock. In addition, we briefly discuss the effects of technology and government expenditure shocks.

Monetary Policy Shock

Figure 3.2 plots the responses of inflation, the output gap, the nominal interest rate and hours worked to a one percent money growth shock for all three models using the baseline parameterization. The sticky information model delivers a hump-shaped pattern of inflation with a maximum impact around the 7th quarter. In period zero when the money growth shock occurs, only the fraction of firms that updated their information in period zero adjust their prices. All other firms remain inattentive and keep setting prices based on outdated information. As time elapses, more and more firms update their information sets and hence change prices in response to the money growth shock. Interestingly, in Mankiw and Reis (2002) original partial equilibrium model, inflation peaks at the 8th quarter after the money growth shock. To that end, our result indicates that sticky information in our DSGE model is able to deliver similar inflation inertia as in Mankiw and Reis (2002). Put differently, we observe a pronounced hump-shape of inflation which indicates that the Sticky Information Phillips curve seems to have a strong internal propagation mechanism in response to a quickly dying out money growth shock in our DSGE model.

Inflation in the standard Calvo sticky price model jumps on impact to its maximum effect and then decreases monotonically. Although prices are sticky inflation is not. By contrast, inflation in the sticky price model with dynamic inflation indexation reacts with delay and gradually to a money growth shock since it is both - forward and backward looking. The maximum impact occurs around the 5th quarter and is somewhat more pronounced than in the sticky information model. However, sticky information and sticky prices with dynamic inflation indexation deliver the same qualitative results for our baseline parameterization.

To that end, we conclude that sticky information generates a delayed and gradual response of inflation to a money growth shock in our DSGE framework. Moreover, the sticky price model with dynamic inflation indexation is also able to deliver a hump-shaped response of inflation.

Sensitivity

Our results depend, of course, on the parameters chosen in section 3.2.6. In this section, we set key parameters to values that represent reasonable bounds of parameter ranges used in the literature. This way, the section serves two purposes. First, it provides a sensitivity analysis for the results reported in the previous section. Second, and more importantly, it enables us to assess the effects of deep parameters of the model on the behavior of inflation especially for the sticky information model.

In particular, we examine how a high inverse Frisch elasticity of $\phi = 6.7$ as in Pencavel (1986) respectively a low inverse Frisch elasticity of $\phi = 0.47$ as used e.g. in Reis (2006) affects the dynamics of inflation in our models. Or baseline value of $\theta = 6$ implies a steady state markup of 20 percent which represents an upper bound in the literature. Alternatively, we set $\theta = 10$ as in Chari, Kehoe, and Mcgrattan (2000) as well as $\theta = 7.88$ as in Rotemberg and Wodford (1997) which imply markups of roughly 11 and 15 percent. Further, our baseline choice of $\sigma = \nu = 2$ implies a moderate degree of intertemporal substitution. Alternatively, we set $\sigma = \nu = 1$ which implies log utility in consumption as in Gali (2003) and many others. Moreover, we also examine the case of high intertemporal substitution by setting $\sigma = \nu = 0.5$.[16] Furthermore, we examine $\alpha = 1$ as in Gali (2003) which results in a linear production technology in hours worked.

Finally, we also allow for variations in information and price rigidity governed by λ_i. In our baseline parameterization we set $\lambda_i = 0.75$ which implies average information updates and price contracts of one year. Recent empirical literature suggests that these values might represent an upper bound. Therefore, we set $\lambda_i = 0.66$ as well as $\lambda_i = 0.5$ which implies average durations of price contracts respectively information updates of 3 and 2 quarters. For sticky price models 3 quarters are in line with Sbordone (2002) while 2 quarters reflect Altig, Christiano, Eichenbaum, and Linde (2004), Bils and Klenow (2004) and Golosov and Lucas (2003) who report that firms change prices on average roughly every 1.5 quarters. Finally, for sticky information models, recent work by e.g. Mankiw and Reis (2006b), Korenok (2004) and Korenok and Swanson (2006) suggest that average durations of information updates of 3 to 2 quarters may not be unrealistic for sticky information models.

Table 3.2 shows the quarter at which inflation peaks after a monetary policy shock in period $t = 0$ for our alternative parameter choices. The table reveals that although the peak of inflation varies the sticky information model as well as the sticky price model with dynamic inflation indexation always generate a delayed response of inflation after a monetary policy shock. By contrast, in the standard Calvo sticky price model inflation peaks always on impact.

Let's examine the effects of deep parameters of the model for the behavior of inflation in the sticky information model. A higher value for θ implies a lower

[16] Note that we set $\sigma = \nu$ in these cases because this implies a unit elasticity of money demand with respect to consumption as documented by the empirical literature, see Walsh (2003) for an excellent survey.

steady state markup and hence results in lower market power for firms. Accordingly, firms change prices less than they would with higher market power and thus inflation peaks later in the sticky information model. A higher value ϕ implies a lower Frisch elasticity of labor supply. Hence, changing labor inputs is more costly for firms in terms of the real wage and therefore they change prices by less which again results in a later peak of inflation. Lower values for σ and ν result in a higher intertemporal elasticity of substitution and therefore lead to less consumption smoothing of households. Thus, aggregate demand displays a steeper intertemporal schedule which is accompanied by an earlier peak of inflation. In addition, a higher value α moves production towards a linear technology and reduces therefore the input costs of firms. Accordingly, inflation attains its peak earlier. Finally, lower values for λ_1 increase the fraction of firms that receive information updates. Therefore, more firms adjust their prices in response to the monetary policy shock which leads to an earlier peak of inflation in the sticky information model.

Finally, to ensure further robustness, we also consider joint variations of parameters. That is, we take many random draws for the parameter set $\{\theta, \phi, \sigma, \nu, \alpha, \lambda_i\}$ and generate the associated impulse responses of inflation for each set. In particular, to construct the above random parameter set, we draw each parameter from the following uniform distributions: $\theta \sim U[6, 10]$, $\phi \sim U[0.47, 6.7]$, $\sigma = \nu \sim U[0.5, 2]$, $\alpha \sim U[0.66, 1]$, $\lambda_i \sim U[0.5, 0.75]$. The intervals of the uniform distributions correspond to the ranges discussed above. We draw 5340 parameter sets and solve the models for each set.[17] Figure 3.3 shows the corresponding impulse responses for each model. Further, we add our baseline impulse responses using white lines. In order to facilitate comparison with respect to the peak of inflation, we normalize all impulse responses such that the initial re-

[17]This takes somewhat more than two weeks on an up-to-date unix machine.

sponse is equal to one, i.e. $\hat{\pi}_0 = 1$. Figure 3.3 reveals that there is not a single response for which inflation is monotonically decreasing after a monetary policy shock in the sticky information model as well as in the Calvo sticky price model with dynamic inflation indexation. In other words, there is always a hump-shape in inflation though it might be short lived. In particular, on average, the peak in the sticky information model occurs at quarter 4.2 while it occurs at quarter 3.4 in the sticky price model with dynamic inflation indexation. These figures are somewhat lower than the reported peaks at quarters 7 and 5 in our baseline sticky information and sticky price with dynamic inflation indexation models. Nevertheless, both models appear to robustly deliver a delayed response of inflation after a monetary policy shock. By contrast, the standard Calvo sticky price model produces always a maximum response on impact. Finally, the white lines in figure 3.3 indicate that our baseline results do not represent an upper or lower bound but are located well within the set of impulse responses that is generated by random parameter draws.

Hence, our analysis shows, that although we vary key parameters in the model inflation reacts with delay to a monetary policy shock in the sticky information model. This is due to the fact that despite considerable parameter variations firms pricing decisions are strategic complements, i.e. $\zeta < 1$. By contrast, Collard and Dellas (2006) as well as Keen (2005) introduce sticky information in alternative DSGE frameworks. These authors report that sticky information models generate maximum inflation responses on impact or at most one quarter after the monetary policy shock. These results occur since their DSGE frameworks imply that firms pricing decisions are strategic substitutes ($\zeta \geq 1$) which produce the early peak of inflation.[18] However, Woodford (2003) surveys and discusses the existing literature at length and concludes that firms pricing deci-

[18]Note that Coibion (2006a) arrives at a similar conclusion.

sions should be strategic complements rather than strategic substitutes to allow for potential inflation inertia. Therefore, in this chapter we allow for sufficient strategic complementarities in firms pricing decisions by employing a commonly used DSGE framework similar to Woodford (2003).

To sum up, our sensitivity analysis shows that the qualitative result of Mankiw and Reis (2002) is also robust in our DSGE framework: inflation reacts with delay and gradually to a monetary policy shock in the sticky information model whereas it does not in the standard Calvo sticky price model. Furthermore, we show that Calvo sticky prices with dynamic inflation indexation and sticky information perform equally well our DSGE model.

Technology and Government Expenditure Shocks

In the previous section we have concluded that inflation behaves inertial after a monetary policy shock. However, in the data inflation is likely to be affected by other disturbances such as supply and government spending shocks. How do they affect inflation in the sticky information model compared to the sticky price models? Mankiw and Reis (2002) are not able to analyze the consequences of these disturbances for the behavior of inflation since their partial equilibrium model did contain monetary policy disturbances only. However, our DSGE model enables us to investigate the effects of technology and government expenditure shocks. Figure 3.4 depicts the effects of a technology shock and figure 3.5 shows the response of the models to a government expenditure shock. Again, inflation peaks on impact in the standard Calvo sticky price model. By contrast, it appears that the reaction of inflation is inertial in the sticky information model in response to these disturbances. Note however, that for our baseline parameterization the peak of inflation occurs somewhat earlier and the hump is less pronounced compared to the monetary shock. Finally, the Calvo sticky price model with dynamic inflation indexation delivers a gradual and delayed response of inflation for technology and government expenditure shocks as well.

A Thought Experiment

Note that we arrive at the above conclusions for given exogenous processes for technology, government spending and money growth as supported by the data. All these processes display relatively high positive autocorrelations and hence shocks to these variables result in a relatively smooth adjustment over time. We do not claim that our findings are invariant to changes in the exogenous processes. Consider the following thought experiment. Imagine that policy behaves deterministically and increases money growth in all even periods and decreases it in all odd periods. Under this policy, sticky information and sticky prices with dynamic inflation indexation would appear to be very different. That is, sticky information firms would mimic the deterministic behavior of monetary policy by setting prices appropriately in all periods e.g. inflation would display a flip-flop pattern. By contrast, sticky price firms would need to set one average profit maximizing price which might then be adjusted smoothly due to dynamic inflation indexation and therefore inflation would still display a smooth pattern. Hence, under these circumstances, both models would appear very differently with respect to e.g. inflation.

However, given empirical evidence on money growth there does not seem to be a deterministic flip-flop pattern. Rather, money growth appears to be fairly smooth with an AR(1) coefficient around 0.5. Hence, although the upper example is illustrative, we consider it as a thought experiment which does not represent observed policy.

Again, given our DSGE model and given the observed exogenous processes sticky information and sticky prices with dynamic inflation indexation appear to perform equally well.

3.3.2 Announced Disinflations

In this section, we analyze the effects of a disinflation that is announced two years in advance. In particular, in period $t = 0$ the central bank announces credibly that it will reduce money growth temporarily from period $t = 2$ (respectively the 8th quarter) onwards. The credibly announced fall in money growth is temporary in the sense that we assume the same stationary process for money growth as before.[19] See appendix A.2 for the technical modeling details.

Figure 3.6 shows the impulse responses to the announced temporary fall in money growth. Again, our DSGE model confirms Mankiw and Reis (2002) result that in the sticky information model a credibly announced disinflation is contractionary with respect to output. Interestingly, the Sticky Information Phillips curve leads to a gradual and delayed downward adjustment of inflation already in the announcement period. It should be stressed that this result is different from Mankiw and Reis (2002) finding. They show that there is absolutely no reaction of inflation in response to the announcement. In their model, variables react only when policy comes into place. By contrast, we show that inflation starts reacting already when the announcement is made. This is due to the existence of perfectly informed and forward looking households which smooth the drop of consumption over time. Despite the reduction of inflation in the pre-

[19] Hence, the disinflation in our experiment is temporary which implies that inflation returns to its steady state. Mankiw and Reis (2002) have considered a permanent reduction of money growth in their original model. We have recalculated the effects of a temporary disinflation in the original Mankiw and Reis (2002) model as well as considered a permanent disinflation in our model. None of our qualitative conclusions, however, changes when considering these alternative cases.

announcement period the disinflation still turns out to be contractionary due to perfectly informed forward looking households and an interest elastic real money demand equation. Since a similar argument applies for the sticky price models, we will explain the detailed mechanism below.

The standard New Keynesian Phillips curve generates an immediate downward jump of inflation whereas the New Keynesian Phillips curve with dynamic inflation indexation leads to a gradual and delayed downward adjustment of inflation in the announcement period. However, in both models, it turns out that the announced disinflations are contractionary too. By contrast, Mankiw and Reis (2002) as well as Ball (1994) find that for standard Calvo sticky price models announced and credible disinflations cause booms rather than recessions. However, this result is not robust in our fully-fledged DSGE framework.

The reason that we observe a fall of output despite the fall of inflation in the announcement period are perfectly informed and forward looking households and real money demand that depends on the nominal interest rate in our DSGE model. Consider the rewritten log-linearized real money demand equation (A.2) from appendix A.1 assuming exogenous technology and exogenous government expenditures are constant:

$$\hat{m}_t = \frac{\sigma}{s_c \nu}\hat{x}_t - \eta \hat{R}_t \tag{3.20}$$

where $\eta = \frac{1}{\nu(\bar{R}-1)}$. The announced fall of inflation has two effects. First, it decreases the nominal interest rate. Second, it increases real money demand. So, it depends on the relative size of each effect, whether the output gap increases or decreases. As it turns out, the interest rate effect dominates for reasonable parametrizations. That is, even if we assume an empirically implausible interest rate elasticity of real money demand which is 25 times smaller then in our baseline parameterization (e.g. by setting $\sigma = \nu = 50$ in equation (3.18) in section

3.2.6) still the interest rate effect dominates and thus the announced disinflation is contractionary with respect to output.[20]

Note, that for $\eta = 0$ only the real money demand effect influences equation (3.20) and hence, the output gap increases in response to a credibly announced disinflation. Thus, it is the exogenously assumed quantity equation which is inelastic with respect to the nominal interest rate that produces the disinflationary boom in the sticky price models in Ball (1994) and Mankiw and Reis (2002). This leads us to conclude that credibly announced disinflations are contractionary even if inflation falls in the announcement period as soon as aggregate demand arises from an intertemporal household maximization problem and real money demand is elastic with respect to the nominal interest rate. It should be mentioned here that for a model with Taylor wage contracts Ascari and Rankin (2002) arrive at a similar conclusion.

To sum up, in this section, we have shown that credibly announced disinflations are contractionary in the sticky information as well as in the Calvo sticky price with and without dynamic inflation indexation models in our DSGE framework.

3.3.3 Acceleration Phenomenon

Similar to Mankiw and Reis (2002), table 3.3 provides values for the correlation between output and the annual change of inflation. We use logged and hp-filtered quarterly US CPI (all items) and real GDP data from 1960:1 to 2001:4. As it turns out, the data suggest a positive correlation between output and the annual change of inflation of about 0.41. For the models we obtain hp-filtered correlation figures by averaging the results of 250 simulations for each model

[20] Korenok and Swanson (2006) report a similar result. They show that the disinflationary boom occurs only for very low interest rate elasticities. As soon as the interest elasticity increases to reasonable values as reported in Lucas (2000) or Chari, Kehoe, and Mcgrattan (2000) - which are in line with our baseline parameterization - the disinflationary boom disappears and turns into a recession.

with a simulation length equal to US data. Consider the first column of table 3.3. It reports the correlation for the models using all three shocks. The sticky information model generates a correlation of 0.55. This is similar to Mankiw and Reis (2002) original partial equilibrium sticky information model which delivers a correlation of 0.43. To that end, we conclude that sticky information in our DSGE model is able to replicate the third conventional view that vigorous economic activity speeds up inflation.

Interestingly, the Calvo sticky price model with dynamic inflation indexation produces a correlation of 0.66. Hence, this model is qualitatively also able to explain the third conventional view and performs similar to the sticky information model. By contrast, the standard Calvo sticky price model generates only a very low correlation of about 0.05. However, since monetary, fiscal and technology shocks have different effects we also compute the correlations if either one of the shocks is used. Columns 2, 3 and 4 reveal that the standard Calvo sticky price model generates a negative correlation for monetary and government expenditure shocks whereas the correlation is positive for technology shocks. Hence, it depends on the relative weight of the technology shock whether the standard Calvo sticky price model can generate the acceleration phenomenon. By contrast, the sticky information model as well as the Calvo sticky price model with dynamic inflation indexation imply positive correlations for all three shocks and thus we conclude that those models may be better suited to explain the third conventional view.

3.3.4 Still Improvable...

How well can the models explain the lead and lag behavior of e.g. inflation in the data? In order to examine this issue, we compare the hp-filtered crosscorrelations of variables to output in the model in the presence of technology, monetary and fiscal shocks with crosscorrelations in the data.[21] Figure 3.7 reports that inflation lags up to 4-5 quarters behind output in the data. The standard Calvo sticky price model is not able to deliver this feature. By contrast, the sticky information model and the Calvo sticky price model with dynamic inflation indexation perform equally well and are able to match the empirical evidence for inflation quite well.

Although the behavior of inflation in the data can be captured by the sticky information and sticky price model with dynamic inflation indexation there are some shortcomings with respect to other variables. E.g. figure 3.7 shows that the crosscorrelation of nominal interest rates and real marginal costs with output cannot be explained within our framework. In order to account for this one might want to introduce sticky information in labor and asset markets to the model. Alternatively, limited participation and nominal labor market frictions may help to explain these facts. Further, the introduction of real frictions like habit formation might also help to improve the match with the data for these variables. Moreover, alternative monetary policy rules like Taylor-type interest rate feedback rules with and without interest rate smoothing, McCallum rules, nominal income targeting rules etc. may help to further improve the performance of the model. Further, deriving optimal monetary policy and optimal simple and implementable monetary policy rules especially for the sticky information model might deliver further insightful results. However, all these

[21]We use quarterly hp-filtered US time series from 1960:1 to 2001:4. Inflation is the quarterly change in the log CPI (all items) and output is log real GDP.

extensions are beyond the scope of this chapter and we leave them to future research.

3.4 Conclusion

Mankiw and Reis (2002) have proposed sticky information as an alternative to Calvo sticky prices in order to model the conventional view that i) inflation reacts with delay and gradually to a monetary policy shock, ii) announced and credible disinflations are contractionary and iii) inflation accelerates with vigorous economic activity. We use a fully-fledged DSGE model with sticky information and compare the results to those when Calvo sticky prices with and without dynamic inflation indexation are assumed instead.

Regarding the sticky information model our results confirm the finding by Mankiw and Reis (2002): all three effects listed above can be replicated in our baseline DSGE model as well. A sensitivity analysis reveals that this result is robust with respect to parameter variations. However, general equilibrium features such as forward looking households and interest elastic money demand are nevertheless important. In particular, we find that e.g. inflation and the output gap in the sticky information model react already in the announcement periods to an announced disinflation due to consumption smoothing households and interest elastic money demand in general equilibrium. Further, we show that a Calvo sticky price model without dynamic inflation indexation can already match the conventional view that announced and credible disinflations are contractionary due to the existence of interest elastic money demand in general equilibrium in our baseline DSGE model. This result appears to be robust within our DSGE framework. Finally, we allow for dynamic inflation indexation in the Calvo sticky price model and show that in our baseline DSGE framework this works just as well as sticky information in delivering all three effects. Again, our result appears to be robust to variations in key structural parameters of the model.

We conclude that sticky information as in Mankiw and Reis (2002) as well as sticky prices with dynamic inflation indexation as in Christiano, Eichenbaum, and Evans (2005) are perfectly capable of replicating the conventional wisdom with respect to inflation inertia, announced disinflations and the acceleration phenomenon in the DSGE model used in this chapter. However, the source of e.g. inflation inertia in both models is different. In the sticky information model, inflation inertia arise due to slow information diffusion. In the sticky price model with dynamic inflation indexation, inflation inertia is hard-wired by assuming that non-optimizing firms index prices to past inflation. Hence, these firms use a very limited outdated information set. From that perspective, one might want to view information stickiness as providing a micro foundation for the particular choice of dynamic inflation indexation in Calvo sticky price models. Although both models perform equally well with respect to our measures, we believe that sticky information might be better suited to explain the underlying micro behavior of price setting firms.

3.5 Tables and Figures

Table 3.1: Baseline Parameterization of the DSGE Model

Variable	Value	Description
β	0.99	Subjective discount factor
σ	2	Relative risk aversion
ϕ	1.5	Inverse Frisch elasticity
ν	2	Elasticity of real money balances
α	$\frac{2}{3}$	Labor share
λ_i	0.75	Price stickiness resp. information rigidity
$\frac{\theta}{\theta-1}$	1.2	Steady state markup of 20 percent
s_c	0.7	Consumption to output ratio in steady state
$\bar{\Pi}$	1	Steady state gross inflation
ρ_z, σ_z	0.95, 0.71	Technology shock
ρ_ξ, σ_ξ	0.50, 0.80	Money growth shock
ρ_g, σ_g	0.95, 0.60	Government expenditures shock

Table 3.2: Sensitivity Analysis: The Peak of Inflation

			θ		ϕ		$\sigma = \nu$		α
		baseline	10	7.88	6.7	0.47	1.0	0.5	1.0
$\lambda_i = 0.75$	sticky information	**7**	8	8	8	5	5	3	5
	sticky prices (index)	**5**	6	5	6	4	4	3	4
	sticky prices	**0**	0	0	0	0	0	0	0
$\lambda_i = 0.66$	sticky information	5	6	5	6	3	3	2	4
	sticky prices (index)	4	4	4	4	3	3	2	3
	sticky prices	0	0	0	0	0	0	0	0
$\lambda_i = 0.50$	sticky information	2	3	3	3	2	2	1	2
	sticky prices (index)	2	3	2	3	2	2	1	2
	sticky prices	0	0	0	0	0	0	0	0

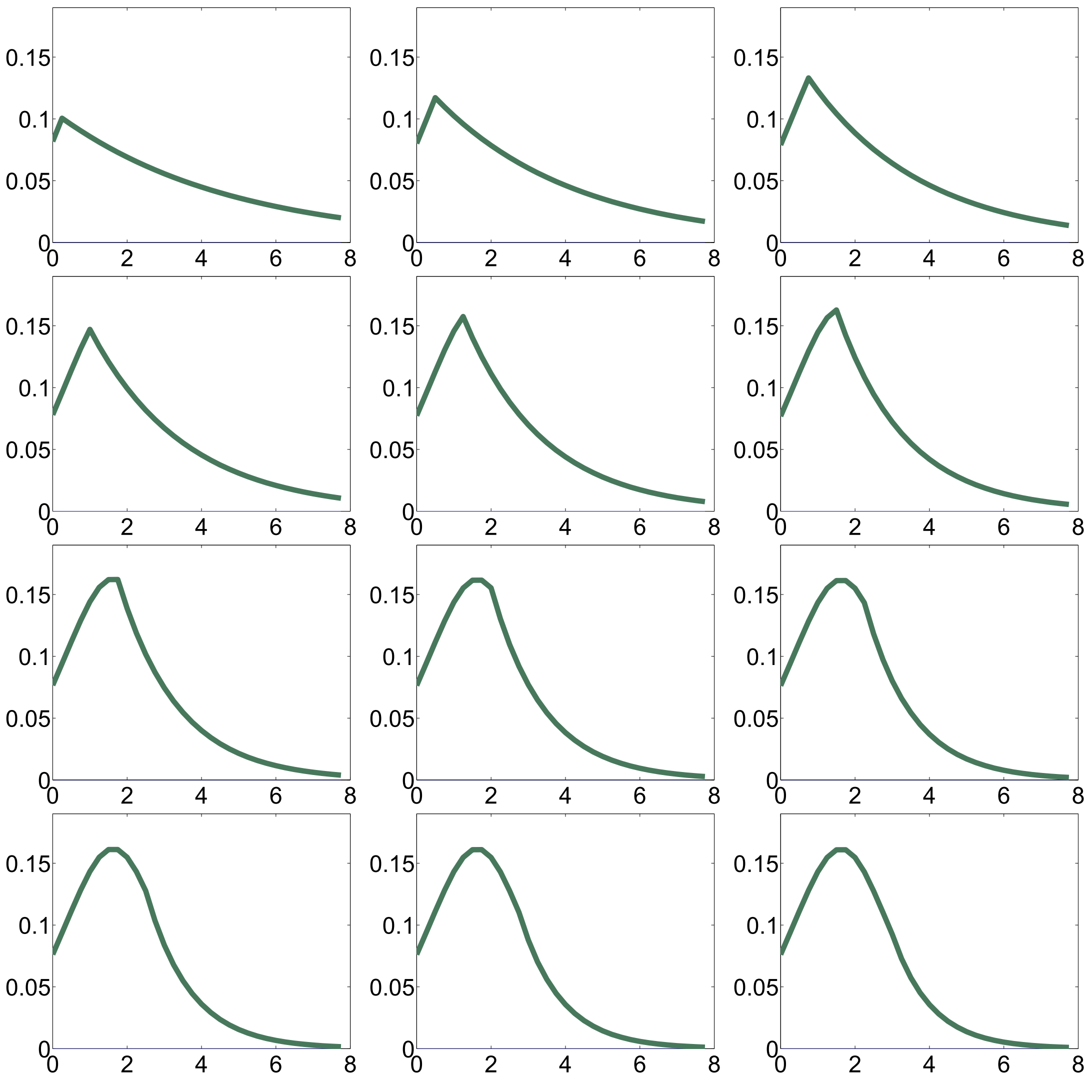
Notes: Quarter at which inflation achieves the peak after a money growth shock for alternative parameter choices. The baseline parameters correspond to our baseline parameterization i.e. $\theta = 6$, $\phi = 1.5$, $\sigma = \nu = 2$, $\alpha = 2/3$.

Table 3.3: Acceleration Phenomenon: Models vs. Data

	Corr($\hat{y}_t$,$\hat{\pi}_{t+2} - \hat{\pi}_{t-2}$)			
	all shocks	mon. shock	gov. shock	tech. shock
sticky information (DSGE)	**0.55**	0.60	0.31	0.61
sticky prices (Index), (DSGE)	**0.66**	0.72	0.51	0.65
sticky prices (DSGE)	**0.05**	-0.002	-0.13	0.56
sticky information (Mankiw-Reis)	**0.43**	–	–	–
sticky prices (Mankiw-Reis)	**-0.13**	–	–	–
data	**0.41**			

Notes: Acceleration phenomenon: correlation of output with the annual change of inflation. We use logged and hp-filtered quarterly US CPI (all items) and real GDP data. We obtain hp-filtered crosscorrelation figures by averaging the results for 250 simulations for each model with a simulation length equal to US data.
The source of uncertainty in the Mankiw and Reis (2002) model is an exogenous money supply shock. However, in their model this shock can also be interpreted as a shock to nominal income so that we report their results here at the column "all shocks".

Figure 3.1: Illustrating the Solution Method



Notes: Impulse responses of inflation to a money growth shock for a stepwise inclusion of lagged expectations in the Sticky Information Phillips curve. The first plot in the top row shows the response of inflation if the model uses $\hat{\pi}_t = \frac{1-\lambda_1}{\lambda_1}\zeta\hat{x}_t + (1-\lambda_1)E_{t-1}[\hat{\pi}_t + \zeta\triangle\hat{x}_t]$. *The next plot depicts the response of inflation if the model uses* $\hat{\pi}_t = \frac{1-\lambda_1}{\lambda_1}\zeta\hat{x}_t + (1-\lambda_1)E_{t-1}[\hat{\pi}_t + \zeta\triangle\hat{x}_t] + (1-\lambda_1)\lambda_1 E_{t-2}[\hat{\pi}_t + \zeta\triangle\hat{x}_t]$ *etc. The x-axis plots years, the y-axis plots percent deviations from steady state.*

Figure 3.2: Impulse Responses to a 1% Shock in Money Growth

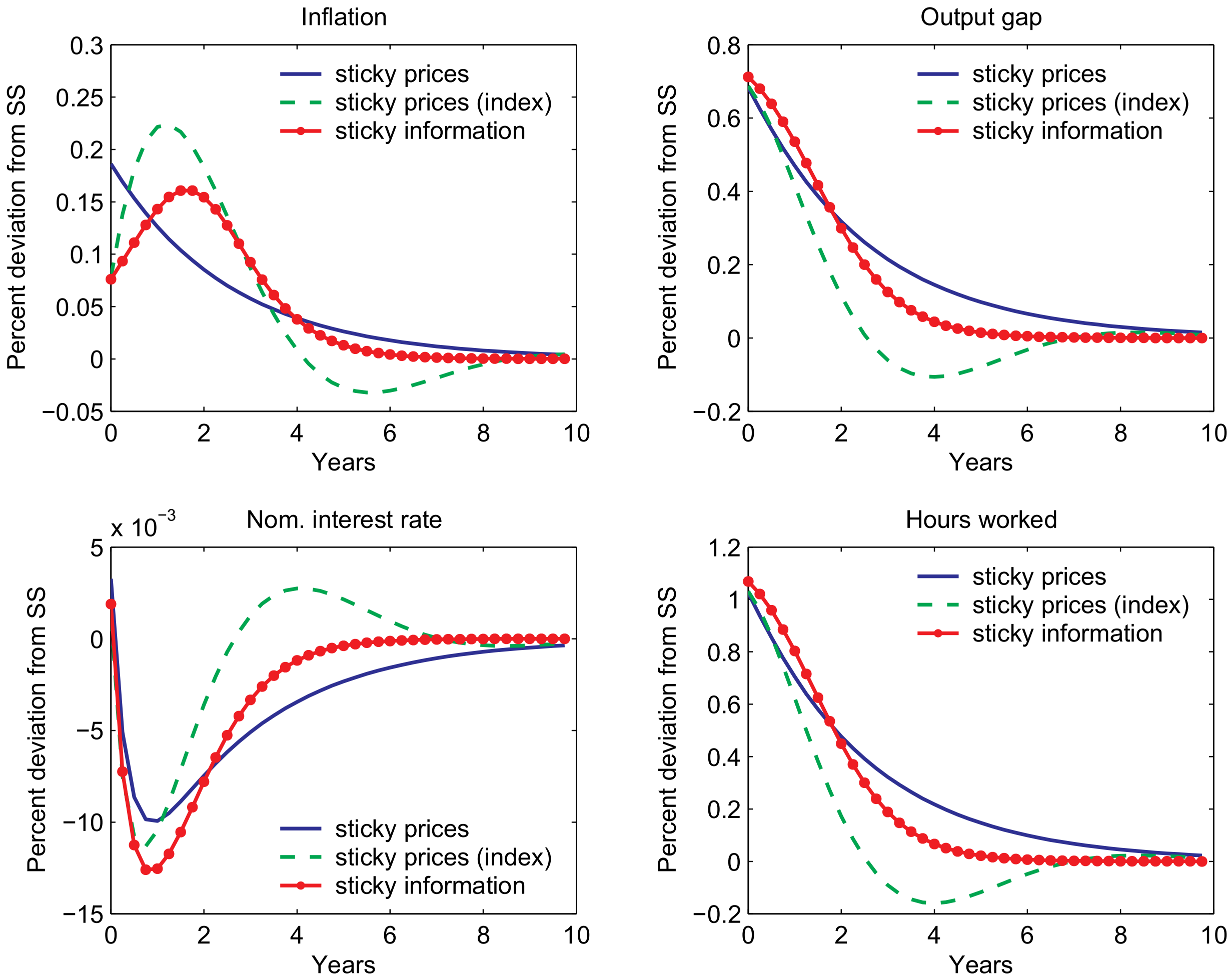
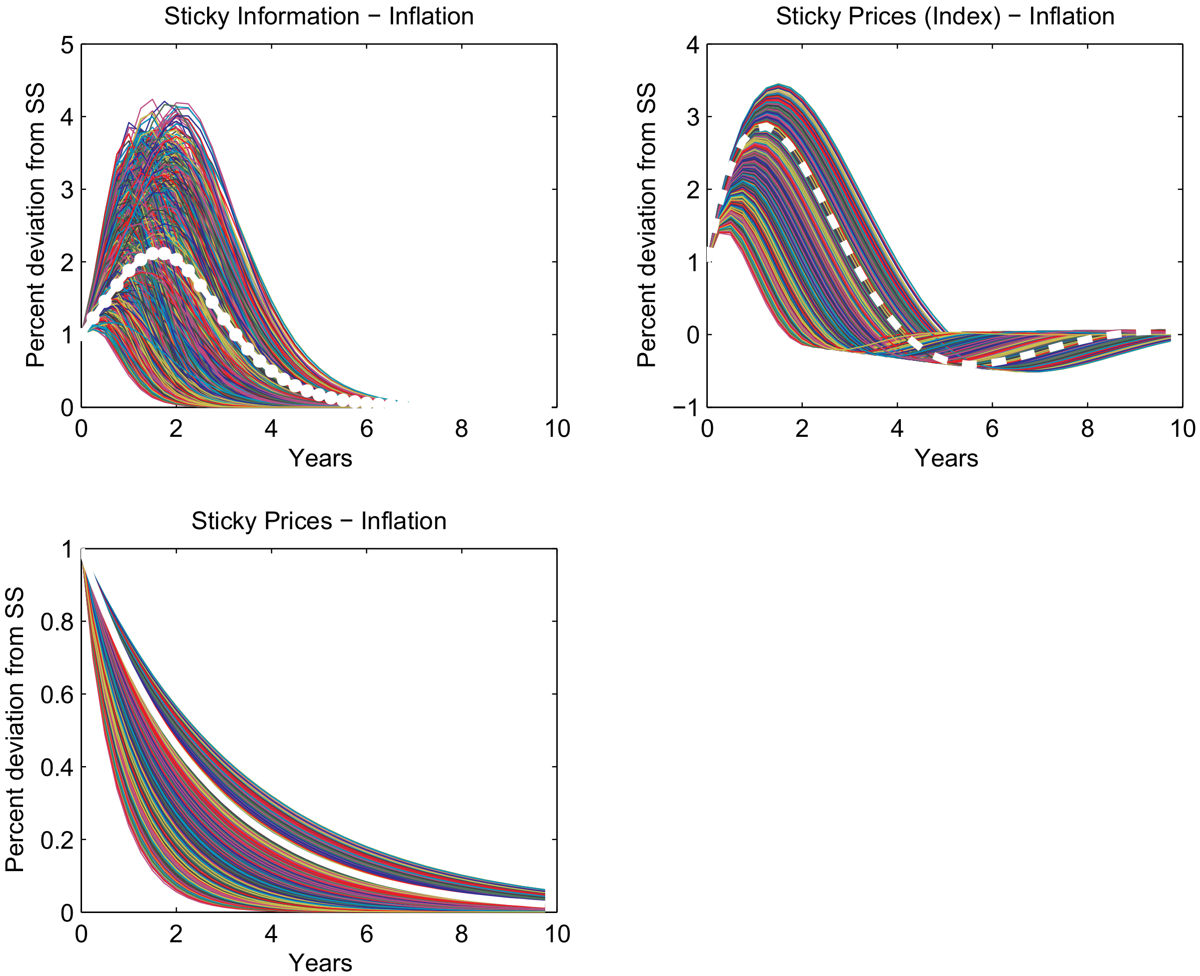


Figure 3.3: Sensitivity: Inflation Responses to a 1% Shock in Money Growth



Notes: Sensitivity of inflation after a money growth shock. Each impulse response is generated after parameters have been drawn from the following uniform distributions: $\theta \sim U[6, 10]$, $\phi \sim U[0.47, 6.7]$, $\sigma = \nu \sim U[0.5, 2]$, $\alpha \sim U[0.66, 1]$, $\lambda_i \sim U[0.5, 0.75]$. *Total number of drawn parameter sets: 5340. The white lines show the baseline impulse responses of our model. In order to facilitate comparison with respect to the peak of inflation, we normalize all impulse responses such that the initial inflation response is equal to one, i.e.* $\hat{\pi}_0 = 1$.

Figure 3.4: Impulse Responses to a 1% Shock in Technology

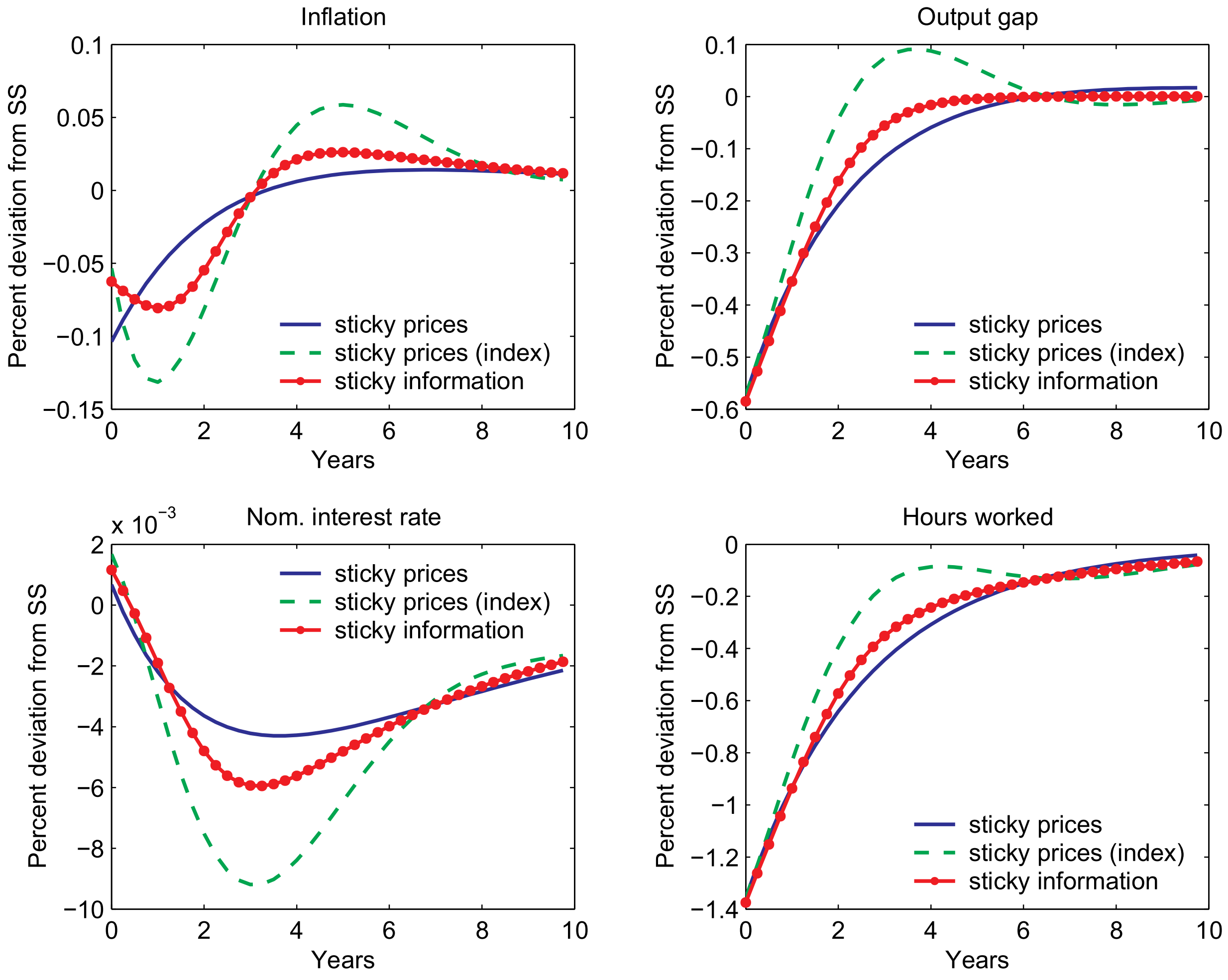


Figure 3.5: Impulse Responses to a 1% Shock in Government Expenditures

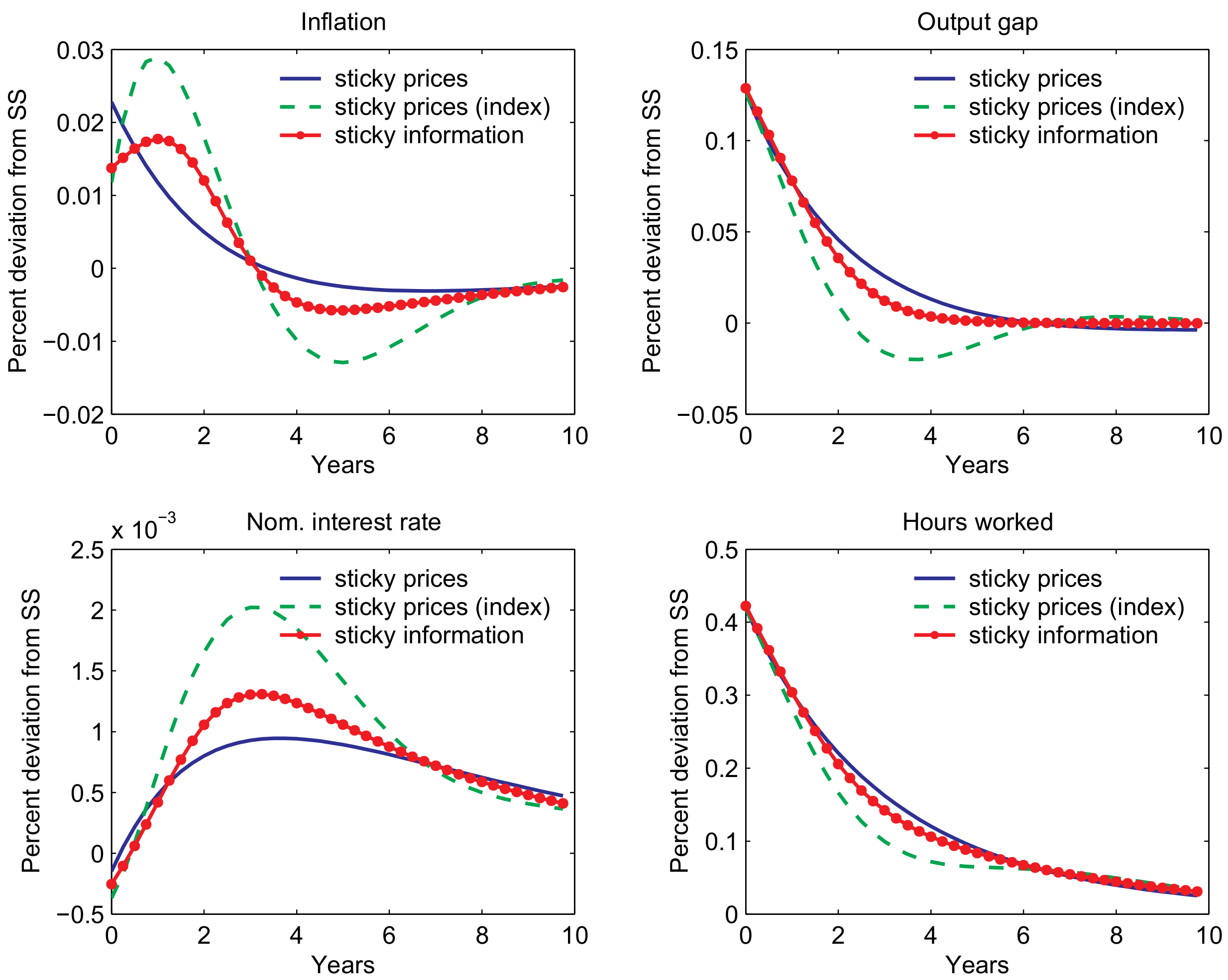
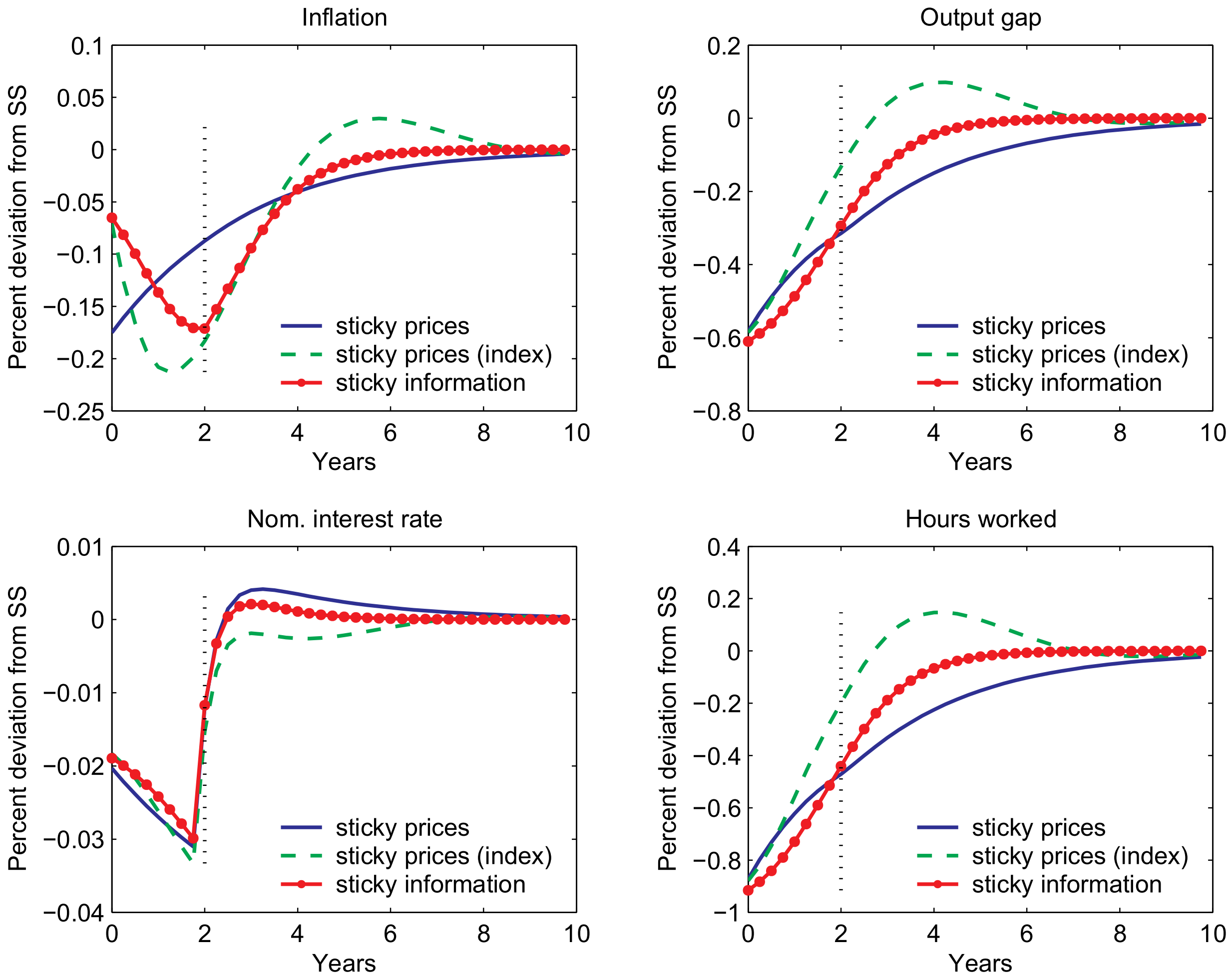
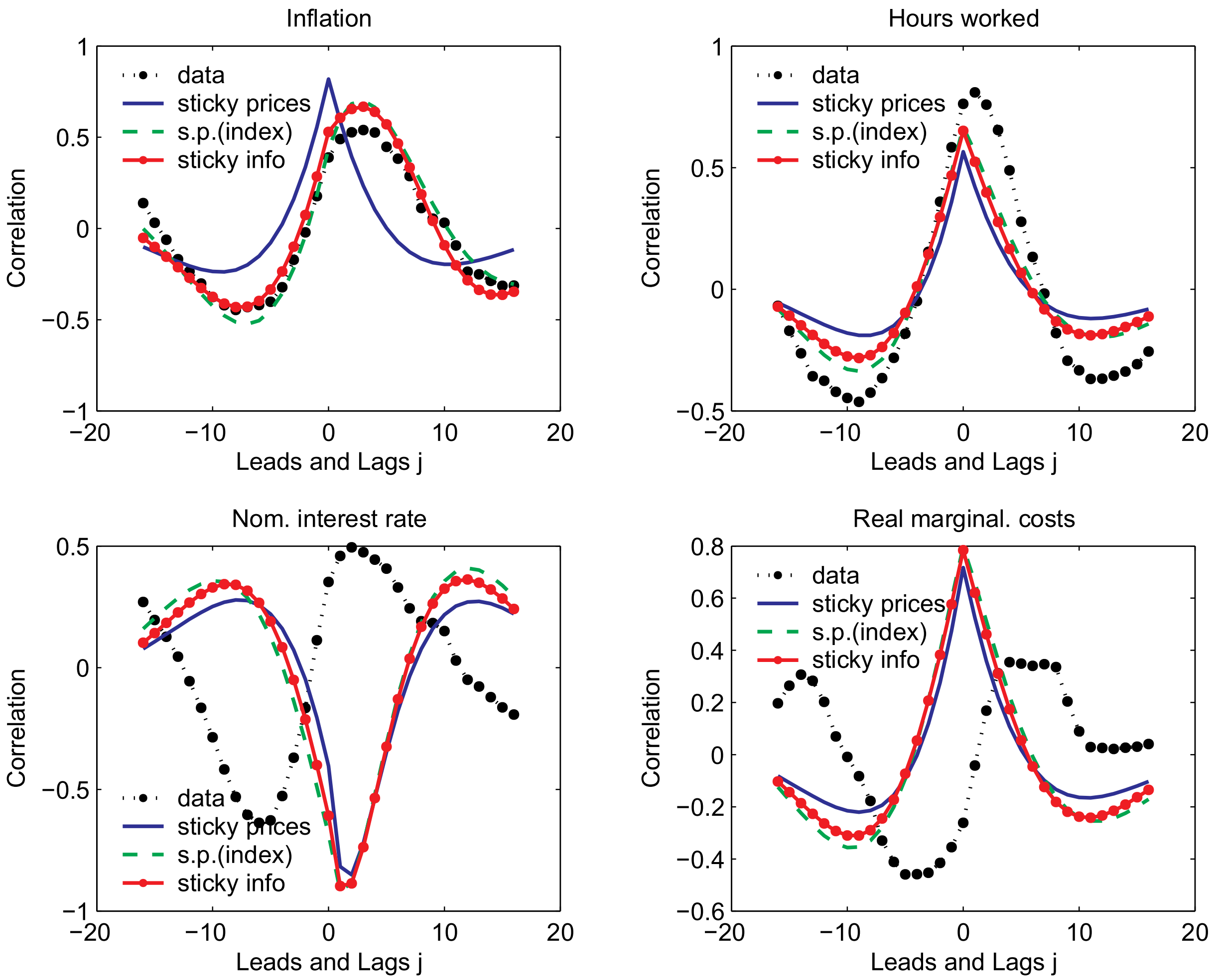


Figure 3.6: Impulse Responses to a Credibly Announced Disinflation



Notes: Impulse responses of model variables to a credible announcement at $t = 0$ that money growth will fall temporarily from period $t = 2$ onwards.

Figure 3.7: Crosscorrelation of Variables $(t+j)$ with Output (t)



Notes: Frequency domain techniques are used to obtain crosscorrelations for the model variables. We use quarterly hp-filtered US time series from 1960:1 to 2001:4 (all in logs). Inflation is the quarterly change of the CPI (all items). The nominal interest rate is a three month government bond yield. We use a manufacturing employment index for hours worked. Output is real GDP and real marginal cost are CPI deflated unit labor cost.

4 How Far Are We From The Slippery Slope? The Laffer Curve Revisited (with Harald Uhlig)

How does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? The Laffer curve provides us with a framework to analyze this question. Hence, the goal of this chapter is to examine the shape of the Laffer curve quantitatively in a simple neoclassical growth model calibrated to the US as well as to the EU-15 economy. We show that the US and the EU-15 area are located on the left side of their labor and capital tax Laffer curves, but the EU-15 economy being much closer to the slippery slopes than the US. Our results indicate that since 1975 the EU-15 area has moved considerably closer to the peaks of their Laffer curves. We find that the slope of the Laffer curve in the EU-15 economy is much lower than in the US which documents a higher degree of distortions in the EU-15 area. A dynamic scoring analysis shows that more than one half of a labor tax cut and more than four fifth of a capital tax cut are self-financing in the EU-15 economy. Therefore, we conclude that there are higher incentive effects in the EU-15 compared to the US in response to tax cuts.

"The supply-side economists...have delivered the largest genuinely free lunch I have seen in 25 years in this business, and I believe we would have a better society if we followed their advice."

Robert E. Lucas (1990)

4.1 Introduction

This chapter attempts to answer the following question: how does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? Hence, the present chapter concentrates on the incentive effects for households and firms in response to changes in taxation. Given a tax cut, are the incentives to change consumption, hours worked and investment higher or lower in the US compared to the EU-15 economic area? The answer to this question has important consequences for the evolution of e.g. government tax revenues. Put differently, is a tax cut more or less self-financing in the US compared to the EU-15 economy? In order to address these questions of economic interest we use a neoclassical growth model extended to include fiscal policy. Interestingly, the model exhibits an inverted U-shape relationship between taxes and tax revenues - the so-called Laffer curve. The Laffer curve provides us with a framework to think about the incentive effects and hence the degree of self-financing of tax cuts.

Thus, the fourth chapter of this dissertation sheds new light on an old debate - the shape of the Laffer curve. In 1974 Arthur B. Laffer noted during a business dinner that "there are always two tax rates that yield the same revenues".[1] After being asked, he illustrated the trade-off between tax rates and tax revenues on his restaurant napkin. In the 1980's, the so-called supply-side economists claimed that the US were on the right hand or slippery slope side of the Laffer curve and

[1] see Wanniski (1978).

therefore, tax cuts would increase tax revenues. In response to the Reagan tax cuts, however, government tax revenues dropped. Perhaps then, the US was on the left side of the Laffer curve.

Thus, one ought to investigate the left side of the Laffer curve more closely. This is important for two reasons. First, the knowledge of the *peak* is important: if it is close, one should be careful about raising taxes to avoid the slippery slope side. Second, the *slope* reminds us of the incentive effects of tax changes. How strong are these effects quantitatively?

The goal of chapter four is a quantitative assessment of the positions of the US and EU-15 economies on their respective Laffer curves by employing a simple calibrated neoclassical growth model. Further, we examine how incentives have changed over time by analyzing how the economies have shifted over time on their Laffer curves. Finally, our analysis enables us to explicitly determine the incentive effects expressed as degrees of self-financing of tax cuts in each respective economic area.

We model each economic area as a closed economy. In the model, the government collects distortionary taxes on labor, capital and consumption and issues debt to finance government consumption, lump-sum transfers and debt repayments. We calibrate key parameters to the US economy as well as to the EU-15 economic area.

We use three different preference specifications to achieve this goal. An important quantity is the Frisch elasticity of labor supply. While it is equal to 3 for a Cobb-Douglas specification of the preferences in our baseline calibration, it is set to roughly 0.25 for a Greenwood-Hercowitz-Huffman specification, while both deliver the same result on a key tax experiment. We also provide a sensitivity analysis as well as an analysis for individual European countries.

We show that there exist steady state Laffer curves for labor taxes as well as capital taxes. This result is robust with respect to variations of preferences of the household. For consumption taxes, however, the existence of a Laffer curve depends on the underlying preferences.

According to the predictions of the model both economies - the US and the EU-15 area - are located on the left side of their Laffer curves, but the EU-15 economy being much closer to the slippery slopes than the US.

We examine how the US and the EU-15 area have shifted on their Laffer curves between 1975 and 2000. We show that the US has moved closer to the peak for labor taxes while it has hardly shifted relative to the peak for capital taxes. By contrast, the EU-15 area has moved considerably closer to the peak for both - labor and capital taxes.

An individual country analysis for the EU-15 area reveals that in terms of labor taxes all individual EU-15 countries are closer to the slippery slopes of their Laffer curves than the US. For capital taxes this conclusion holds also for the majority of countries in the EU-15 area. Finally, the long-run slopes of the labor and capital tax Laffer curves are smaller in all individual EU-15 countries compared to the US.

We quantify the dynamic impact of unexpected and announced tax cuts, financed by corresponding cuts in government spending. The results for our baseline calibration are as follows. For US capital taxes, we find that an unexpected permanent 1% tax cut corresponds to an endogenous *cut* of government spending of 1.6% on impact and 0.8% in the long-run. A 5-years-in-advance announced permanent 1% cut of capital taxes leads to an endogenous *increase* of government spending of up to 0.4% during the announcement period and a *cut* of government expenditures of 0.8% in the long-run. For the EU-15 economy, we obtain the same qualitative results. However, quantitatively, the figures are smaller than in the US. Thus, the slope of the Laffer curve in the EU-15 economy is much lower than in the US documenting higher distortions in the EU-15 area.

To that end, our analysis indicates that the incentive effects to increase consumption, hours worked and investment due to tax changes are stronger in the EU-15 than in the US. For a given cut in taxes, EU-15 tax revenues fall by less than in the US as documented by the lower slope of the Laffer curve in the EU-15.

Following Mankiw and Weinzierl (2005), we pursue a dynamic scoring exercise. That is, we analyze by how much a tax cut is self-financing if we take incentive feedback effects into account. We find that for the US model 19% of a labor tax cut and 47% of a capital tax cut are self-financing in the steady state. In the EU-15 economy 54% of a labor tax cut and 85% of a capital tax cut are self-financing. Hence, the efficiency gains from cutting taxes in the EU-15 area are considerably larger than in the US economy. Thus, a tax cut may not deliver a free lunch. However, a large fraction of the lunch will typically be paid for by the efficiency gains in the economy due to tax cuts.

The chapter is organized as follows. We specify the model in section two. Section three discusses our results. Finally, section four concludes.

4.2 The Model

We use a standard neoclassical growth model extended to include fiscal policy.[2] In particular, the government collects distortionary taxes on labor, capital and consumption and issues debt to finance government consumption, lump-sum

[2]Following Prescott (2002, 2004) we abstract from a monetary sector. See Leeper and Yun (2005) for an exposition of the fiscal theory of the price level with monetary-fiscal policy interactions and their effects on the Laffer curve.

transfers and debt repayments. We model the US and the EU-15 economy each as a closed economy.[3] Time is discrete, $t = 0, 1, ..., \infty$.

The representative household maximizes the discounted sum of life-time utility subject to an intertemporal budget constraint and a capital flow equation. Formally,

$$max_{c_t,n_t,k_t,x_t,b_t} \quad E_0 \sum_{t=0}^{\infty} \beta^t \left[u(c_t, n_t) + v(g_t) \right]$$

s.t.

$$\begin{aligned} (1+\tau_t^c)c_t + x_t + b_t &= (1-\tau_t^n)w_t n_t + (1-\tau_t^k)(d_t - \delta)k_{t-1} \\ &\quad + \delta k_{t-1} + R_t^b b_{t-1} + s_t + \Pi_t \\ k_t &= (1-\delta)k_{t-1} + x_t \end{aligned}$$

where c_t, n_t, k_t, x_t, b_t denote consumption, hours worked, capital, investment and government bonds. The household takes government consumption g_t, which provides utility, as given.[4] Further, the household receives wages w_t, dividends d_t and profits Π_t from the firm. Moreover, the household obtains interest earnings R_t^b and lump-sum transfers s_t from the government. The household has to pay consumption taxes τ_t^c, labor income taxes τ_t^n and capital income taxes τ_t^k. Note that capital income taxes are levied on dividends net-of-depreciation as in Prescott (2002, 2004) and in line with Mendoza, Razin, and Tesar (1994).

[3] This assumption implies that input factor markets for labor and capital are internationally independent. Labor immobility between the US and the EU-15 is a well known fact and a commonly used assumption in the literature. For capital the closed economy assumption can be motivated by either the Feldstein and Horioka (1980) observation that domestic saving and investment are highly correlated or by interpreting the model in the light of ownership-based taxation instead of source-based taxation. In both cases changes in fiscal policy will have only minor cross border effects. However, for explicit tax policy in open economies, see e.g Mendoza and Tesar (1998) or Kim and Kim (2004) and the references therein.

[4] For similar models with valuable government spending see e.g. Christiano and Eichenbaum (1992), Baxter and King (1993), McGrattan (1994), Lansing (1998), Cassou and Lansing (2006), Klein, Krusell, and Rios-Rull (2004) as well as chapter five of this dissertation.

The representative firm maximizes its profits subject to a Cobb-Douglas production technology,

$$max_{k_{t-1},n_t} \quad y_t - d_t k_{t-1} - w_t n_t \tag{4.1}$$

s.t.

$$y_t = z_t k_{t-1}^{\theta} n_t^{1-\theta} \tag{4.2}$$

where z_t denotes total factor productivity which is defined as $z_t = \xi^t \gamma_t$. We assume that γ_t follows a stationary stochastic AR(1) process.

The government faces the following budget constraint,

$$g_t + s_t + R_t^b b_{t-1} = b_t + T_t \tag{4.3}$$

where government tax revenues T_t can be summarized as

$$T_t = \tau_t^c c_t + \tau_t^n w_t n_t + \tau_t^k (d_t - \delta) k_{t-1}. \tag{4.4}$$

We assume that lump-sum transfers s_t as well as the three tax rates on labor, capital and consumption follow exogenous AR(1) processes. To keep things simple, we assume that government consumption is adjusted accordingly to balance the government budget. Thus, we assume that government debt does not deviate from its balanced growth path[5] i.e. $b_{t-1} = \psi^t \bar{b} \quad \forall t \geq 0$ and therefore the government budget (4.3) can be rewritten as

$$g_t = \psi^t \bar{b}(\psi - R_t^b) + T_t - s_t. \tag{4.5}$$

[5]This assumption is similar to Lucas (1990). For models with variable debt and alternative financing forms, see e.g. Ludvigson (1996) or Schmitt-Grohe and Uribe (1997) and the references therein.

4.2.1 Equilibrium

In equilibrium the household chooses plans to maximize its utility, the firm solves its maximization problem and the government sets policies that satisfy its budget constraint. Except for hours worked, interest rates, taxes and the stationary component of technology, all other variables grow at a constant rate $\psi = \xi^{\frac{1}{1-\theta}}$. In order to obtain a stationary solution, we detrend all non-stationary variables by the balanced growth factor ψ^t. Appendix B.1 summarizes the equations that describe the stationary equilibrium. For the dynamics, we log-linearize the equations around the balanced growth path and use Uhlig (1999) to solve the model. See appendix B.2 for a description of the system of log-linearized equations.

4.2.2 Preference Specifications

We consider three different utility functions for the representative agent. First, we assume a standard Cobb-Douglas utility function, $U_{c-d}(c_t, n_t) = \frac{(c_t^\alpha(1-n_t)^{1-\alpha})^{1-\eta}-1}{1-\eta}$ as in Cooley and Prescott (1995), Chari, Christiano, and Kehoe (1995) or Uhlig (2004). We consider this as our favorite preference specification since it is most widely used in the macroeconomic literature. Second, we analyze the model when a power utility function $U_{pow}(c_t, n_t) = \frac{(\frac{c_t}{\psi^t})^{1-\eta'}-1}{1-\eta'} - \kappa' \frac{1}{1+\phi'} n_t^{1+\phi'}$ is assumed as in Clarida, Gali, and Gertler (2002), Gali (2003), King and Rebelo (1999) or Merz (1995). Finally, we consider the case of GHH preferences as in Greenwood, Hercowitz, and Huffman (1988) or Correia, Neves, and Rebelo (1995). In this case utility takes the following form: $U_{ghh}(c_t, n_t) = \frac{(c_t - \kappa'' \psi^t \frac{1}{1+\phi''} n_t^{1+\phi''})^{1-\eta''}-1}{1-\eta''}$. Note that we augment POW and GHH preferences by ψ^t to obtain a formulation that is consistent with balanced growth.

4.2.3 Calibration and Parameterization

We calibrate the model to post-war data of the US and EU-15 economy. For data on tax rates, we are grateful to Carey and Rabesona (2002) to have obtained their dataset. The authors recalculate average tax rates on labor, capital and consumption from 1975 to 2000 following the methodology developed by Mendoza, Razin, and Tesar (1994).[6]

In principle, there are five arguments why we use average tax rates instead of marginal tax rates for the calibration of the model. First, we are not aware of a comparable and coherent empirical methodology that could be used to calculate marginal labor, capital and consumption tax rates for the US and 15 European countries for a time span of the last 25 years. By contrast, Mendoza, Razin, and Tesar (1994) and Carey and Rabesona (2002) calculate average tax rates for labor, capital and consumption for our countries of interest. Second, if any we probably make an error on side of caution since average tax rates can be seen as as representing a lower bound of statutory marginal tax rates. Third, marginal tax rates differ all across income scales. In order to properly account for this, a heterogenous agent economy is needed. This might be a useful next step but may fog up key issues analyzed in this chapter initially. Fourth, statutory marginal tax rates are often different from realized marginal tax rates due to a variety of tax deductions etc. So that potentially, the average tax rates computed and used here may reflect realized marginal tax rates more accurately than statutory marginal tax rates in legal tax codes. Fifth, using average tax rates following the methodology of Mendoza, Razin, and Tesar (1994) facilitates comparison to previous studies that also use these tax rates as e.g. Mendoza and Tesar (1998) and

[6]Carey and Rabesona (2002) also develop a new methodology to calculate average tax rates. We take a conservative stand here and use the part of their work where the average tax rates are based on the original Mendoza, Razin, and Tesar (1994) methodology. However, our results do not change much when using their new methodology.

many others. Nonetheless, a further analysis taking these points into account in detail is a useful next step on the research agenda.

All other data we use for the calibration comes from the AMECO database of the European Commission.[7] Although our data comes on an annual basis, time is taken to be quarters in our calibration.

US Model

In line with the above data on tax rates we set $\bar{\tau}^n = 0.26$, $\bar{\tau}^k = 0.37$ and $\bar{\tau}^c = 0.05$. Further, we set $\bar{b}$ such that it matches the average annual debt to GDP ratio in the data of 61%. Hence, in our quarterly stationarized model we impose $\psi\frac{\bar{b}}{\bar{y}} = 0.61 \times 4$. Further, we set $\bar{s}$ such that $\frac{\bar{s}}{\bar{y}} = 0.11$ which corresponds to the "implicit" government transfer to GDP ratio in the data.[8] See figure 4.1 for plots of the time series we use for the calibration of the above variables. The exogenous balanced growth factor ψ is set to 1.0075 which corresponds to the average annual growth rate of real US GDP of roughly 3%. In line with Mendoza and Tesar (1998) and King and Rebelo (1999) we set $\bar{R} = 1.015$ which implies a 6% real interest rate per year. Depending on preferences this implies a discount factor $\beta \in [0.9915, 0.9926]$. Further, we set the capital share $\theta = 0.36$ as in Kydland and Prescott (1982). In line with Stokey and Rebelo (1995) and Mendoza and Tesar (1998) we set $\delta = 0.015$ which implies an annual rate of depreciation of 6%. Steady state technology $\bar{\gamma}$ is normalized to one. Let us turn to the parameterization of preferences. We set κ', κ'' and α such that the household chooses $\bar{n} = 0.25$ in this baseline calibration. This is consistent with

[7]The database is available online at $http://ec.europa.eu/economy\_finance/indicators/annual\_macro\_economic\_database/ameco\_en.htm$

[8]Since there is no model-consistent data available for government transfers, we calculate "implicit" government transfers that are consistent with our government budget constraint. From the steady state representation of equation (4.3) total government expenditures are equal to $\bar{g} + (\bar{R}^b - \psi)\bar{b} + \bar{s}$. Since data is available for total gov. expenditures, gov. consumption and net interest payments we can easily back out government transfers.

McGrattan and Rogerson (2004) who provide evidence that workers supply on average roughly 40 hours of work per calendar-week.

Our previous choices of steady states and parameter values are motivated by restrictions imposed by the data. However, there are parameters left in the models that need to be pinned down and that are potentially free. These parameters are:

$$\eta, \eta', \eta'', \phi', \phi''.$$

We apply the following discipline in order to pin down these parameters. First, we set η equal to 1 which is in line with e.g. Cooley and Prescott (1995) and King and Rebelo (1999). This implies a unit elasticity of intertemporal substitution with respect to consumption for C-D preferences, e.g. $1/\sigma_{cc}^{US} = -\frac{U_{\bar{c}}}{U_{\bar{c}\bar{c}}\bar{c}} = \frac{1}{1-\alpha(1-\eta)} = 1$.[9] We also impose $1/\sigma_{cc}^{US} = 1$ for POW and GHH preferences and it turns out that we need to set $\eta' = 1$ and $\eta'' = 0.855$. For POW preferences this is in line with Gali (2003) and for GHH utility this is roughly in line with one of the experiments in Correia, Neves, and Rebelo (1995).

Frisch Labor Supply Elasticity

In order to discipline our choices for ϕ' and ϕ'' observe that the model with C-D preferences is already fully parameterized. That is, we are already able to calculate e.g. steady state tax revenues in the C-D case. Note further that $1/\phi'$ and $1/\phi''$ are the Frisch elasticities of labor supply[10] in the case of POW and GHH preferences. Hence, these parameters should matter a lot for the labor supply decision of households and in turn for government tax revenues if e.g. labor income taxes are changed.

[9] Empirical estimates of the intertemporal elasticity vary considerably. Hall (1988) estimates it to be close to zero. Recently, Gruber (2006) provides an excellent survey on estimates in the literature. Further, he estimates the intertemporal elasticity to be two. Hence, our choice reflects a combination of both extremes.

[10] In general, the Frisch elasticity is defined as $\sigma_f = \frac{dn}{dw}\frac{w}{n}|_{\bar{U}_c}$. Hence, from our model we can derive $\sigma_f = -\frac{U_{\bar{n}}}{\bar{n}}\left(\frac{U_{\bar{c}\bar{n}}U_{\bar{n}\bar{c}}}{U_{\bar{c}\bar{c}}} - U_{\bar{n}\bar{n}}\right)^{-1}$ in steady state.

There are two ways to proceed. One is to estimate each parameter specification with e.g. DYNARE as provided by Julliard (2006) and then parameterize each model separately according to the parameter estimates. The different preference specifications, each with their own specific parameter choices, then deliver potentially rather different results for the impact of tax changes on tax revenues. In such a comparison, it is hard to evaluate, how much of the differences are due to specific features of the preferences, and how much are due to implicit and possibly unintended variations across preference specifications, due to the preference-specific parameter choices. A comparison along these lines provides only limited information, in particular as there is considerable disagreement regarding key parameters in the literature. We return to this issue when discussing sensitivity to the parameterization, e.g. in figure 4.3.

We therefore choose to proceed differently. We select a baseline calibration for our preferred Cobb-Douglas preference specification and calculate the local marginal impact on total tax revenues from a change in labor taxation along the steady state Laffer curve. We then set ϕ' and ϕ'' to keep this quantity the same for the US economy, i.e. such that $\frac{\partial \bar{T}^{US}_{C-D}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{POW}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{GHH}}{\partial \bar{\tau}^n}$. Thus, the change of government tax revenues after changing the steady state labor income tax is identical across all three preference specifications at our baseline calibration. We take the resulting baseline calibration for the POW and GHH preferences seriously if the resulting parameters are within the range of values suggested in the literature. Put differently, our procedure allows us to pin down preference parameters across the three preference specifications within the range suggested in the literature so that the resulting implications are compatible and comparable. This has some surprising implications.

The specific value of the Frisch labor supply elasticity is of course of central importance for the shape of the Laffer curve. Note that in the case of our favorite

C-D preferences the Frisch elasticity cannot be pinned down by a free parameter. It is given by $\frac{1-\bar{n}}{\bar{n}}\frac{1-\alpha(1-\eta)}{\eta}$ and equals 3 in our baseline calibration. This value is in line with e.g. Kydland and Prescott (1982), Cooley and Prescott (1995) and Prescott (2002, 2004). Due to our above calibration discipline that the slopes of the labor tax Laffer curves should be the same across preferences we need to set $\phi' = 1/3$. For POW preferences this value is roughly in line with Rotemberg and Wodford (1997). Thus, also for POW preferences the Frisch labor supply elasticity is 3. In allowing for this value for C-D and POW preferences we follow Prescott (2006). He surveys the literature and discusses at length that the Frisch labor supply elasticity should be 3 in macroeconomic models.

However, there is also a large literature that estimates the Frisch labor supply elasticity from micro data. Domeij and Floden (2006) argue that labor supply elasticity estimates are likely to be biased downwards by up to 50 percent. However, the authors survey the existing micro Frisch labor supply elasticity estimates and conclude that many estimates range between 0 and 0.5. Further, Kniesner and Ziliak (2005) estimate a Frisch labor supply elasticity of 0.5 while and Kimball and Shapiro (2003) obtain a Frisch elasticity close to 1. Hence, this literature suggests an elasticity in the range of 0 to 1 instead of a value of 3 as suggested by Prescott (2006).

As it turns out, our model is not inconsistent with these rather low Frisch labor supply estimates. Indeed, for GHH preferences we need to set $\phi'' = 3.879$ in order to fulfill our calibration discipline that the slope of the labor tax Laffer curves are equal across preferences. Hence, this implies an elasticity of roughly 0.25 and is well within if not at the lower end of the above micro estimate range. Why then is the Frisch labor supply elasticity for GHH utility so different from POW and C-D utility if the slopes of the labor tax Laffer curves are all the same? The reason is in breaking the connection between income and substitution effects for the GHH specification, and more specifically, the quasi-linearity of GHH preferences with respect to consumption. This implies that the labor supply decision is entirely determined by the real wage. Hence, only the substitution effect (and no income effect) determines the labor supply decision. Since typically, the substitution effect results in reduced labor supply in response to a labor tax increase, while the income effect delivers an increase, and since the latter is missing in the GHH specification, the Frisch labor elasticity is considerably lower. Conversely, an elasticity as high as for C-D and POW preferences would imply much larger reductions in labor supply due to the substitution effect which would imply a lower slope of the labor tax Laffer curve.

We will pursue a sensitivity analysis in section 4.3.3 with respect to the parameters $\eta, \eta', \eta'', \phi', \phi''$ in order to evaluate their implications for the shape of the Laffer curve.

EU-15 Model

As an alternative, we calibrate the model to data for the EU-15 economic area. Appendix B.3 summarizes how we calculate EU-15 tax rates, debt to GDP and transfer to GDP ratios. For the years from 1975 to 2000 average tax rates in the EU-15 economy are equal to $\bar{\tau}^n = 0.38$, $\bar{\tau}^k = 0.34$ and $\bar{\tau}^c = 0.17$.[11] In our quarterly stationarized model we set $\bar{b}$ such that $\psi \frac{\bar{b}}{\bar{y}} = 0.53 \times 4$ which corresponds to the average annual debt to GDP ratio of 53 % in the data. As for the US we calculate the "implicit" government transfers to GDP ratio which is equal to 0.19 in the EU-15 economy. Hence we set $\bar{s}$ such that $\frac{\bar{s}}{\bar{y}} = 0.19$. See figure 4.1 for plots of the time series we use for the calibration. The balanced growth factor ψ is set to 1.0075 which is consistent with the average annual growth of real GDP in the EU-15 countries of roughly 3 %. All other parameters are set to the same values

[11]Note that due to lack of data Luxembourg is not included in these figures.

as in the US model. Hence, we do not take a stand on structural differences other than implied by fiscal policy in the US and EU-15 economies. Note that this implies that the household may chooses a different amount of hours worked in the EU-15 model compared to the US model due to differences in fiscal policy. This corresponds to Prescott (2002, 2004) who argues that differences in hours worked between the US and Europe arise due to changes in labor income taxes. By contrast, Blanchard (2004) as well as Alesina, Glaeser, and Sacerdote (2005) argue that changes in preferences respectively labor market regulations and union policies rather than different fiscal policies are the driving forces for the observation that hours worked have fallen in Europe compared to the US.

Tables 4.1 and 4.2 summarize the calibration and the parameterization of the baseline models. Additionally, table 4.3 shows further characteristics of our different preference assumptions which will be of particular importance for the dynamics of our models respectively for the slope of the Laffer curve.

4.3 Results

The following section discusses the results of our models. We concentrate on the following aspects: steady states and steady state Laffer curves, sensitivity analysis, shifts of Laffer curves over time, joint variations of tax rates, individual European country Laffer curves, dynamic effects of tax cuts and a dynamic scoring exercise.

4.3.1 Steady States

Table 4.4 compares the government share on GDP of the data with the baseline models. In the data, the government consumption to GDP ratio is 16.5 percent for the US and 21.3 percent for the EU-15 countries. Our baseline models predict

15.2 percent for the US and 20.9 percent for the EU-15.[12] Although there is some gap we argue that the models are roughly able to match average government consumption to GDP data.[13]

The models are also roughly in line with the total government expenditures to GDP ratio for both - the US and the EU-15. The bigger gap occurs since in our models, total government expenditures are the sum of government consumption, transfers and net-interest payments only. We abstract from additional expenditures as e.g. government investment, government military investment and subsidies which certainly affect total government expenditures in the data.

At this point, we want to emphasize the labor supply decisions of the households. We set κ', κ'' and α in the US model such that the agent chooses to work $\bar{n}_{us} = 0.25$. We use the same numbers for these structural parameters as well in the the EU-15 model. It turns out that the household chooses to work $\bar{n}_{c-d} = 0.22$, $\bar{n}_{pow} = 0.22$ and $\bar{n}_{ghh} = 0.23$ in the EU-15 economy. Thus, higher tax rates and government shares on GDP reduce the incentive to work and generate lower labor supply. This result corresponds to Prescott (2002, 2004) who finds that lower labor supply in the EU countries is due to higher tax burdens.[14]

Table 4.5 summarizes the tax revenue to GDP ratios for labor, capital and consumption taxes.[15] For the US, labor tax revenues are the largest source of revenue

[12]One might wonder, why all three models predict the same steady state ratios. The real interest rate is the same across models which implies that the capital to output ratio is the same and due to that all other *ratios* are the same along our models.

[13]The match could be improved by allowing for different values for δ or $\bar{R}$. However, we to not take a stand on structural differences other than implied by fiscal policy.

[14]Prescott (2004) reports in table 2 labor supply for Germany, France, Italy, United Kingdom and the USA for the periods from 1970-1974 and 1993-1996. Taking the average over time and over the 4 European countries shows that in these countries labor supply is 14% lower compared to the US. Our models predict that in the EU-15 labor supply is - depending on preferences - between 8% and 12% lower than in the US. Taking the average over preferences of our EU-15 models implies that European labor supply is roughly 11% lower than in the US.

[15]The methodology of Mendoza, Razin, and Tesar (1994) of calculating average tax rates allows to calculate implicit tax revenues to GDP ratios for our three tax rates.

followed by capital and consumption taxes. For the EU-15, labor tax revenues also contribute mostly to government revenues. Conversely to the US, consumption tax revenues are the second largest source of revenue in the EU-15 followed by capital tax revenues. Aside from the fact that the models are able to match this structural difference the quantitative match is acceptable as well.

Finally, table 4.6 compares the steady state consumption, investment and capital to output ratios of the models with the data. The models understate the consumption and capital to output ratios but overstate the investment to output ratio. More importantly, however, the US and EU-15 models are able to capture the relative differences of US and EU-15 data. That is, the models correctly predict that US consumption to GDP is higher than in the EU-15 area. Conversely, the models also predict that the investment and capital to GDP ratios are smaller in the US compared to the EU-15 economy.

We conclude that although the absolute match of the models is not perfect the models roughly match the relative differences between the US and EU-15. Hence, the following results regarding the absolute numbers of e.g. the peaks of the Laffer curves should be interpreted with caution. Most insightful will be the relative comparisons of the US and the EU-15 economic area.

4.3.2 Steady State Laffer Curves

The top panel of figure 4.2 shows steady state Laffer curves for labor taxes in the US and EU-15 Model. We obtain the Laffer curves by varying the steady state labor tax rate - while holding all other taxes and parameters fixed - and then compute total tax revenues in steady state. In order to facilitate comparison across preferences and models we normalize steady state tax revenues by steady state tax revenues obtained for C-D utility at the baseline tax rate. Three things are noticeable. First, the US and the EU-15 economies are located on the left side of the labor tax Laffer curve for all preference specifications. Second, the EU-15 economy is much closer to the peak than the US. Third, the slope of the labor tax Laffer curves at the average tax rate is lower in the EU-15 compared to the US implying higher distortions in the EU-15 economy.[16] Note that as a consequence of our calibration/parameterization discipline in section 4.2.3 the slope of the US labor tax Laffer curve is locally identical for all preference specifications at the US average labor income tax rate. For the EU-15 labor tax Laffer curve this is not the case since we use the same parameters as in the US model. This implies e.g. different and lower labor supply across preferences in the EU-15 and hence different slopes of the labor tax Laffer curve in the EU-15.

The mid panel of figure 4.2 draws steady state Laffer curves for capital taxes. Here the results are even more striking. Again, both economies are on the left side of the capital tax Laffer curve but the EU-15 economy is much closer to the peak than the US. Moreover, the slope of the EU-15 capital tax Laffer curve at the average tax rate is almost flat for all three preference specifications. Cutting capital income taxes - even to zero as Chamley (1986) and Lucas (1990) show to be optimal - would imply only marginal losses in tax revenues.

The bottom panel of figure 4.2 depicts steady state tax revenues dependent on consumption taxes. For C-D preferences there does not exist a steady state Laffer curve for steady state consumption taxes.[17] The income and substitution effects cancel exactly which implies that labor supply is unchanged when the consumption tax changes. By contrast, consumption falls but never to zero since it has a

[16]Note that there exists a maximum tax rate up to which we can calculate Laffer curves. The government budget constraint in steady state is given by: $\bar{g} = (\psi - \bar{R})\bar{b} - \bar{s} + \bar{T}$. If tax rates become very high tax revenues may be smaller than interest and transfer payments and hence, government consumption would be negative.

[17]Note that e.g. $\bar{\tau}^c = 0.5$ is a 50 % tax rate. Hence figure 4.2 depicts consumption taxes on the interval from 0 to 1000 %. We also experimented with a maximum steady state consumption tax rate of 100 000 % but our result that there is no consumption tax Laffer curve for C-D preferences remains.

positive value in the utility function. In particular, consumption falls with the same rate as the consumption tax rate rises. Since labor supply is unchanged capital is also constant and thus tax revenues from these factors are constant. This implies that tax revenues converge to an upper bound for C-D preferences. In case of POW preferences the parameter η' determines whether the income or the substitution effect dominates and hence whether there exists a Laffer curve. If $\eta = 1$ both effects cancel exactly and no consumption tax Laffer curve occurs. For $\eta < 1$ the substitution effect dominates and hence labor supply and capital fall in addition to consumption - a consumption tax Laffer curve arises. In case of $\eta > 1$ the income effect dominates and labor supply and capital rise while consumption falls - tax revenues converge to an upper bound again. For GHH preferences, however, there always exists a Laffer curve. The income effect is zero for this utility function and thus labor supply, capital and consumption fall if consumption taxes rise.

However, across preferences we obtain a mixed result with respect to the existence of the consumption tax Laffer curve. If anything, the slope of tax revenues with respect to consumption taxes is steeper in the US than in the EU-15 model - documenting again higher distortions EU-15 area. However, the lower slope of the Laffer curves in the EU-15 compared to the US document also stronger steady state incentive effects to increase consumption in response to steady state tax cuts. That is, for a given cut in taxes, EU-15 tax revenues fall by less than in the US.

4.3.3 Sensitivity Analysis

The labor supply elasticity plays a key role for the shape of the Laffer curve. For POW and GHH preferences figure 4.3 shows the effects of different Frisch elasticities of labor supply ($\frac{1}{\phi'}$ respectively $\frac{1}{\phi''}$) on the shape of the Laffer curve.[18] We choose alternative values for ϕ' and ϕ'' from the literature. E.g., $\phi = 6.7$ as in Pencavel (1986) or $\phi = 1.25$ respectively $\phi = 0.47$ as in Reis (2006). We also experiment with $\phi = 3$. For each of these alternative values we redo our calibration exercise of section 4.2.3 (holding η' and η'' fixed) and then vary steady state tax rates as before.

For POW preferences, figure 4.3 reveals that the shape of the Laffer curve changes modestly with the Frisch labor supply elasticity. By contrast, for GHH utility we obtain dramatic changes with possible peaks at almost the entire tax range.

Nevertheless, a clear picture emerges. The lower ϕ' respectively ϕ'', the higher is the Frisch elasticity of labor supply and the earlier occurs the peak of the Laffer curve. This result is intuitive. A rise in labor taxes reduces the real after-tax wage. If the household's labor supply is more elastic with respect to the real after-tax wage, it will reduce its labor supply more strongly. Therefore, the marginal increase of tax revenues is smaller with higher labor supply elasticities - the peak occurs earlier.

In addition, we also pursue a sensitivity analysis with respect to η, η' and η''. Interestingly, steady state tax revenues in the case of C-D and GHH preferences are invariant with respect to changes in η and η''. That is, steady state labor supply, steady state capital and steady state consumption do not depend on η and η''.[19] By contrast, in the case of POW preferences steady state tax revenues depend on η' via the labor supply decision of the household, i.e. $\kappa' \bar{n}^{\phi'} \bar{c}^{\eta'} = (1 -$

[18]We noted earlier that for the C-D case the Frisch labor supply elasticity is determined endogenously. In particular is depends not only on the parameters α and η but also on steady state labor supply. Since $\bar{n}$ changes with different tax rates the Frisch elasticity changes endogenously too. Therefore, we cannot pin down the elasticity to one particular value as in the POW and GHH preference cases.

[19]Variations in η or η'' lead only to variations in β since $\bar{R}$ is given in our model. However, β has no effect on the steady state of labor, capital and consumption. Nevertheless, η and η'' are of course important for the dynamics of the models.

$\theta)\frac{1-\bar{\tau}^n}{1+\bar{\tau}^c}\frac{\bar{y}}{\bar{n}}$. We choose alternative values for η' from the literature. E.g., House and Shapiro (2006) set $\eta' = 5$, King and Rebelo (1999) use $\eta' = 3$ in their extended model and Lucas (1990) chooses $\eta' = 2$. We further experiment with $\eta' = 0.2$ and $\eta' = 0.5$. For each of these alternative values we redo our calibration exercise of section 4.2.3 (holding ϕ' fixed) and then we vary steady state tax rates as before.

Figure 4.4 shows that the shape of the Laffer curve for steady state capital income taxes changes with different values for η' in the case of POW preferences. In particular, the higher η' the later occurs the peak of the Laffer curve. This result is intuitive. The higher η', the lower is the intertemporal elasticity of substitution and therefore the elasticity of capital with respect to capital income taxes. That is, for a higher η', the household reacts less to decreases in the real interest rate induced by increases in capital income taxes. Hence, the peak of the Laffer curve occurs later the higher η'.

4.3.4 Shifts of Laffer Curves

The preceding analysis is based on the calibration of the models to the average of taxes, transfers etc. to post-war data. One might wonder, how the Laffer curves have shifted over time during this period. We investigate this by calculating the Laffer curves at different points in time, e.g. for the earliest and latest available observations in our dataset. US data for the year 1975 suggest that we set $\bar{\tau}^n = 0.22$, $\bar{\tau}^k = 0.40$, $\bar{\tau}^c = 0.06$, $\bar{s}/\bar{y} = 0.11$ and $\psi\bar{b}/\bar{y} = 0.48 \times 4$. Alternatively, for the year 2000 we obtain the following values for the US: $\bar{\tau}^n = 0.29$, $\bar{\tau}^k = 0.38$, $\bar{\tau}^c = 0.05$, $\bar{s}/\bar{y} = 0.11$ and $\psi\bar{b}/\bar{y} = 0.59 \times 4$. Using these two alternative sets of variables and holding all other parameters fixed, we calculate steady state Laffer curves for labor and capital taxes for the US model.[20]

[20] In detail, we use the alternative tax rates and set $\bar{b}$ and $\bar{s}$ such that the model matches the debt and transfer to GDP ratio while holding all other parameters fixed as in the baseline calibration. Then, we vary steady state tax rates to calculate the Laffer curves.

For our favorite C-D preferences, the left panel of figure 4.5 shows that the labor tax Laffer curve has shifted very little and that the US has moved closer to the peak. By contrast, the capital tax Laffer curve has shifted outwards and the US has hardly moved relative to the peak. The outward shift is mostly due to the rise in labor taxes.

Let's turn to the EU-15 economy. According to the data for the year 1975, we set $\bar{\tau}^n = 0.34$, $\bar{\tau}^k = 0.31$, $\bar{\tau}^c = 0.16$, $\bar{s}/\bar{y} = 0.17$ and $\psi\bar{b}/\bar{y} = 0.31 \times 4$. For the year 2000 the data suggest $\bar{\tau}^n = 0.42$, $\bar{\tau}^k = 0.38$, $\bar{\tau}^c = 0.21$, $\bar{s}/\bar{y} = 0.19$ and $\psi\bar{b}/\bar{y} = 0.62 \times 4$. The right panel of figure 4.5 shows the corresponding Laffer curves for the EU-15 area. For labor taxes the EU-15 economy has moved considerably closer to the peak and the slope has flattened. Even more strikingly, in the case of capital taxes the EU-15 economy has moved almost exactly to the top of the Laffer curve. Hence, we conclude that since 1975 the EU-15 area has moved closer to the peaks of their steady state Laffer curves thereby increasing distortions and increasing incentives of households and firms to increase consumption, hours worked and investment in response to tax cuts.

4.3.5 Joint Variations of Steady State Taxes

The previous sections analyzed the effects of variations of single steady state tax rates on steady state tax revenues. Now, we consider joint variations of steady state capital and labor tax rates. We do so by varying $\bar{\tau}^k = \bar{\tau}^n$ jointly holding all other parameters fixed. Then, we calculate steady state tax revenues. Figure 4.6 shows the resulting Laffer curves for the US and EU-15 model. Again, the results indicate that the US and EU-15 are located on the left side of the Laffer curve. However, the EU-15 economy is closer to the slippery slopes.

We also calculate steady state iso-tax revenue curves. That is, we work out the combinations of steady state capital and labor tax rates that yield a given level of government tax revenues. Figure 4.7 shows the steady state iso-tax revenue curves for the US and EU-15 model. Interestingly, in both economic areas a cut in steady state capital income taxes accompanied by an increase of steady state labor income taxes would move the economies on top of the “Laffer hill”. However, notice that for steady state labor taxes the EU-15 economy is much closer located to the summit of the “Laffer hill” than the US. Moreover, the figure reveals that the “Laffer hill” of the US model has a steeper slope compared to the EU-15. That is, in order to increase tax revenues from say 90 to 100 tax rates need to change less compared to the EU-15 model.

4.3.6 Individual European Country Laffer Curves

In the previous sections we have compared steady state Laffer curves of the US and EU-15 economy. The latter, however, consists of individual countries with most likely different fiscal policies. How do steady state Laffer curves look for individual European countries? We proceed as follows. For each individual country we calculate the average over time of tax rates for consumption, labor and capital. In addition we compute the transfer to GDP ratio as well as the debt to GDP ratio for each country. Then, we feed our model with these five variables that characterize country specific fiscal policies. Further, we keep all other parameters unchanged and then calculate steady state Laffer curves for each country.

The top panel of figure 4.8 plots the distance in terms of tax rates to the peak of the steady state Laffer curves for each European country. In addition, we add the US as well as the EU-15 average. The figure reveals that all European countries are closer to the peaks of their labor tax Laffer curves compared to the US. Interestingly, Sweden appears to be on the slippery slope side of the labor tax Laffer curve.[21] For capital taxes the majority of European countries are closer to the peak of their Laffer curves. Only Spain, Greece, Ireland and Portugal have a larger distance to the peak than the US. However, these countries together have only a relatively small share on total European GDP. For capital taxes the model predicts that the Netherlands, Finland, Belgium, Great Britain, Sweden and Denmark are located on the slippery slope side of their Laffer curves.

The mid panel depicts the distance to the peak of the individual country Laffer curves in terms of tax revenues expressed in percent of country specific baseline GDP. For labor taxes the figure shows that tax revenues increase only modestly for the majority of European countries if they would move to the peak of their Laffer curve. In all cases the increase in tax revenues is less than for the US. By contrast, for capital taxes Sweden and Denmark could raise much more revenues by moving to the top of their Laffer curve since they are located relatively far on the slippery slope side.

Finally, the lower panel shows the slope of the Laffer curves for a one percent increase of steady state labor and capital taxes. We measure the slope as the change of tax revenues in percent of baseline GDP. The slope of the US labor and capital tax Laffer curve is steeper compared to all European countries which documents higher distortions in the EU-15.

The analysis shows that there is considerable country specific variation within Europe with respect to the shape of the Laffer curve. However, the EU-15 average economy captures fairly well the relative differences between the US and Europe. This is especially true for the distance to the peak for labor taxes. Regarding the distance to the peak for capital taxes this applies to the majority

[21] Floden and Linde (2001) report a similar finding for labor taxes. Further, Jonsson and Klein (2003) report that Sweden is on the slippery slope side of the Laffer curve for several tax instruments.

of European countries with most economic weight in terms of GDP. Finally, the EU-15 average economy summarizes well that the slopes of the labor and capital tax Laffer curves are lower in all individual European countries compared to the US. Hence, in the following sections we return to a comparison of the US and the average EU-15 economic area.

4.3.7 Unexpected vs. Announced Tax Cuts

We now turn to the dynamic properties of the models. In principle, the government may choose to cut taxes either unexpectedly or with a pre-announcement period. Figure 4.9 depicts the responses of tax revenues to unexpected and 5-years-in-advance announced labor and capital tax cuts for the US model.[22,23] Appendix B.2 as well as appendix B.4 explain in detail how we obtain these results. The subsequent results focus on the C-D utility case. However, the results are robust with respect to our alternative preference specifications. Some interesting results are worth to be pointed out here.

First, an unexpected permanent labor tax cut leads to a fall of tax revenues for low steady state tax rates. However, if steady state tax rates become sufficiently large, tax revenues will increase in response to the tax cut. This is due to the incentive effect. A cut from very high tax levels creates very strong incentives to work. This enlarges the tax base by more than the reduction of the tax rate. Therefore, we observe a Laffer curve effect even for the dynamics.

[22] We analyze tax cuts that are symmetric. Giannitsarou (2006) shows that supply-side reforms can be asymmetric under adaptive learning. The author shows that if a capital tax cut coincides with a negative technology shock the transition to the new steady state is slower than if the capital tax cut would coincide with a positive technology shock.

[23] We have chosen a five years pre-announcement horizon here for illustrative purposes. However, it also reflects the maximum length of a legislative period in most modern democracies. On optimal pre-announcement durations of optimal labor and capital tax reforms see e.g. Domeij and Klein (2005) and chapter five of this dissertation.

Second, an unexpected permanent capital tax cut always leads to a drop in tax revenues in the short-run. However, in the long-run we also observe a dynamic Laffer effect dependent on the level of steady state taxes. The short-run drop - irrespective of the level of taxes - occurs since capital is immobile and therefore cannot react immediately.

Third, an announced labor tax cut leads to a decrease of tax revenues in the short-run regardless of the level of steady state labor taxes. This is due to two effects. The announcement of lower future labor taxes induces the household to work less and to accumulate less capital. Thus tax revenues from these two factors decrease. By contrast, consumption rises during the announcement period due to lower investment. The first effect dominates the latter and thus tax revenues fall in the announcement period. It should be mentioned here that House and Shapiro (2006) document a similar effect. However, when policy is put into place, we observe the dynamic Laffer effect as before.

Fourth, an announced capital tax cut leads to an increase of tax revenues during the announcement period followed by the dynamic Laffer effect in the long-run. The announcement of a cut in capital taxes creates an investment boom which in turn induces a rise in labor supply. Thus tax revenues from labor and capital increase. By contrast, consumption decreases in order to accumulate capital. Again, the consumption effect is dominated by the capital/labor effect during the announcement period. In the long-run, however, we observe the Laffer effect dependent on the level of steady state capital taxes.

Fifth, tables 4.7 and 4.8 show the evolution of government consumption for the US and EU-15 model for the baseline calibration. E.g., for US capital taxes, we find that an unexpected permanent 1% tax cut corresponds to an endogenous cut of government spending of 1.6% on impact and 0.8% in the long-run. A 5-years-in-advance announced permanent 1% cut of capital taxes leads to an endogenous increase of government spending of up to 0.4% during the announcement period and a cut of government expenditures of 0.8% in the long-run. For the EU-15 economy, we obtain the same qualitative results. However, quantitatively, the figures for unexpected tax cuts and the long-run values for announced tax cuts are smaller than in the US. Thus, the slope of the Laffer curves in the EU-15 economy are much lower than in the US which again documents a higher degree of distortions in the EU-15 area compared to the US. To that end, our analysis indicates that the incentive effects to increase consumption, hours worked and investment due to tax changes are stronger in the EU-15 than in the US. For a given cut in taxes, EU-15 tax revenues fall less than in the US documented by the lower slopes of the Laffer curves in the EU-15.

4.3.8 Dynamic Scoring

Our previous results indicate that tax cuts are not fully self-financing in the US and EU-15 area. However, it is interesting to which extend tax cuts are self-financing given the positions of the US and EU-15 on their respective Laffer curves. Following Mankiw and Weinzierl (2005), we perform a static and dynamic scoring exercise for steady state tax revenues in response to e.g. a steady state capital tax cut. Static scoring is obtained from cutting steady state capital taxes while holding capital, hours and consumption at their steady state levels. Hence, there is no dynamic feedback effect from lower taxes to e.g. higher capital accumulation. By contrast, dynamic scoring allows for the feedback effect from lower taxes to higher capital accumulation and corresponds to the response of tax revenues in our DSGE model. Hence, χ is the fraction of the static effect that equals the dynamic effect, i.e.

$$\frac{\partial \bar{T}^{DSGE}}{\partial \bar{\tau}^k} = \chi \frac{\partial \bar{T}^{Static}}{\partial \bar{\tau}^k}. \tag{4.6}$$

Then, the degree of self-financing can be calculated as $100(1-\chi)$. We find for the US model that 19% of a labor tax cut and 47% of a capital tax cut are self-financing in the steady state.[24] In the EU-15 economy 54% of a labor tax cut and 85% of a capital tax cut are self-financing. Hence, the efficiency gains from cutting taxes in the EU-15 area are comparably large.

These results are obtained from a steady state analysis and do not take a transition over time into account. Figure 4.10 shows the responses of tax revenues to unexpected and announced labor and capital tax cuts for static as well as dynamic scoring over time. Again, the plots reveal that the size of the dynamic feedback effect is considerable. For each point in time we calculate the proportions of tax cuts that are self-financing. Tables 4.9 and 4.10 summarize our results. It turns out that in the EU-15 area the degree of self-financing is higher compared to the US at every point in time during the transition period.

Also following Mankiw and Weinzierl (2005), we calculate the "Present Value" of the self-financing. To do so, we sum up the discounted changes in the static as well as DSGE tax revenues. As discount factors we use the after-tax real interest rates obtained from the dynamics. Finally, we calculate the self-financing as

[24] Note that Mankiw and Weinzierl (2005) report for their model that 17% of a labor tax cut and 53% of a capital tax cut are self-financing. Recently, Leeper and Yang (2005) argue that Mankiw and Weinzierl's result that static scoring overestimates the revenue loss hinges on the assumption that lump-sum transfers adjust to balance the government budget. In particular, Leeper and Yang show that a bond-financed tax cut can have adverse effects on growth. Interestingly, they show that when the government consumption to GDP *ratio* is adjusted to rising debt in response to a labor tax cut then static scoring underestimates the revenue loss as opposed to Mankiw and Weinzierl. By contrast, in our experiments government debt is fixed and the *level* of government consumption adjusts. We find that static scoring overestimates the revenue loss for labor and capital tax cuts and thereby confirm Mankiw and Weinzierl (2005).

before using now the previously calculated discounted sums. For the US model we obtain a "Present Value" of self-financing for unexpected labor tax cuts of 19% and −2.2% for 5-years-in-advance announced labor tax cuts.[25] For unexpected capital tax cuts the "Present Value" is 37% and for 5-years-in-advance announced capital tax cuts we obtain a "Present Value" of 48%.

The same exercise yields the following results in the EU-15 model. The "Present Value" of self-financing for unexpected labor tax cuts is 53% and 18% for 5-years-in-advance announced labor tax cuts. For unexpected capital tax cuts the "Present Value" is 65% and for 5-years-in-advance announced capital tax cuts we obtain a "Present Value" of 82%. Our results show that by any measure there is a much higher degree of self-financing possible in the EU-15. This shows again that there are higher distortions in the EU-15 area compared to the US.

To sum up, our analysis reveals that there rarely is a free lunch due to tax cuts. However, a large fraction of the lunch will be paid for by the efficiency gains in the economy due to tax cuts.

4.4 Conclusion

This chapter examines the following question: how does the behavior of households and firms in the US compared to the EU-15 adjust if fiscal policy changes taxes? The Laffer curve provides us with a framework to think about the incentive effects of tax cuts. Therefore, the goal of this chapter is to examine the shape of the Laffer curve quantitatively in a simple neoclassical growth model calibrated to the US as well as to the EU-15 economy. We show that there exist

[25] The negative number for 5-years-in-advance announced labor tax cuts is due to the fact that tax revenues fall in the announcement period in the DSGE model but in the static model tax revenues remain constant at zero. Hence, the discounted sum of changes in tax revenues can become larger in absolute value in the DSGE case than in the static model case which produces the negative self-financing number.

robust steady state Laffer curves for labor taxes as well as capital taxes. According to the model the US and the EU-15 area are located on the left side of their Laffer curves. However the EU-15 countries are much closer to the slippery slopes than the US. Our results show that if taxes in the EU-15 area continue to rise as they have done in the past, the peak of the Laffer curve becomes very close. By contrast, tax cuts will boost the incentives to work and invest in the EU-15 economy.

In addition, our results indicate that tax cuts in the EU-15 area are to a much higher degree self-financing compared to the US which again reflects higher incentive effects from tax cuts in the EU-15 economy compared to the US. We therefore conclude that there rarely is a free lunch due to tax cuts. However, a large fraction of the lunch will be paid for by the efficiency gains in the economy due to tax cuts.

4.5 Tables and Figures

Table 4.1: Calibration of the Baseline Models

Variable	US Model	EU-15 Model	Description	Restriction
$\bar{\tau}^n$	0.26	0.38	Labor tax rate	Data
$\bar{\tau}^k$	0.37	0.34	Capital tax rate	Data
$\bar{\tau}^c$	0.05	0.17	Consumption tax rate	Data
$\bar{s}/\bar{y}$	0.11	0.19	Government transfers to GDP ratio	Data
$\psi\bar{b}/\bar{y}$	0.61×4	0.53×4	Gov. debt to GDP ratio (quarterly)	Data
ψ	1.0075	1.0075	Balanced growth factor (quarterly)	Data
$\bar{R}$	1.015	1.015	Gross real interest rate (quarterly)	Data

Table 4.2: Parameterizing the Baseline Models

Variable	US Model	EU-15 Model	Description	Restriction
η, η'	1.00	1.00	Det. IES for C-D and POW	$1/\sigma_{cc}^{US} = 1$
η''	0.855	0.855	Det. IES for GHH	$1/\sigma_{cc}^{US} = 1$
ϕ'	0.333	0.333	Inverse Frisch elasticity POW	$\frac{\partial \bar{T}_{POW}^{US}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}_{C-D}^{US}}{\partial \bar{\tau}^n}$
ϕ''	3.879	3.879	Inverse Frisch elasticity GHH	$\frac{\partial \bar{T}_{GHH}^{US}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}_{C-D}^{US}}{\partial \bar{\tau}^n}$
α	0.321	0.321	Consumption weight in C-D	$\bar{n}_{us} = 0.25$
κ'	4.479	4.479	Weight of labor in POW	$\bar{n}_{us} = 0.25$
κ''	341.79	341.79	Weight of labor in GHH	$\bar{n}_{us} = 0.25$
$\bar{\gamma}$	1.00	1.00	Technology (normalization)	-
θ	0.36	0.36	Capital share on production	Data
δ	0.015	0.015	Depreciation rate (quarterly)	Data

Table 4.3: Implications of Preference Assumptions

	C-D Preferences			POW Preferences			GHH Preferences		
	Theory	Calibration		Theory	Calibration		Theory	Calibration	
		US	EU-15		US	EU-15		US	EU-15
$\sigma_{cc} = \frac{-U_{\bar{c}\bar{c}}\bar{c}}{U_{\bar{c}}}$	$1-\alpha(1-\eta)$	1	1	η'	1	1	$\eta''(1-\frac{\kappa''}{\bar{c}(1+\phi'')}\bar{n}^{1+\phi''})^{-1}$	1	0.973
$\sigma_{cn,n} = \frac{-U_{\bar{c}\bar{n}}\bar{n}}{U_{\bar{c}}}$	$\frac{(1-\eta)(1-\alpha)}{1-\bar{n}}\bar{n}$	0	0	0	0	0	$-\kappa''\eta''(\frac{\bar{c}}{\bar{n}^{1+\phi''}}-\frac{\kappa''}{1+\phi''})^{-1}$	-0.705	-0.573
$\sigma_{nc,c} = \frac{U_{\bar{n}\bar{c}}\bar{c}}{U_{\bar{n}}}$	$(1-\eta)\alpha$	0	0	0	0	0	$-\eta''(1-\frac{\kappa''}{\bar{c}(1+\phi'')}\bar{n}^{1+\phi''})^{-1}$	-1	-0.973
$\sigma_{nn} = \frac{U_{\bar{n}\bar{n}}\bar{n}}{U_{\bar{n}}}$	$\frac{((1-\alpha)\eta+\alpha)}{1-\bar{n}}\bar{n}$	0.333	0.278	ϕ'	0.333	0.333	$\phi''+\kappa''\eta''(\frac{\bar{c}}{\bar{n}^{1+\phi''}}-\frac{\kappa''}{1+\phi''})^{-1}$	4.584	4.452
$\sigma_w = \frac{-U_{\bar{n}}}{U_{\bar{c}}\psi^t}$	$\frac{(1-\alpha)}{\alpha(1-\bar{n})}\bar{c}$	1.579	1.206	$\kappa'\bar{n}^{\phi'}\bar{c}^{\eta'}$	1.579	1.206	$\kappa''\bar{n}^{\phi''}$	1.579	1.206
$\sigma_f = \frac{-U_{\bar{n}}U_{\bar{c}\bar{c}}}{\bar{n}(U_{\bar{c}\bar{n}}U_{\bar{n}\bar{c}}-U_{\bar{n}\bar{n}}U_{\bar{c}\bar{c}})}$	$\frac{1-\bar{n}}{\bar{n}}\frac{1-\alpha(1-\eta)}{\eta}$	3	3.596	$\frac{1}{\phi'}$	3	3	$\frac{1}{\phi''}$	0.258	0.258

Notes: σ_w and σ_f are not needed to determine the dynamics. These characteristics are listed here for completeness. σ_w can be interpreted as the after-tax real wage. σ_f denotes the Frisch labor supply elasticity.

Table 4.4: Government Share on GDP (in %)

	Government Consumption		Total Government Expenditures	
	US	EU-15	US	EU-15
Data	16.5	21.3	31.7	45.0
Model				
C-D	15.2	20.9	28.0	41.5
POW	15.2	20.9	28.0	41.5
GHH	15.2	20.9	28.0	41.5

Table 4.5: Sources of Government Tax Revenues as a Share of GDP (in %)

	Labor Tax Rev.		Capital Tax Rev.		Consumption Tax Rev.	
	US	EU-15	US	EU-15	US	EU-15
Data	14.9	20.5	8.3	7.5	3.6	9.5
Model						
C-D	16.6	24.3	8.2	7.4	3.2	9.8
POW	16.6	24.3	8.2	7.4	3.2	9.8
GHH	16.6	24.3	8.2	7.4	3.2	9.8

Table 4.6: Consumption, Investment and Capital as a Share of GDP (in %)

	Priv. Consumption		Total Investment		Capital	
	US	EU-15	US	EU-15	US	EU-15
Data	67.0	57.9	17.8	20.6	260	312
Model						
C-D	63.9	57.6	20.9	21.5	234	240
POW	63.9	57.6	20.9	21.5	234	240
GHH	63.9	57.6	20.9	21.5	234	240

Table 4.7: US Model: Unexpected vs. Announced Tax Cuts

	$\hat{T}_t$				$\hat{g}_t$			
	$t = 0$	$t = 19$	$t = 20$	$t = \infty$	$t = 0$	$t = 19$	$t = 20$	$t = \infty$
Labor Tax Cut								
unexpected	-1.89	-1.86	-1.86	-1.84	-3.58	-3.48	-3.48	-3.38
announced	-0.34	-1.06	-2.09	-1.84	-0.50	-2.00	-4.39	-3.38
Capital Tax Cut								
unexpected	-0.64	-0.53	-0.52	-0.42	-1.61	-1.19	-1.17	-0.77
announced	0.07	0.20	-0.60	-0.42	0.10	0.38	-1.46	-0.77

Notes: Dynamic effects of unexpected and 5-years-in-advance announced permanent 1% tax cuts; C-D utility; baseline calibration. $\hat{T}_t$ *and* $\hat{g}_t$ *denote percentage deviations of tax revenues and government consumption from steady state.* t *counts quarters.*

Table 4.8: EU-15 Model: Unexpected vs. Announced Tax Cuts

	$\hat{T}_t$				$\hat{g}_t$			
	$t = 0$	$t = 19$	$t = 20$	$t = \infty$	$t = 0$	$t = 19$	$t = 20$	$t = \infty$
Labor Tax Cut								
unexpected	-0.83	-0.76	-0.75	-0.69	-1.78	-1.56	-1.55	-1.36
announced	-0.30	-0.96	-1.15	-0.69	-0.47	-1.91	-2.69	-1.36
Capital Tax Cut								
unexpected	-0.39	-0.23	-0.22	-0.07	-1.06	-0.59	-0.57	-0.15
announced	0.06	0.20	-0.33	-0.07	0.10	0.40	-0.87	-0.15

Notes: Dynamic effects of unexpected and 5-years-in-advance announced permanent 1% tax cuts; C-D utility; baseline calibration.$\hat{T}_t$ *and* $\hat{g}_t$ *denote percentage deviations of tax revenues and government consumption from steady state.* t *counts quarters.*

Table 4.9: US Model: Dynamic Scoring

	Degree of Self-Financing (in Percent)					
	$t = 0$	$t = 10$	$t = 20$	$t = 40$	$t = 80$	Steady State
Labor Tax Cut						
unexpected	17.5	18.2	18.6	19.2	19.6	19.2
announced	-	-	8.4	14.3	18.5	19.2
Capital Tax Cut						
unexpected	19.5	28.1	34.0	41.9	45.7	46.6
announced	-	-	24.6	36.4	44.7	46.6

Notes: Dynamic scoring for unexpected and 5-years-in-advance announced permanent 1 % tax cuts; C-D utility; baseline calibration. t counts quarters. "Self-Financing" is calculated as $1 - \frac{\hat{T}_t^{DSGE}}{\hat{T}_t^{Static}}$.

Table 4.10: EU-15 Model: Dynamic Scoring

	Degree of Self-Financing (in Percent)					
	$t = 0$	$t = 10$	$t = 20$	$t = 40$	$t = 80$	Steady State
Labor Tax Cut						
unexpected	46.1	49.1	51.2	53.5	55.1	54.4
announced	-	-	25.4	41.6	52.6	54.4
Capital Tax Cut						
unexpected	25.0	44.4	57.7	72.9	83.1	85.1
announced	-	-	37.8	63.6	81.2	85.1

Notes: Dynamic scoring for unexpected and 5-years-in-advance announced permanent 1 % tax cuts; C-D utility; baseline calibration. t counts quarters. "Self-Financing" is calculated as $1 - \frac{\hat{T}_t^{DSGE}}{\hat{T}_t^{Static}}$.

Figure 4.1: Data used for Calibration of the Baseline Models

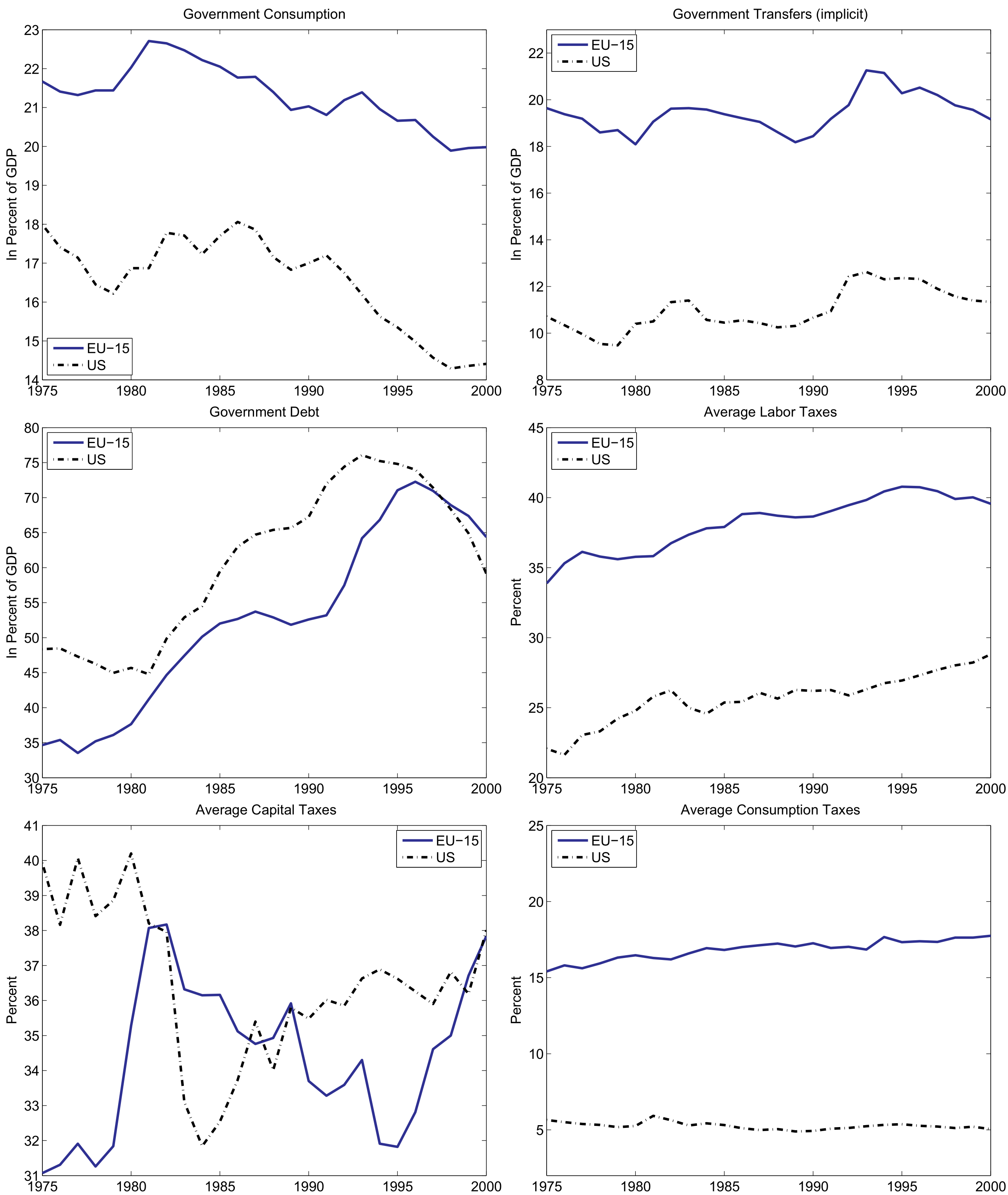


Figure 4.2: Steady State Laffer Curves

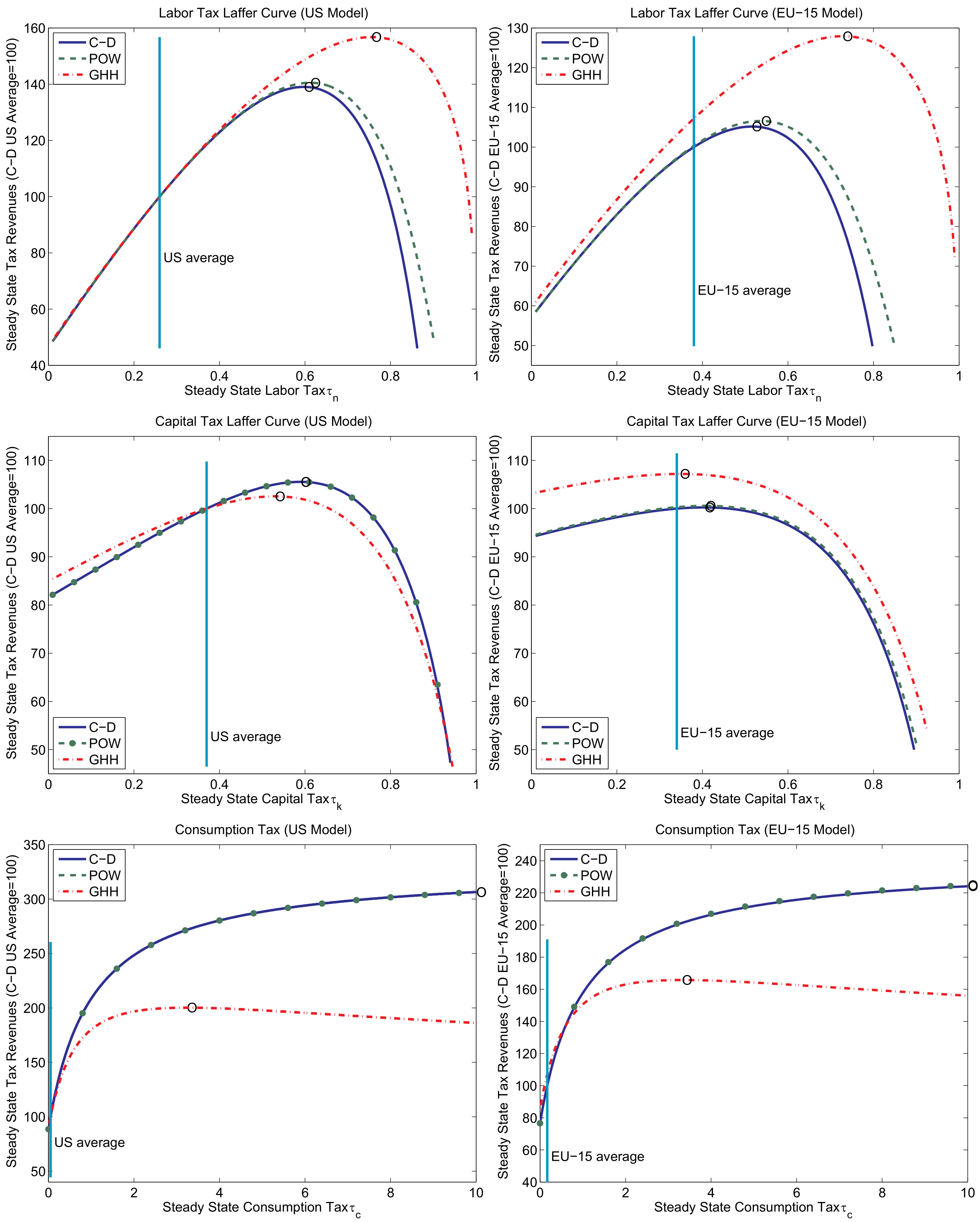


Figure 4.3: Sensitivity Analysis on ϕ' and ϕ''

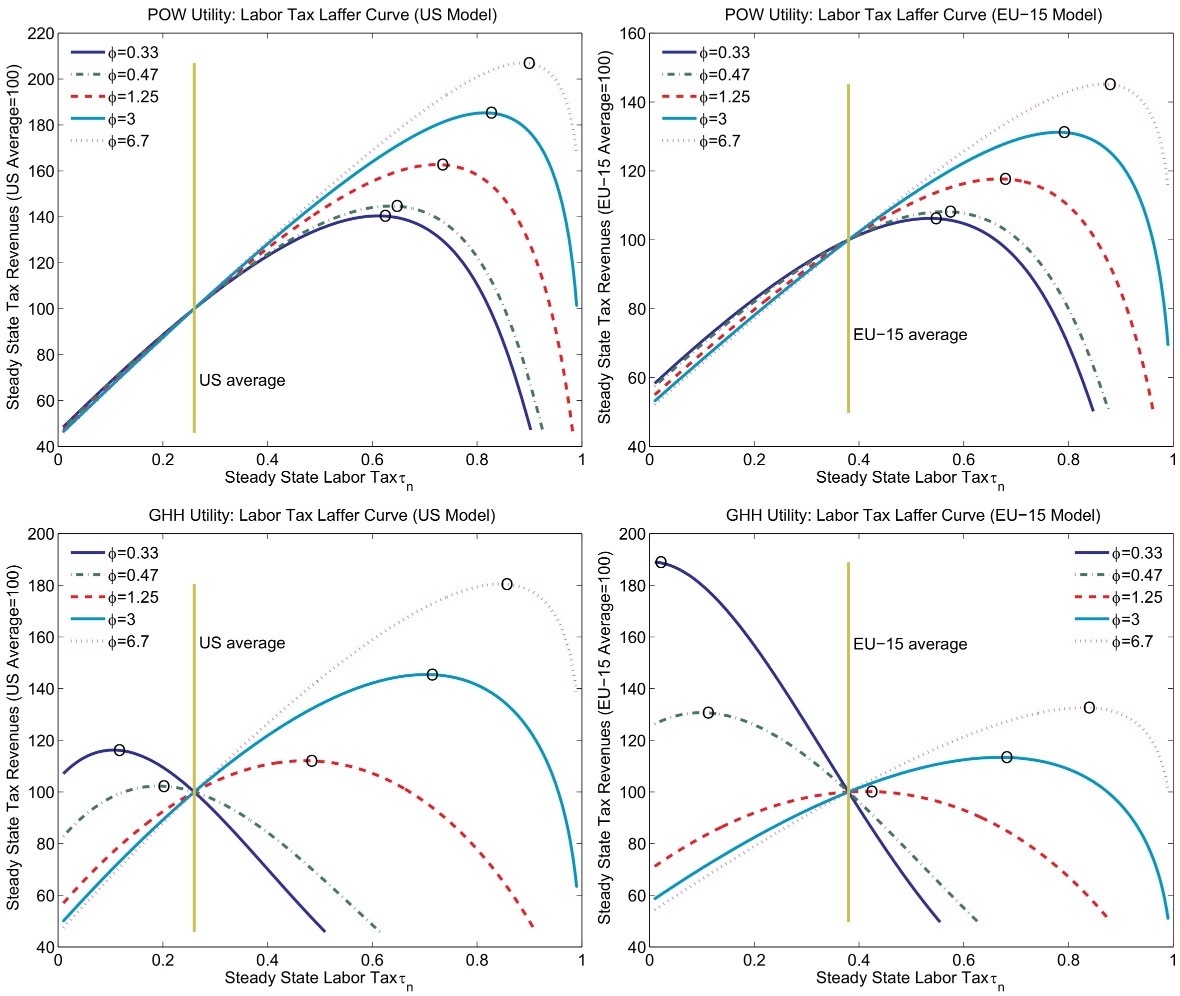


Figure 4.4: Sensitivity Analysis on η'

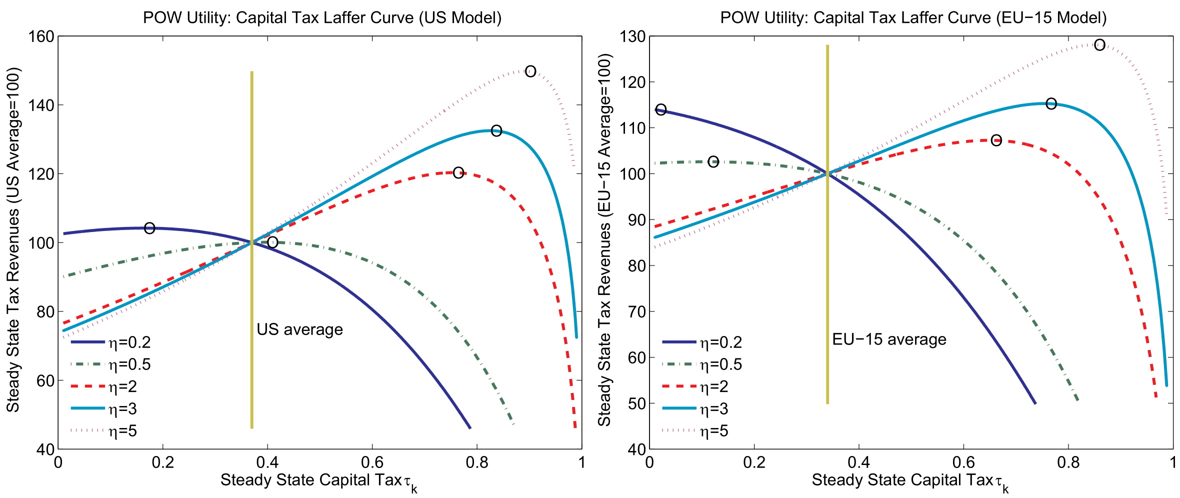


Figure 4.5: Shifts of Laffer Curves over Time; C-D Utility

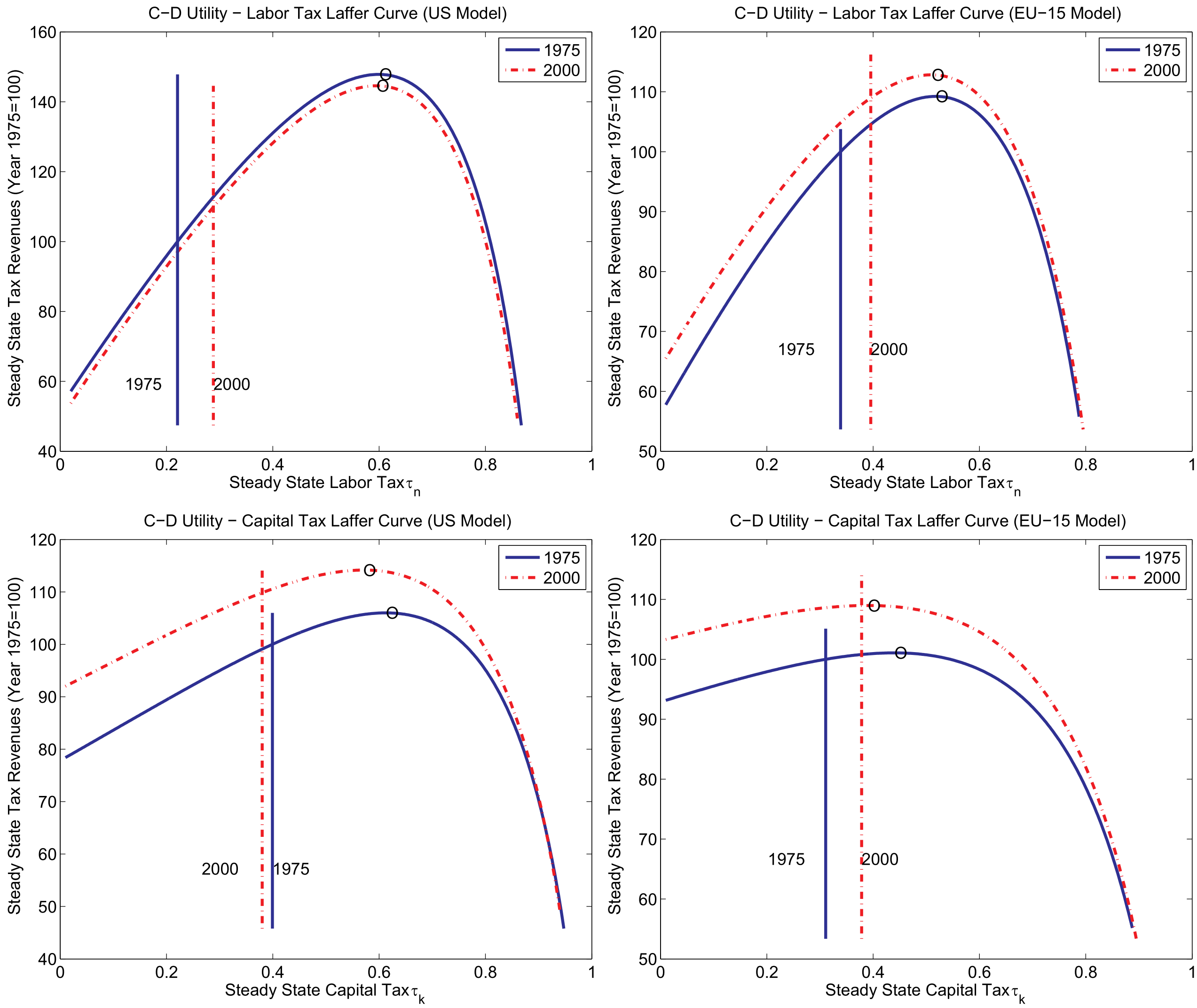


Figure 4.6: Steady State Laffer Curves for Capital and Labor Taxes ($\bar{\tau}^k = \bar{\tau}^n$)

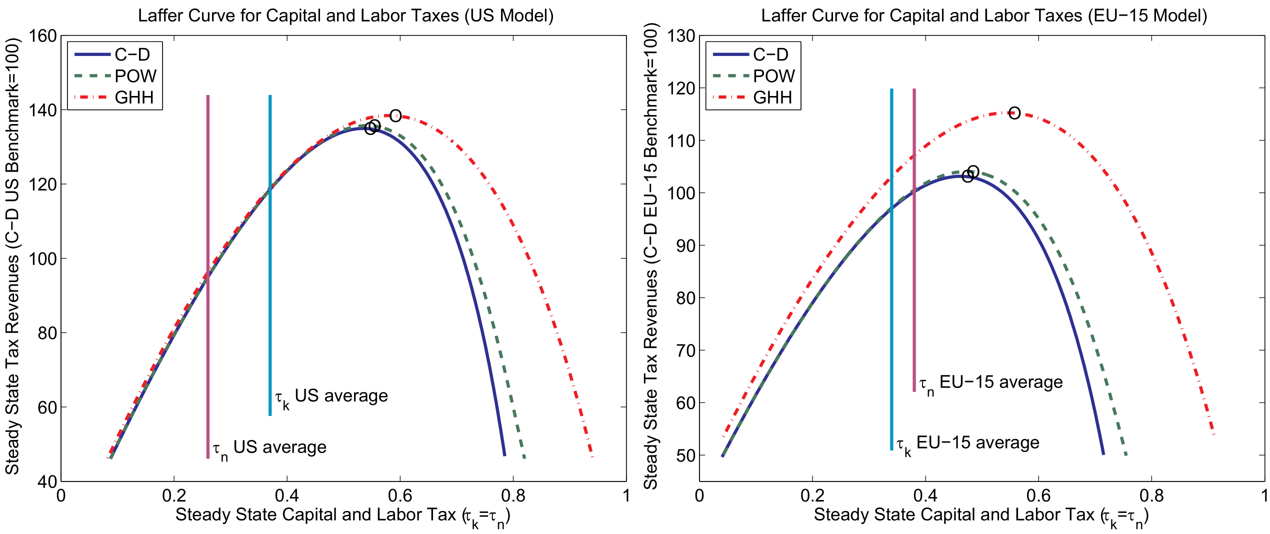
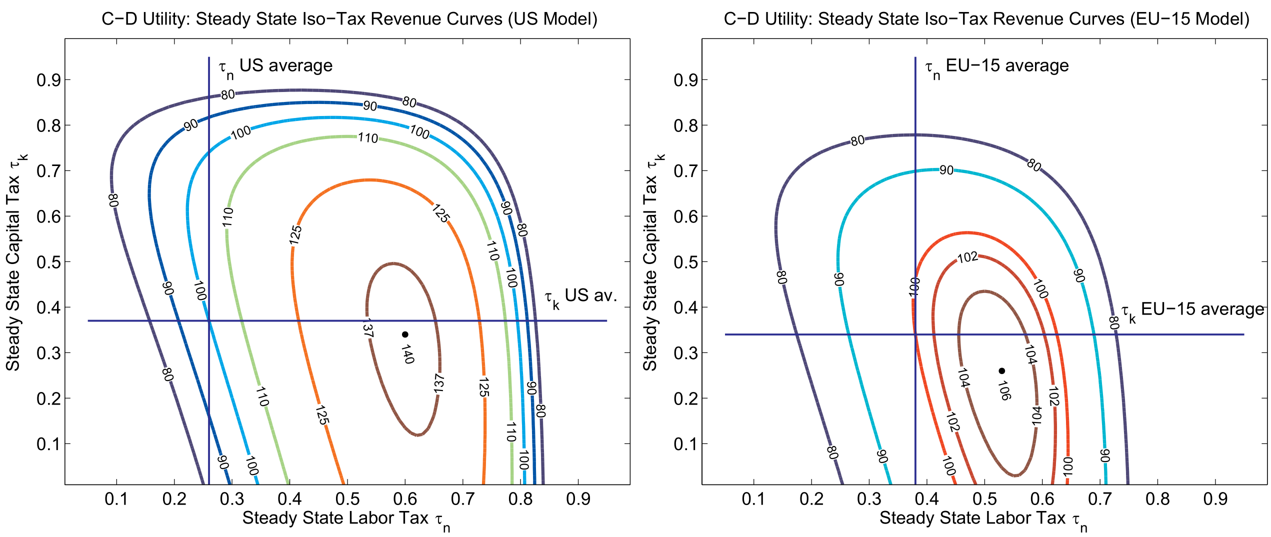
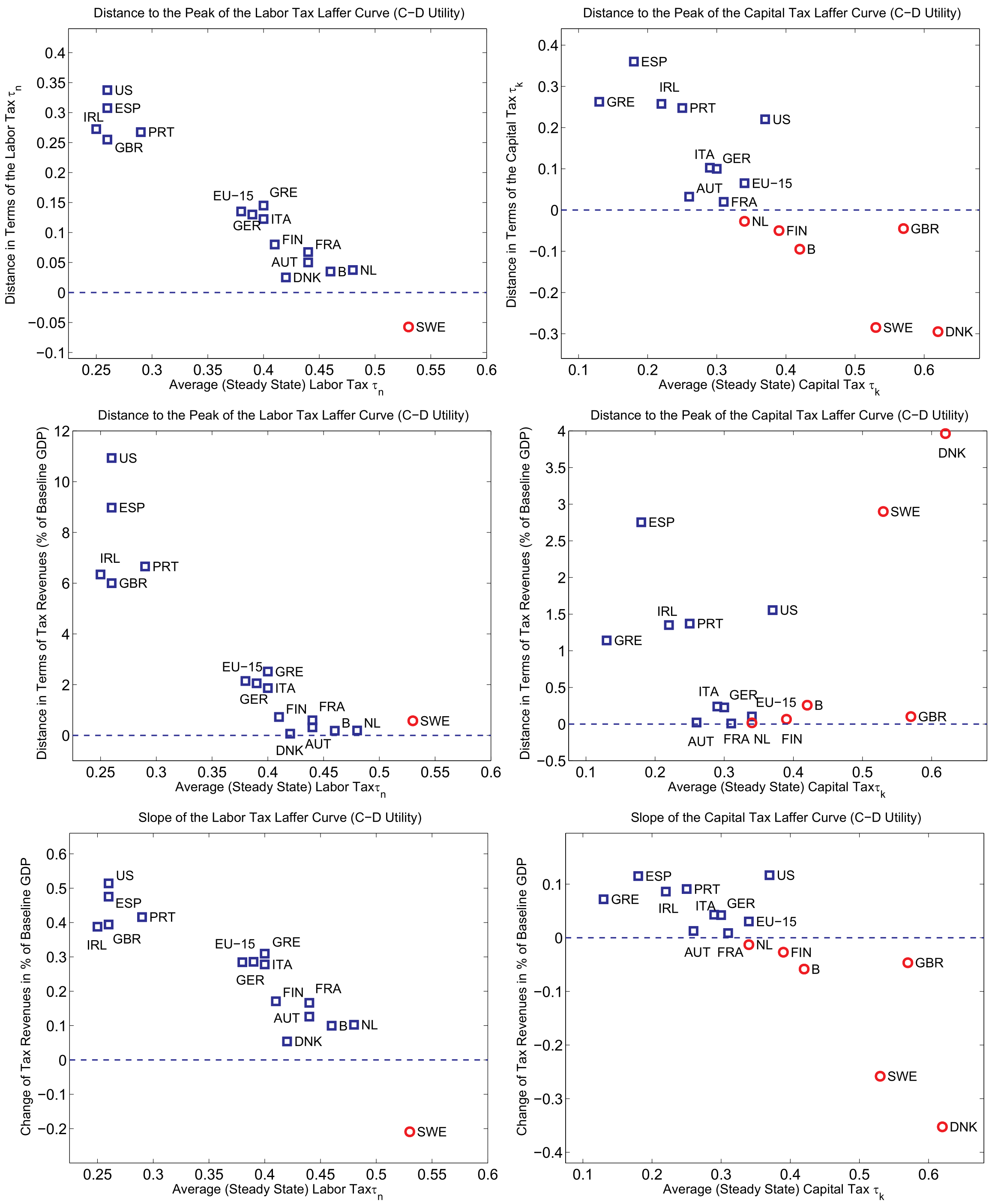


Figure 4.7: Steady State Iso-Tax Revenue Curves



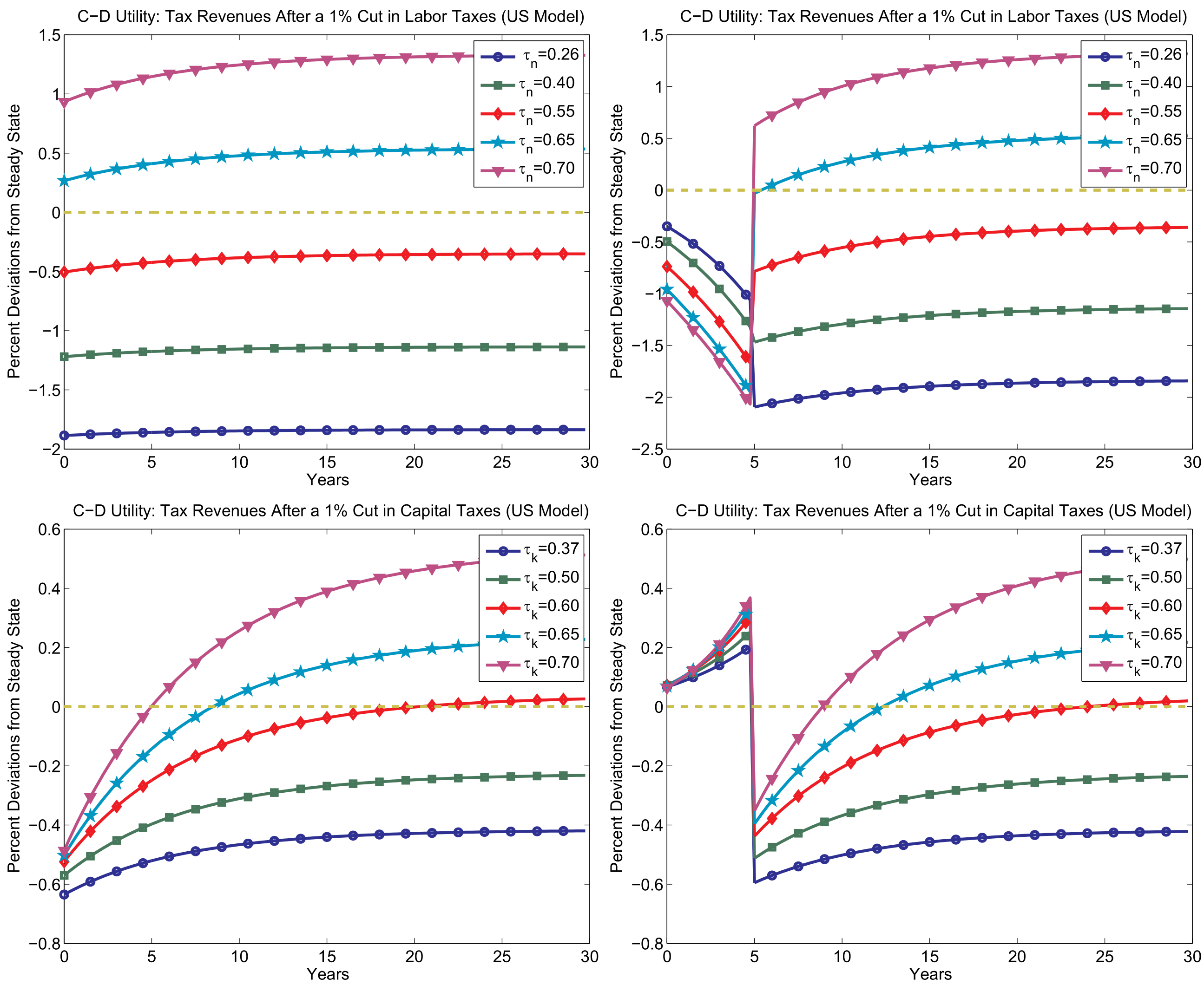
Notes: Steady state iso-tax revenue curves for capital and labor taxes; C-D utility; baseline calibration with US and EU-15 steady state tax revenues=100.

Figure 4.8: Individual Country Laffer Curves



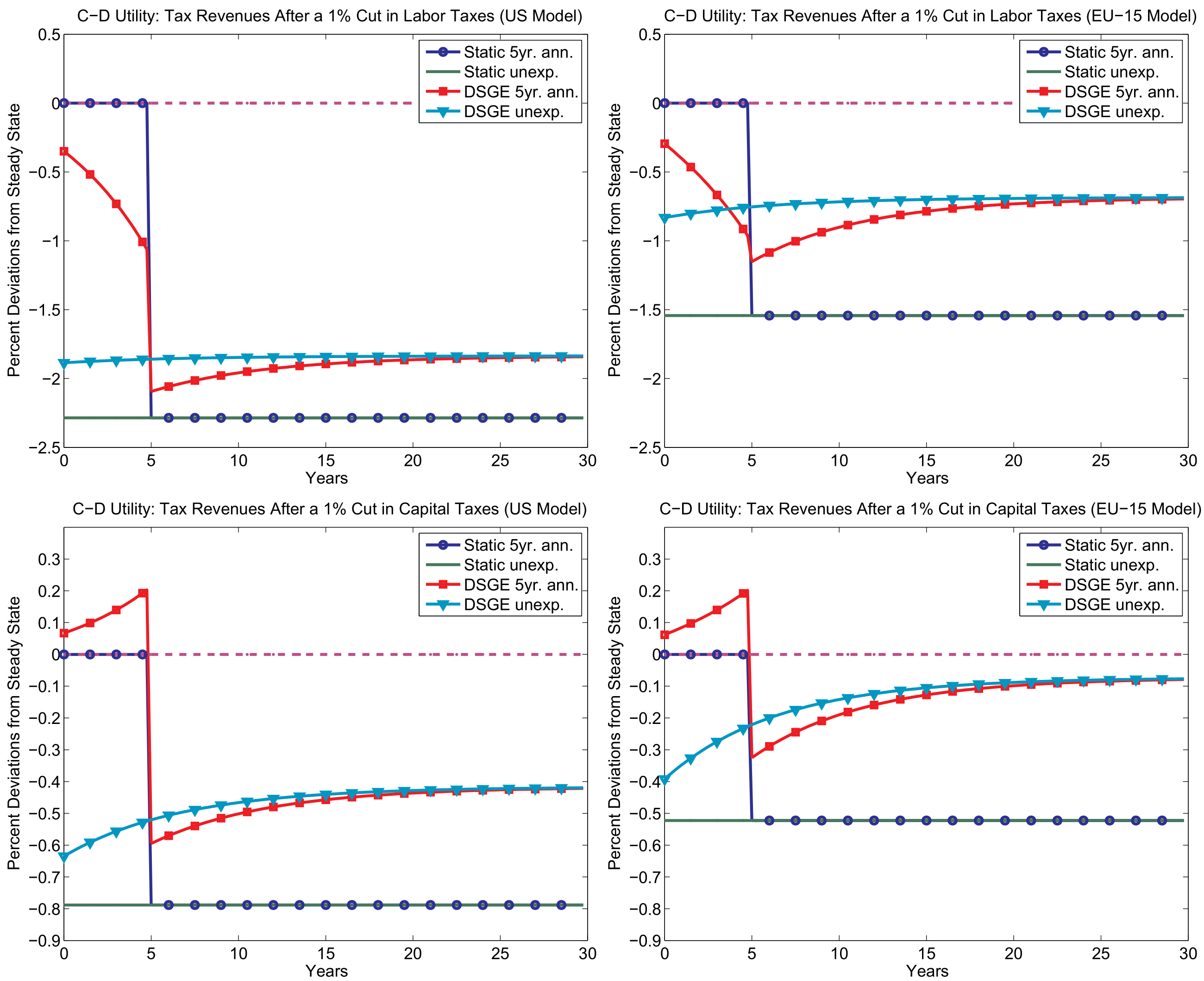
Notes: Individual country labor and capital tax Laffer curves (C-D utility, steady state). The upper two panels show the distance to the peak of the Laffer curves measured either in tax units or tax revenues in percent of baseline GDP. The lower panel depicts the slope of the Laffer curves measured as the change of tax revenues in percent of baseline GDP in response to a one percent steady state tax increase. Blue squares denote countries on the left side whereas red circles denote countries that are located on the right side of their Laffer curves.

Figure 4.9: US Model: Unexpected vs. Announced Tax Cuts



Notes: US Model: Dynamic effects of unexpected and 5-years-in-advance announced permanent 1 % tax cuts; Different steady state tax rates; C-D utility.

Figure 4.10: Dynamic Scoring



Notes: Dynamic vs. static effects of unexpected and 5-years-in-advance announced permanent 1 % tax cuts; baseline calibration; C-D utility.

5 Optimal Pre-Announced Tax Reforms Under Valuable And Productive Government Spending

Domeij and Klein (2005) have shown that the welfare gains of an optimal capital and labor income tax reform decline the longer the reform is pre-announced before its implementation. In other words, pre-announcement is costly in terms of welfare. We reexamine their claim by taking two additional features of government spending into account: public goods and public capital. In our baseline optimal reform, we show that valuable and productive government spending is likely to reduce the welfare costs of pre-announcement. Further, the baseline optimal pre-announced reform displays short-run confiscation and/or subsidy of capital and labor income. As a further contribution, we show that these short-run properties are not important for the welfare gains of pre-announced reforms with sufficiently long pre-announcement duration. In particular, a 4 years pre-announced suboptimal reform in which taxes move - without confiscation and subsidy - directly to their endogenous long-run values at the implementation date generates similar welfare gains as the 4 years pre-announced baseline optimal reform. The underlying tax structure of both reforms, however, appears to be very different.

5.1 Introduction

Should fiscal policy pre-announce tax reforms before their implementation from a welfare point of view? This chapter sheds new light on this issue. Domeij and Klein (2005) show that the welfare gains of an optimal capital and labor tax reform decline the longer the reform is pre-announced before its implementation. Hence, pre-announcement is costly in terms of welfare. The authors argue that the incentive effects of the future anticipated tax reform are dominated by the time delay effect and therefore fiscal policy should not pre-announce this type of tax reform.

In line with the classical optimal taxation literature, Domeij and Klein (2005) use a neoclassical growth model in which the fiscal authority collects distortionary taxes. The resulting tax revenues are rebated lump-sum to households or represent simply wasteful government spending. Is that an economically sensible description of the behavior of e.g. US fiscal policy? We believe it is not. Rather, we observe that fiscal policy uses tax revenues also to provide e.g. public goods and public capital. In this chapter, we describe public goods as non-productive but directly utility providing expenditures like government consumption while public capital describes productive government spending that is likely to affect private sector production through a public capital stock.

If these valuable and productive elements of government spending adjust endogenously in general equilibrium they are likely to affect the welfare consequences of pre-announced tax reforms. What are these welfare implications quantitatively? Does pre-announcement become more or less costly for a society in terms of welfare when taking public goods and public capital into account?

We attempt to answer this question by analyzing the welfare consequences of optimal pre-announced capital and labor tax reforms in a calibrated neoclassical growth model augmented with valuable and productive government spending.

Our approach allows us to investigate an additional interesting issue. It turns out that the short- and long-run properties of the optimal tax system appear to be quantitatively very different. Put differently, the baseline optimal pre-announced tax reform displays short-run confiscation and/or subsidy of capital and labor income followed by a rather quick transition to the steady state of taxes. How important are the short-run properties of the optimal tax system for the resulting welfare gains of the pre-announced tax reform? In other words, is confiscation and/or subsidy quantitatively important for the resulting overall welfare gains of pre-announced tax reforms?

Therefore, the goal of this chapter is twofold. First, we reexamine the claim of Domeij and Klein (2005) by taking two additional features of government spending explicitly into account: public goods and public capital. In other words, we examine the welfare consequences of utility providing government consumption and productive government capital in a pre-announced optimal tax reform. Second, we analyze how important the short-run properties of the optimal tax system - in other words confiscation and/or subsidy of capital and labor income - are for the resulting overall welfare gains of the pre-announced tax reform.

Our analysis employs a standard neoclassical growth model with distortionary taxation. The key ingredients of the model are government consumption that is part of a household utility function as well as productive government capital that enters the production function of firms, similar to Baxter and King (1993).

Suppose, the Ramsey planner is benevolent and is able to commit itself to the following type of tax reform. At time zero he credibly pre-announces an optimal capital and labor income tax reform that will be implemented at some future point in time. We study the transition to the Ramsey steady states as well as the welfare consequences of different pre-announcement horizons.

In our baseline optimal tax reform we find that valuable and productive government spending leads to higher absolute welfare gains and makes pre-announcement less costly in terms of relative welfare gain reductions. More precisely, we find that the welfare gain of the baseline immediate optimal capital and labor income tax reform corresponds to a permanent increase of private consumption of 6.6 percent. By contrast, the welfare gain is 5 percent if the reform is pre-announced 4 years in advance. Hence, relative welfare gains fall by roughly 24 percent. By contrast, for a baseline optimal tax reform with fixed and non-valued government consumption and without public capital the welfare gains amount to 5.3 percent (immediate) and 3.4 percent (4 years pre-announced). This implies a relative reduction of welfare gains by roughly 36 percent similar to Domeij and Klein (2005). Hence, for our baseline reform, valuable and productive government spending - as employed in our model - leads to higher absolute welfare gains and makes pre-announcement less costly in terms of relative welfare gain reductions.

These results depend of course on the valuation of government consumption by households as well as on the public capital share in private production. We show that if either the valuation of government consumption or the public capital share are low or high then pre-announcement is less costly than in an economy without valuable and productive government spending. Interestingly, if both the valuation of government consumption and the public capital share are moderate then pre-announcement can be as costly as in an economy without these ingredients. A sensitivity analysis based on empirically reasonable parameter estimates reveals that for the overwhelming majority of parameter combinations pre-announcement is less costly than in an economy without valuable and productive government spending. Hence, we conclude that public goods and public capital are likely to reduce the welfare losses that are associated with pre-announcement.

Thus, our results show that the welfare costs of pre-announcing an optimal tax reform are likely to be smaller than previously thought. Interestingly, the reduction of welfare costs due to a more realistic description of the spending side of fiscal policy are not dramatic. Nevertheless, they are economically significant and therefore, the effects of valuable and productive government spending should be taken into account when benefits and costs of an optimal pre-announced tax reform are considered.

The second contribution of this chapter focuses on the question whether short-run properties of the optimal pre-announced tax system are important for the resulting overall welfare gains. The baseline optimal tax reform displays short-run confiscation and/or subsidy of capital and labor income followed by a rather quick transition to the long-run values of taxes. How important is this short-run deviation from the long-run optimal taxes for the welfare consequences of the reform? In order to answer this question, we design a tax reform in which capital and labor income taxes move - without confiscation and subsidy - directly to their endogenous long-run values from the implementation date of the reform onwards. We argue that this pattern for the path of taxes is more in line with observed behavior of fiscal policy. Interestingly, we show that welfare gains for this "no confiscation/subsidy" tax reform increase with the pre-announcement horizon as opposed to the decrease observed in the baseline optimal pre-announced tax reform.

In particular, we show that welfare gains for the "no confiscation/subsidy" tax reform increase substantially with the pre-announcement horizon. An immediate reform generates 3.5 percent higher permanent private consumption. By contrast, a 4 years pre-announced tax reform yields 4.7 percent higher permanent private consumption. Thus, we find that relative welfare gains increase by roughly 35 percent if the tax reform is pre-announced 4 years in advance.

Moreover, we show that the level of welfare gains is very different for the baseline optimal and the "no confiscation/subsidy" reform in case of immediate implementation. By contrast, the level of welfare gains becomes very similar for 4 years pre-announcement. Despite this, however, the underlying structure of taxes in both reforms appears still to be very different. For 4 years pre-announcement, the first freely chosen capital tax in the baseline optimal tax reform is still 178 percent. By contrast, the "no confiscation/subsidy" reform moves straight to zero percent capital taxes. The resulting loss of revenues in the "no confiscation/subsidy" reform is made up for by moving to moderately higher steady state labor taxes of 30 percent compared to 28 percent in the baseline optimal tax reform.

Therefore, our results indicate that confiscation and subsidy of capital and labor income is not important for the level of welfare gains that arise from an optimal tax reform which is sufficiently pre-announced in advance of its implementation. Finally, we show that our results prevail qualitatively even if the government has no access to government debt.

The chapter is organized as follows. Section two presents the model. The results of the pre-announced tax reforms are discussed in section three. Finally, section four concludes.

5.2 The Model

We use a standard neoclassical growth model similar to the one employed by Domeij and Klein (2005). However, with respect to utility providing government consumption and productive public capital we draw from the model in Baxter and King (1993).

5.2.1 Economic Environment

Time is discrete, $t = 0, 1, ..., \infty$. The representative household maximizes the discounted sum of life-time utility subject to an intertemporal budget constraint and a capital flow equation. Formally,

$$max_{c_t, n_t, k_t, x_t, b_t} \sum_{t=0}^{\infty} \beta^t u(c_t, n_t, g_t)$$

s.t.

$$\begin{aligned} (1+\tau_t^c)c_t + x_t + q_t b_t &= (1-\tau_t^n)w_t n_t + (1-\tau_t^k)(d_t - \delta)k_{t-1} \\ &\quad +\delta k_{t-1} + b_{t-1} + s_t + \Pi_t \\ k_t &= (1-\delta)k_{t-1} + x_t \end{aligned}$$

where c_t, n_t, k_t, x_t and b_t denote private consumption, hours worked, capital, investment and government bonds. q_t is the price that the household has to pay per government bond. The household takes government consumption g_t as given. Further, the household receives the wage w_t for supplying labor as well as dividends d_t for renting out capital to the firms. In addition, the household receives profits Π_t from the firms and lump-sum transfers s_t from the government. The household has to pay distortionary taxes on consumption, labor and capital income. By contrast to Domeij and Klein (2005), we add consumption taxes to the model since they are an important part of government tax revenue in US data and thus help to calibrate the model later on.

The representative firm maximizes its period-by-period profits subject to a Cobb-Douglas production technology. Formally,

$$max_{k_{t-1},n_t} \quad f_t(k_{t-1}, n_t, k^g_{t-1}) - d_t k_{t-1} - w_t n_t \tag{5.1}$$

s.t.

$$f_t(k_{t-1}, n_t, k^g_{t-1}) = k^{\theta_k}_{t-1} n^{\theta_n}_t (k^g_{t-1})^{\theta_g} \tag{5.2}$$

where k^g_{t-1} denotes the public capital stock that is provided by the government. Note that equilibrium profits of the firm will be zero as long as $\theta_k + \theta_n = 1$ which we will impose when calibrating the model.

The government faces the following budget constraint,

$$g_t + s_t + b_{t-1} + x^g_t = \tau^c_t c_t + \tau^n_t w_t n_t + \tau^k_t (d_t - \delta) k_{t-1} + q_t b_t. \tag{5.3}$$

where x^g_t denotes government investment in the public capital stock. The latter has the following law of motion,

$$k^g_t = (1 - \delta_g) k^g_{t-1} + x^g_t. \tag{5.4}$$

At this point we would like to highlight the key differences to the model in Domeij and Klein (2005). First, government consumption g_t provides utility for the household and second, public capital k^g_{t-1} contributes to private production. A minor difference is the explicit introduction of consumption taxes for the reason given above.

5.2.2 Competitive Equilibrium

Given the economic environment, we are now ready to define a competitive equilibrium similar to Domeij and Klein (2005) and Ljungqvist and Sargent (2004).

Definition: A competitive equilibrium consists of prices $\{w_t, d_t, q_t\}_{t=0}^{\infty}$, quantities $\{c_t, n_t, k_t, x_t\}_{t=0}^{\infty}$, profits $\{\Pi_t\}_{t=0}^{\infty}$ and fiscal policy $\{\tau_t^c, \tau_t^n, \tau_t^k, s_t, g_t, b_t, k_t^g, x_t^g\}_{t=0}^{\infty}$ such that (1) given prices, fiscal policy and profits, the household solves its maximization problem, (2) given prices and fiscal policy, the firm solves its maximization problem, (3) the aggregate resource constraint $c_t + g_t + x_t + x_t^g = f(k_{t-1}, n_t, k_{t-1}^g)$ holds, (4) the government sets fiscal policy such that the government budget constraint is satisfied, (5) bond prices q_t are determined by the no-arbitrage condition $\frac{1}{q_t} = R_{t+1} = 1 + (1 - \tau_{t+1}^k)(d_{t+1} - \delta)$ and (6) profits are zero in all periods, i.e. $\{\Pi_t = 0\}_{t=0}^{\infty}$.

5.2.3 Calibration and Parameterization

We calibrate and parameterize the steady state of the competitive equilibrium to US data from 1975 to 2005. Time is taken to be annual. In principle, there are two ways to proceed.

First, estimate the model and use the estimation results to calibrate and parameterize the model. This, however, turns out to be a thorny issue. Similar to Domeij and Klein (2005), we have chosen a deterministic model. Hence, in order to estimate it with e.g. recent Bayesian model estimation procedures, we would need to put the economy into a stochastic environment with many shocks or by mechanically integrating measurement errors. Further, we use a small-scale model without any nominal or real rigidities. Estimating the model would potentially deliver biased or non-identified parameter estimates since Christiano, Eichenbaum, and Evans (2005), Smets and Wouters (2003), Mankiw and Reis

(2006b) and others have shown that additional features such as sticky prices, sticky wages, sticky information, investment and capacity utilization costs, limited participation etc. are important ingredients for a model in order to explain macroeconomic time series behavior. These features, however, would complicate the model considerably and simultaneously fog up the key issues this chapter attempts to address. Finally, in order to estimate the model, we would need to specify fiscal policy rules, e.g. how taxes or transfers adjust to changes in debt or other types of government expenditures in the competitive equilibrium. We believe, that the particular choice of fiscal policy rules as well as their dynamic lead/lag pattern has important effects for the resulting parameter estimates of the model. Due to these reasons, we do not estimate the model. However, addressing these issues thoroughly would be a useful next step on the research agenda and would certainly justify a separate piece of research.

Instead, and in line with Domeij and Klein (2005), we calibrate the competitive equilibrium steady state to historical averages of data respectively parameterize the model using standard parameter values used in the literature. Later on, we perform a sensitivity analysis with respect to key parameters of the model. In particular, we set $\bar{\tau}^c = 0.057$, $\bar{\tau}^n = 0.235$ and $\bar{\tau}^k = 0.514$ as in Jonsson and Klein (2006). Further, we set $\bar{g}$ and $\bar{b}$ such that $\bar{g}/\bar{y} = 0.162$ and $\bar{b}/\bar{y} = 0.509$ as in the data. Moreover, we fix $\bar{k}$ and $\bar{k}^g$ such that $\bar{k}/\bar{y} = 2.6$ and $\bar{k}^g/\bar{y} = 0.6$ correspond to the data as reported by Lansing (1998).

Comparable to Klein, Krusell, and Rios-Rull (2004) we specify preferences of the household as follows:

$$u(c_t, n_t, g_t) = \frac{(c_t^{\alpha}(1-n_t)^{1-\alpha} g_t^{\alpha\chi})^{1-\sigma} - 1}{1-\sigma}. \tag{5.5}$$

We set $\alpha = 0.323$ to match $\bar{n} = 0.25$ which corresponds to the estimate of McGrattan and Rogerson (2004). Moreover, we set $\sigma = 1$ which implies a unit intertemporal elasticity of substitution with respect to private consumption which is in line with e.g. Domeij and Klein (2005).

The parameter χ pins down the marginal rate of substitution between private and government consumption. Formally, $MRS^{model}_{\bar{g},\bar{c}} = \frac{u_{\bar{g}}}{u_{\bar{c}}} = \chi\frac{\bar{c}}{\bar{g}}$. We set $\chi = 0.2443$ to obtain a marginal rate of substitution that is equal to 1. This choice is within the estimated two standard deviations range of the implied $MRS^{data}_{g,c} \in [0.86, 1.73]$ in Amano and Wirjanto (1998).[1]

We set the depreciation rates $\delta = 0.0542$ and $\delta_g = 0.0567$ in order to match private and public investment to GDP ratios in the data i.e. $\bar{x}/\bar{y} = 0.141$ and $\bar{x}^g/\bar{y} = 0.034$.

Moreover, we fix $\theta_k = 0.36$ and $\theta_n = 0.64$ which is in line with e.g. Gomme and Rupert (2005) and Domeij and Klein (2005). Finally, we set $\theta_g = \bar{x}^g/\bar{y} = 0.034$ as in Baxter and King (1993).[2] Tables 5.1 and 5.2 summarize our calibration and parameterization.

5.3 Optimal Pre-Announced Tax Reforms

In this section, we set up and analyze the optimal baseline as well as the "no confiscation/subsidy" pre-announced capital and labor income tax reforms. For

[1]From Amano and Wirjanto (1998) we can back out the implied marginal rate of substitution which is given by $MRS^{data}_{g,c} = \exp(\mu)\left(\frac{\bar{c}}{\bar{g}}\right)^{\alpha}$. The estimated two standard deviations ranges for the parameters are $\alpha \in [0.494, 0.778]$ and $\exp(\mu) \in [0.431, 0.571]$. From the data we obtain $\frac{\bar{c}}{\bar{g}} = 4.06$. These estimates result in the range for the $MRS^{data}_{g,c}$ given in the text.

[2]Note that this implies, as in Baxter and King (1993), that we have constant returns to scale for private capital and hours worked while we have increasing returns to scale for private capital, hours worked and public capital. We have also examined the consequences of imposing constant returns to scale for all three factors. However, our conclusions later on with respect to the welfare implications appear to be robust to this modification.

both reforms, we also consider the cases when the government has no access to choose government debt optimally.

5.3.1 Modeling Pre-Announcement

Similar to Domeij and Klein (2005), we assume that the Ramsey planner is benevolent and has access to a commitment technology. The Ramsey planner credibly announces in period $t = 0$ that from period T onwards there will be an optimal capital and labor income tax reform. For the periods from $t = 0, .., T-1$ the government keeps the capital and labor income tax at the competitive equilibrium steady states. We can translate this into the following pre-announcement constraints for the Ramsey planner,

$$\tau_t^k = \bar{\tau}^k \quad \text{and} \quad \tau_t^n = \bar{\tau}^n \qquad \forall t = 0, .., T-1.$$

In order to obtain a non-trivial Ramsey problem in case of an immediate reform ($T = 0$), we follow Domeij and Klein (2005) and fix the initial capital tax to its competitive equilibrium steady state, i.e. $\tau_0^k = \bar{\tau}^k$ for $T = 0$.[3]

[3]If the government would be free to choose τ_0^k in case of an immediate reform ($T = 0$) it would confiscate initial capital k_{-1} through an initial capital tax levy that is high enough to finance all future government expenditures while simultaneously achieving zero future capital and labor income taxes. Ljungqvist and Sargent (2004) note on a standard immediate tax reform "To make the Ramsey problem interesting, we always impose a restriction on τ_0^k". In the literature there exist at least two approaches. Either fix τ_0^k to a small or historical value as in Sargent and Ljungqvist or Domeij and Klein (2005) or impose an upper bound for τ_0^k as in Chamley (1986) or Jones, Manuelli, and Rossi (1993). We examine the latter case in one of the subsequent sections.

5.3.2 Baseline Ramsey Reform

It is convenient for the formulation of the baseline Ramsey problem that the government budget constraint can be rewritten as follows,[4]

$$\sum_{t=0}^{\infty} \beta^t \frac{U_c(t)}{1+\tau_t^c} \left[Rev_t - g_t - s_t - k_t^g + (1-\delta_g)k_{t-1}^g\right] = \frac{U_c(0)}{1+\tau_0^c} b_{-1} \tag{5.6}$$

with tax revenues $Rev_t = \tau_t^c c_t + \tau_t^n f_{n,t} n_t + \tau_t^k (f_{k,t} - \delta) k_{t-1}$. As Domeij and Klein (2005), we assume that the Ramsey planner takes government transfers $\{s_t\}_{t=0}^{\infty}$ as a given stream of expenditures. In terms of taxes, we assume that the Ramsey planner in our model chooses optimal labor and capital income taxes $\{\tau_t^n, \tau_t^k\}_{t=0}^{\infty}$ as in Domeij and Klein (2005) but takes consumption taxes $\{\tau_t^c\}_{t=0}^{\infty}$ as given.[5] Similar to Ljungqvist and Sargent (2004), we are now ready to define the Ramsey problem.

Definition: Given the pre-announcement horizon T, initial capital and government debt k_{-1}, b_{-1} as well as consumption taxes and transfers $\{\tau_t^c, s_t\}_{t=0}^{\infty}$, the Ramsey problem is to choose a competitive equilibrium that maximizes $\sum_{t=0}^{\infty} \beta^t u(c_t, n_t, g_t)$.

[4]We obtain this by repeated substitution of government bonds in consecutive government budget constraints. Further, we impose the transversality condition $\lim_{t\to\infty} \prod_{i=0}^{t} q_i b_t = 0$ and make use of the equilibrium relationship $\beta^t \frac{U_c(t)}{U_c(0)} \frac{1+\tau_0^c}{1+\tau_t^c} = \prod_{i=0}^{t-1} q_i$ which can be derived from the Euler equation for bonds.

[5]As pointed out earlier, we have introduced consumption taxes since they are an important part of government tax revenue in US data and thus help us to calibrate the model. However, choosing capital, labor and consumption taxes simultaneously would imply non-unique solutions since labor and consumption taxes affect the labor supply decision of the household in the same way. That is, a high labor tax and a low consumption tax are equivalent to a low labor tax and high consumption tax. Hence, we leave the consumption tax at its competitive equilibrium steady state value and solve for the optimal labor and capital income taxes as in Domeij and Klein (2005).

In other words, the Ramsey planner maximizes household utility subject to the competitive equilibrium conditions and pre-announcement constraints. Formally,

$$max \sum_{t=0}^{\infty} \beta^t \left[u(c_t, n_t, g_t) + \phi \frac{U_c(t)}{1+\tau_t^c} \left(Rev_t - g_t - s_t - k_t^g + (1-\delta_g) k_{t-1}^g \right) \right.$$

$$-\mu_t \left(U_n(t)(1+\tau_t^c) + U_c(t)(1-\tau_t^n) f_{n,t} \right)$$

$$-\gamma_t \left(c_t + g_t + k_t + k_t^g - f_t(k_{t-1}, n_t, k_{t-1}^g) - (1-\delta)k_{t-1} - (1-\delta_g) k_{t-1}^g \right)$$

$$-\omega_t \Big(Rev_t - \tau_t^c c_t - \tau_t^n f_{n,t} n_t - \tau_t^k (f_{k,t} - \delta) k_{t-1} \Big)$$

$$\left. -\eta_t \left(\beta \frac{U_c(t+1)}{1+\tau_{t+1}^c} \Big((1-\tau_{t+1}^k)(f_{k,t+1} - \delta) + 1 \Big) - \frac{U_c(t)}{1+\tau_t^c} \right) \right] - \phi \frac{U_c(0)}{1+\tau_0^c} b_{-1}$$

$$- \sum_{t=0}^{T-1} \beta^t \nu_t \left(\tau_t^k - \bar{\tau}^k \right) - \sum_{t=0}^{T-1} \beta^t \kappa_t \left(\tau_t^n - \bar{\tau}^n \right).$$

Given the pre-announcement horizon T, the Ramsey planner solves for the sequences $\{c_t, n_t, k_t, g_t, k_t^g, Rev_t, \tau_t^n\}_{t=0}^{\infty}, \{\tau_t^k \mid \tau_0^k = \bar{\tau}^k\}_{t=1}^{\infty}$ if $T = 0$ and $\{c_t, n_t, k_t, g_t, k_t^g, Rev_t, \tau_t^n\}_{t=0}^{\infty}, \{\tau_t^k\}_{t=0}^{\infty}$ if $T \geq 1$. We assume that the Ramsey planner takes k_{-1}, b_{-1}, τ_t^c and s_t at their competitive equilibrium steady states as given.

Finally, note that the multiplier η_t on the Euler equation constraint becomes a state variable. As discussed in Marcet and Marimon (1998), optimal policy decisions in period t then depend on η_{t-1} with $\eta_{-1} = 0$.

Appendix C.1 summarizes the first order optimality conditions for the Ramsey problem. We follow Domeij and Klein (2005) regarding the solution technique. Appendix C.2 explains in detail how we solve the model.

Baseline Results

Table 5.3 provides a comparison of the data, the competitive equilibrium steady state as well as the Ramsey steady states. Consider the column "Baseline" for the moment. The Ramsey planner chooses a zero capital income tax in steady state which is in line with the classical optimal taxation literature. Further, the Ramsey planner chooses a higher private capital to output ratio but a lower public capital to output ratio. It turns out that the public capital stock is lower in the Ramsey compared to the competitive equilibrium steady state.[6] Note that the private and public capital to output ratios are independent of the pre-announcement horizon since the steady state capital income tax is zero irrespective of the pre-announcement period.

By contrast, the Ramsey steady state labor income tax rate is higher than in the competitive equilibrium steady state. Furthermore, it increases with the pre-announcement horizon. Front-loading of government debt decreases with pre-announcement and lower receipts must be financed by higher labor income taxes. Finally, private and government consumption increase in the Ramsey steady state but output increases by more so that the private and government consumption to output ratios decrease relative to the competitive equilibrium steady state.

Figure 5.1 shows the transition of the key variables in response to the baseline optimal tax reform. In line with Domeij and Klein (2005) we observe that the

[6]This is due to the public capital share $\theta_g = 0.034$. If we assume, e.g. $\theta_g = 0.05$, the Ramsey planner chooses a higher public capital stock than in the competitive equilibrium steady state. We examine the implications of this in the sensitivity analysis.

initially chosen capital income tax, the consumption boom and the front-loading of government debt reduces with the pre-announcement horizon. However, the Ramsey planner also chooses government consumption and public capital in our model. The figure reveals that government consumption is reduced initially before it smoothly converges towards a higher level than in the competitive equilibrium steady state. Interestingly, the transition path of government consumption is smooth throughout all pre-announcement horizons and thus, the government contributes to smooth out household utility.

On the other hand, the government chooses to reduce the public capital stock initially before it converges upwards towards a lower steady state than in the competitive equilibrium steady state. Hence, the existing competitive equilibrium steady state public capital stock is inefficiently high and its reduction enhances efficiency since distortionary labor taxes do not need to increase as much as with maintaining a high public capital stock. The initial fall of public capital serves the following purpose. The government uses these resources to reduce the amount of outstanding debt and thereby the interest payments. Note that this occurs almost irrespective of the chosen pre-announcement period. Since the household accumulates less government debt it uses free resources to invest in the private capital stock which partly makes up for the lower public capital stock.

Figure 5.4 shows the welfare effects of the optimal pre-announced tax reform for different pre-announcement horizons. We measure welfare in permanent private consumption equivalents. See appendix C.3 for the details of these calculations. According to the solid blue line in the upper panel of the figure the welfare gain of an immediate optimal tax reform corresponds to a permanent increase of private consumption of 6.6 percent. By contrast, the welfare gain is 5 percent if the reform was pre-announced 4 years in advance. Hence, pre-announcement leads to relative welfare gain reductions of 24 percent in this baseline reform.

By contrast, as shown in figure 5.5, for a baseline optimal tax reform with fixed and non-valued government consumption and without public capital the welfare gains amount to 5.3 percent (immediate) and 3.4 percent (4 years pre-announced). This implies a relative reduction of welfare gains by roughly 36 percent similar to Domeij and Klein (2005). Hence, for our baseline reform, valuable and productive government spending - as employed in our model - leads to higher absolute welfare gains and makes pre-announcement less costly in terms of relative welfare gain reductions.

The higher absolute welfare gain in our baseline reform is due to the efficiently chosen levels of government consumption and public capital which lead to less distortions and hence higher welfare. The lower relative reduction of welfare gains can be explained by two facts. First, the higher absolute level of welfare gains reduces the relative costs of pre-announcement. Second, the government chooses smooth pathes for government consumption and public capital irrespective of the pre-announcement horizon and hence smoothes out the welfare effects. Thus, for our baseline reform valuable and productive government spending leads to higher absolute welfare gains and makes pre-announcement less costly in relative terms.

Hence, our results show that the welfare costs of pre-announcing an optimal tax reform are likely to be smaller than previously thought. Interestingly, the reduction of welfare costs due to a more realistic description of the spending side of fiscal policy are not dramatic. Nevertheless, they are economically significant and therefore, the effects of valuable and productive government spending should be taken into account when benefits and costs of an optimal pre-announced tax reform are considered.

Sensitivity

Our results depend of course on the valuation of government consumption by households χ as well as on the public capital share in private production θ_g. For illustrative purposes, we experiment with the following alternative values: $\theta_g \in \{0.005; 0.1\}$ and $\chi \in \{0.15; 0.35\}$. We choose these particular values since each combination of these values represents the cases that either government consumption or public capital converges to a higher and/or lower Ramsey steady state compared to the competitive equilibrium steady state. Figure 5.5 shows that if either the valuation of government consumption or the public capital share are low then pre-announcement is even less costly than in our baseline optimal reform. Interestingly, if both the valuation of government consumption and the public capital share are set to higher values then pre-announcement can be almost as costly as in an economy without these ingredients.

In order to investigate this issue more thoroughly and to ensure further robustness of our results, we proceed as follows. We construct many random parameter combinations (θ_g, χ) by drawing both parameters from the following uniform distributions: $\theta_g \sim U[0.00001, 0.2]$ and $\chi \sim U[0.00001, 0.6]$.[7] We draw 329 parameter sets and solve the baseline model for the following pre-announcement horizons $T \in \{0, 2, 4\}$.[8] The case of $\theta_g = 0.00001$ resembles a non-productive government capital stock which is similar to the standard Cobb-

[7] We have chosen lower bounds of 0.00001 since the solution algorithm has difficulties to find solutions if the lower bound is strictly zero.

[8] It takes roughly one hour to solve the model for a given parameter combination and a given pre-announcement horizon. Hence, total time for this analysis is 329 hours times 3 pre-announcement horizons which amounts to roughly 5.5 weeks of total computation time. Thus, generating additional draws respectively incorporating further pre-announcement horizons is extremely computationally burdensome.

Douglas production function as in e.g. Cooley and Prescott (1995). By contrast, $\theta_g = 0.2$ corresponds to a comparably high public capital share relative to our baseline specification. However, this value is still only half as large as the estimate in Aschauer (1989). To that end, we keep the upper bound $\theta_g = 0.2$ since our solution algorithm appears to be sensitive to higher values of θ_g.[9] Nevertheless, we consider the uniformly distributed interval $[0.00001, 0.2]$ for θ_g as still reasonably large for a useful sensitivity analysis. The uniformly distributed interval for χ implies marginal rates of substitutions between private and government consumption in the competitive equilibrium steady state of $MRS^{Model}_{\bar{g},\bar{c}} \in (0.00004, 2.45)$ which captures considerably more than the two standard deviations range $MRS^{data}_{g,c} \in (0.86, 1.73)$ of the empirical estimate reported in Amano and Wirjanto (1998).

The upper left panel of figure 5.6 shows the random parameter combinations for θ_g and χ. The upper right panel shows the resulting welfare gains for each random parameter combination. In addition, we add the results of our baseline parameterization (bold black solid line) as well as the results of the model with non-valued and fixed government consumption and no productive public capital (bold black dashed line) similar to Domeij and Klein (2005). In order to facilitate comparison with respect to the welfare losses of pre-announcement, we normalize all welfare gains such that they equal 100 for $T = 0$. The figure shows that it is possible that 4 years pre-announcement is almost costless in terms of relative welfare gain reductions. On the other hand, it is also possible that 4 years pre-announcement is as costly as in the model that features non-valued and fixed government consumption and no productive public capital, i.e. 36 percent relative welfare gain reduction. However, the overwhelming majority of cases is

[9] In particular, values $\theta_g \gg 0.2$ imply that the Ramsey steady state of public capital is very far away from its competitive equilibrium steady state level. In these cases, the solution algorithm appears to have difficulties to calculate stable transition paths to the Ramsey steady state.

located somewhere in between theses two extremes. In particular, the mean of the relative welfare gain reduction for 4 years pre-announcement is 20 percent. Moreover, our baseline parameterization generates a relative welfare gain reduction of 4 years pre-announcement of 24 percent which is located well within if not slightly on the upper end of possible relative welfare gain reductions.

The question that arises is which parameter combinations are responsible for these results? The lower two panels of figure 5.6 examine the relative welfare gain reductions that are due from moving from $T = 0$ (immediate reform) to $T = 4$ (4 years pre-announced reform) for all random parameter combinations and from different angles. It appears that our baseline parameter combination ($\theta_g = 0.034, \chi = 0.2443$) generates a relative welfare gain reduction of roughly 24 percent whereas the parameter combination ($\theta_g = 0.071, \chi = 0.325$) generates the maximum reduction of 36 percent. For the latter, both, government consumption and public capital converge to Ramsey steady states that are higher than their competitive equilibrium counterparts. For this parameter combination, it turns out that the additional transitional costs are as large as the additional steady state gains that arise from valuable and productive government spending. In other words, the relative welfare gains are as large as for the non-valued and constant government consumption and no public capital model similar to Domeij and Klein (2005). For the overwhelming majority of alternative parameter combinations, that is higher or lower values of θ_g and χ, the transitional costs are lower than the steady state gains which results in higher relative welfare gains throughout all pre-announcement horizons.

To sum up, using empirically reasonable parameter intervals, it turns out that for the overwhelming majority of cases pre-announcement is less costly than in an economy without valuable and productive government spending. From this, we conclude that public goods and public capital are likely to reduce the welfare losses that are associated with pre-announcement.

5.3.3 Baseline Ramsey Reform With Upper Bound On Capital Taxes

The baseline optimal tax reform is characterized by initial capital income taxes much higher than 100 percent. That is, capital income is confiscated entirely and moreover, the household pays to rent out capital to the firms. By contrast, Chamley (1986) and Jones, Manuelli, and Rossi (1993) analyze optimal immediate tax reforms with an upper bound on capital taxes - say 100 percent. As a further extension to Domeij and Klein (2005), we analyze the effects of imposing an upper bound of 100 percent on capital taxes in our baseline optimal pre-announced tax reform. In this case, the Ramsey planner faces the following additional constraint for the Ramsey problem in section 5.3.2:

$$\tau_t^k \leq 1 \quad \forall t = 0, .., \infty. \tag{5.7}$$

Baseline Results With Upper Bound On Capital Taxes

The column "Baseline (τ^k bound)" in table 5.3 shows the steady state characteristics of this reform. The upper bound on capital taxes prevents the government from accumulating an asset position as large as before. The loss in revenues is made up for by higher labor income taxes. Figure 5.2 shows the transition of variables for this reform. In case of immediate implementation (T=0) capital taxes hit the upper bound for 5 periods before turning to zero fairly quickly afterwards. The relatively prolonged period of 100 percent capital income taxes leads to a long lasting consumption boom as opposed to the short lived consumption boom in the baseline reform. It turns out that the longer the reform is pre-announced the smaller is the amount of periods in which the capital tax hits the upper bound. The case of T=6 is the first time when the first freely chosen capital tax is below 100 percent.

The upper panel of figure 5.4 shows the welfare gains of this reform. Again, an immediate reform generates the highest welfare gains which are now 5.9 percent. However, the welfare gains are lower by roughly 0.7 percent compared to the baseline optimal tax reform without upper bounds. In case the reform is pre-announced 4 years in advance welfare gains fall to 5 percent. Hence, relative welfare gains decline by roughly 15 percent. However, one has to be careful by comparing this figure to Domeij and Klein (2005) since they did not consider the case of an upper bound for capital taxes. If anything, in our case it leads to a further reduction of the welfare losses due to pre-announcement. Finally, note that as the pre-announcement horizon becomes sufficiently large, welfare gains coincide with the baseline optimal reform since the upper bound constraint is not binding anymore.

5.3.4 "No confiscation/subsidy" Tax Reform

In this section, we focus on the question whether short-run properties of the optimal pre-announced tax system are important for the resulting overall welfare gains. More precisely, as we have seen in the previous sections, the baseline optimal tax reform displays short-run confiscation and/or subsidy of capital and labor income followed by a rather quick transition to the long-run values of taxes. How important is this short-run deviation from the long-run taxes for the welfare consequences of the reform? Put differently, how much of the welfare gains are attributable to the initial confiscation and/or subsidy of capital and labor income and how much of the welfare gains are due to the long-run constant tax rates? In order to answer this question, we design a tax reform in which capital and labor income taxes move - without confiscation and subsidy - directly to their endogenous long-run values from the implementation date of the reform onwards. We call this reform "no confiscation/subsidy" tax reform.[10]

This type of reform shares one dimension of one of the experiments in Chari, Christiano, and Kehoe (1994), Domeij and Klein (2005) and Dominguez (2006a). These authors analyze the case when the government imposes a constant zero capital income tax over time in case of an immediate reform. They show that welfare declines compared to the case when the government confiscates capital through a high initial capital income tax. In particular, Chari, Christiano, and Kehoe (1994) report that 80 percent while Domeij and Klein (2005) report that 45 percent of the welfare gains are due to the initial confiscation of capital income. However, these papers consider the confiscation effects of this policy for an immediate reform only.[11] Hence, our analysis extends the existing literature in two dimensions. First, we analyze the importance of confiscation and subsidy for the welfare properties of a pre-announced tax reform. In addition, we consider the case that the government moves capital *and* labor taxes to their endogenous long-run values at the implementation date of the tax reform.

The policy that capital and labor taxes move directly to their long-run values in this alternative reform can be translated into the following additional constraints for the Ramsey planners problem in section 5.3.2,

$$\tau_t^k = \bar{\tau}_{n-cs}^k \quad \text{and} \qquad \tau_t^n = \bar{\tau}_{n-cs}^n \qquad \forall t = T, .., \infty \tag{5.8}$$

[10]Note that for short pre-announcement horizons confiscation of capital income occurs. As in Domeij and Klein (2005), for very long pre-announcement horizons the initial capital income tax is negative and hence a subsidy occurs. Finally, for immediate reforms, labor income taxes are initially negative which is also a subsidy. The label "no confiscation/subsidy" is chosen since the reform avoids all these confiscation and subsidy pattern.

[11]Dominguez (2006a) assumes a one period implementation lag. However, she does not discuss welfare implications in the presence of the zero capital income tax policy.

where $\bar{\tau}^k_{n-cs}$ and $\bar{\tau}^n_{n-cs}$ denote the endogenously determined long-run steady state values of capital and labor income taxes that correspond to the "no confiscation/subsidy" reform.[12]

Results "No confiscation/subsidy" Tax Reform

The column "no confiscation/subsidy" in table 5.3 shows the steady states of the pre-announced tax reform with impact tax transitions. As for the baseline reform, the optimal steady state capital income tax is zero and hence, we obtain the same private and government capital to output ratios. Since the government cannot confiscate capital through a high initial capital tax we observe less front-loading with respect to government debt. In particular, for $T = 0$ the government can only attain a roughly zero debt to output ratio and in order to cover expenditures a higher steady state labor income tax is needed. By contrast, for $T = 4$ the government accumulates surpluses and reaches a negative debt position that generates interest revenues. Hence, the steady state labor income tax is lower than for $T = 0$. Note that this is exactly the opposite effect compared to the baseline optimal reform. Now, pre-announcement leads to less distortions in steady state for this type of tax reform. The private and government consumption to output ratios change only very little. Finally, labor supply and output in steady state increase with pre-announcement as opposed to the baseline optimal reform.

Figure 5.3 shows the transition of variables for the "no confiscation/subsidy" tax reform. Interestingly, the government prefers again a smooth pattern of gov-

[12]These additional constraints for the Ramsey planner can be motivated alternatively by imposing time-invariant taxes. E.g. for capital taxes we impose that $\tau^k_t = \tau^k_{t+1} = \tau^k_{t+2} = \tau^k_{t+3} = ... = \tau^k_\infty$. However, at $t = \infty$ we are at the "no confiscation/subsidy" steady state and hence $\tau^k_\infty = \bar{\tau}^k_{n-cs}$. Thus, we can write $\tau^k_t = \tau^k_{t+1} = \tau^k_{t+2} = \tau^k_{t+3} = ... = \bar{\tau}^k_{n-cs}$ or alternatively $\tau^k_t = \bar{\tau}^k_{n-cs} \quad \forall t = 0, .., \infty$. Finally, in the presence of T pre-announcement periods we obtain the above constraint $\tau^k_t = \bar{\tau}^k_{n-cs}$ $\forall t = T, .., \infty$. The case of labor taxes follows accordingly.

ernment consumption and public capital even for different pre - announcement horizons. By contrast again, the transition of government debt depends much more on the pre-announcement length. The government accumulates only a net asset position if the pre-announcement horizon is sufficiently large. There is no initial consumption boom since there is no longer any initial confiscation of capital. An immediate reform moves the capital income tax to zero in the initial period which induces a large increase in the real return on capital. In order to expand the private capital stock the individual reduces consumption by a relatively large amount. By contrast, if the reform is pre-announced consumption declines by less since in anticipation of the reform, the capital stock increases smoothly over time in the pre-announcement periods.

Figure 5.4 depicts the welfare effects of pre-announcement for the "no confiscation/subsidy" tax reform. The solid red line with squares shows that the welfare gains from pre-announcement increase with the pre-announcement horizon. The upper panel shows that an immediate reform implies 3.5 percent higher permanent private consumption whereas a 4 years pre-announced reform delivers 4.7 percent higher permanent private consumption.[13] Hence, relative welfare gains increase by roughly 35 percent.

This is due to the following reason. In case of an immediate reform, the government is not able to initially choose very high capital taxes and negative labor taxes. The absence of the capital confiscation implies that the government cannot accumulate a net-asset position in steady state and hence a higher steady state

[13]Note that our results for the immediate reform are in line with the existing literature. As pointed our earlier, Chari, Christiano, and Kehoe (1994) find that 80 percent of the welfare gains of an immediate optimal reform are due to confiscation of capital income. Domeij and Klein (2005) report that 45 percent of the welfare gains are due to high initial capital taxes. We find that removing confiscation and subsidy of capital and labor taxes reduces the welfare gains from 6.6 percent to 3.5 percent and hence by 53 percent in an immediate reform. However, the literature does only examine these effects for immediate reforms while we take a further step ahead by analyzing how pre-announcement affects these results.

labor income tax is needed to generate enough tax revenues to balance the government budget. Hence, higher distortions imply low welfare gains. Consider the case of pre-announcement. Now, the government can accumulate a net-asset position because tax revenues rise in the pre-announcement period due to higher labor supply and capital accumulation. A steady state net-asset position implies lower steady state labor income taxes and therefore lower distortions. This in turn results in larger welfare gains for the pre-announced tax reform.[14]

Moreover, notice that there are rather large differences between the level of welfare gains of the optimal baseline and the "no confiscation/subsidy" tax reform in case of an immediate implementation. These differences become very small if the reforms are pre-announced 4 years in advance. However, and more importantly, although the level of welfare gains appear to be rather similar in both reforms the structure of taxes is rather different. For 4 years pre-announcement, the first freely chosen capital tax in the baseline optimal tax reform is still 178 percent. By contrast, the "no confiscation/subsidy" reform moves straight to zero percent capital taxes. The resulting loss of revenues in the "no confiscation/subsidy" reform is made up for by moderately higher steady state labor taxes of 30 percent compared to 28 percent in the baseline optimal tax reform.

To sum up, we have analyzed a tax reform in which the government moves taxes - without confiscation and subsidy - directly to their endogenous long-run values. For this reform, we have seen that the welfare gains - though the absolute level is lower compared to the baseline optimal reform - increase with the pre-announcement horizon. Further, we show that the level of welfare gains is very similar to those of an optimal 4 years pre-announced reform. Hence, our

[14]Technically, pre-announcement reduces the immediate tax transition constraints and hence the government has more degrees of freedom. However, for very long pre-announcement periods, the gains from pre-announcement may be out-weighted by the delay effect since households discount the future.

analysis indicates that confiscation and subsidy of capital and labor income is not important for the level of welfare gains that arise from an optimal tax reform which is sufficiently pre-announced in advance of its implementation.

5.3.5 Pre-Announced Tax Reforms With Fixed Debt

In the previous sections, we have seen that the transition path of public capital and government consumption is smooth despite different pre-announcement periods. By contrast, the pattern of government debt changed a lot with the pre-announcement horizon. Moreover, in many of the cases that we have considered the government accumulates a net asset position. Although this is a standard result in the optimal taxation literature with immediate implementation it is not a typical observation in the data. A natural question to ask is therefore: what happens to the results if we assume that the government has no access to government debt? That is, the government leaves the existing stock of government debt untouched at its competitive equilibrium steady state. In order to capture this variation formally, we impose

$$b_t = \bar{b} \qquad \forall t = 0, .., \infty. \tag{5.9}$$

Technically, the intertemporal government budget constraint in section 5.3.2 is replaced by its period-by-period version. In addition, we impose the constant debt requirement as well as the no-arbitrage condition which results in the following period-by-period government budget constraint for the Ramsey planner,

$$\begin{aligned} g_t + s_t + k_t^g &= \tau_t^c c_t + \tau_t^n w_t n_t + \tau_t^k (\theta_k \frac{y_t}{k_{t-1}} - \delta) k_{t-1} + (1 - \delta_g) k_{t-1}^g \\ &\quad + ((1 + (1 - \tau_{t+1}^k)(\theta_k \frac{y_{t+1}}{k_t} - \delta))^{-1} - 1)\bar{b}. \end{aligned} \tag{5.10}$$

We study the effects of the fixed debt assumption for the baseline as well as for the “no confiscation/subsidy” tax reform.

Results Fixed Debt Reforms

Consider the column “Baseline/No conf-subsidy (Fixed Debt)” in table 5.3 now. Both reforms result in the same steady state since debt is not available as a policy instrument for the government. For the same reason, the steady states of the variables do not depend on the pre-announcement horizon anymore. Again, the optimal steady state capital income tax is zero which delivers the same private and public capital to output ratios as before. The absence of government debt as an instrument for the government implies that labor taxes are higher compared to the previous reforms. The debt to output ratio falls because output rises. Note however, that the increase of output is the smallest for all reforms.

Figures 5.7 and 5.8 show the transition of variables in response to the tax reforms.[15] And indeed, if government debt is fixed, the transition pathes of public capital and government consumption are not as smooth as before and depend much more on the pre-announcement horizon. Under fixed debt, the Ramsey planner allocates the revenues from immediate or pre-announced taxation between government consumption and public capital which in turn affects the transition of e.g. private consumption, hours and private capital.

Figure 5.9 shows the welfare effects for the baseline (dashed-dotted) as well as “no confiscation/subsidy” (dashed-dotted/squares) tax reform under the fixed government debt requirement. Two things are noticeable. First, both curves are

[15]We do not report results when an upper bound on capital taxes is imposed. The upper bound only binds for $T = 0$ and then only for two periods. The changes in allocations are only minimal. Further, the changes in welfare gains are almost indistinguishable for $T = 0$ and identical to the baseline reform with fixed debt for $T \geq 1$. These results make sense since the $\tau_0^k = \bar{\tau}^k$ constraint for $T = 0$ is replaced by the constraint $\tau_0^k \leq 1$ which is active for two periods only. Hence, the allocations and welfare gains are rather similar to the baseline reform with fixed debt and due to this we do not report them here.

below the ones that allow for variable debt. If the government has no access to government debt this reduces the set of its instruments and hence the benefits of an optimal reform will be lower. Second, the "no confiscation/subsidy" tax reform with fixed debt also generates increases of welfare gains in the presence of pre-announcement. However, longer pre-announcement horizons are needed to obtain almost the same welfare gains as in the baseline reform with fixed debt. Nevertheless, our result that pre-announcement increases welfare gains in case of the "no confiscation/subsidy" tax reform prevails qualitatively even if the government has no access to government debt.

5.4 Conclusion

This chapter has analyzed the following question: should fiscal policy pre-announce tax reforms before their implementation from a welfare point of view? Domeij and Klein (2005) show that the welfare gains of an optimal capital and labor tax reform decline the longer the reform is pre-announced before its implementation. Hence, pre-announcement is costly in terms of welfare. We have reexamined the claim of Domeij and Klein (2005) by taking two additional features of government spending explicitly into account: public goods and public capital.

In our baseline optimal tax reform we find that valuable and productive government spending leads to higher absolute welfare gains and makes pre-announcement less costly in terms of relative welfare gain reductions due to pre-announcement. More precisely, a 4 years pre-announced reform reduces relative welfare gains compared to an immediate reform by roughly 24 percent in the presence of valuable and productive government spending. By contrast, the relative loss is roughly 36 percent in an economy without valuable and productive government spending. In addition, a sensitivity analysis based on empirically reasonable parameter estimates reveals that for the overwhelming majority of parameter combinations pre-announcement is less costly than in an economy without valuable and productive government spending. Hence, we conclude that public goods and public capital are likely to reduce the welfare losses that are associated with pre-announcement.

Thus, our results show that the welfare costs of pre-announcing an optimal tax reform are likely to be smaller than previously thought. Interestingly, the reduction of welfare costs due to a more realistic description of the spending side of fiscal policy are not dramatic. Nevertheless, they are economically significant and therefore, the effects of valuable and productive government spending should be taken into account when benefits and costs of an optimal pre-announced tax reform are considered.

The second contribution of this chapter focuses on the question whether short-run properties of the optimal pre-announced tax system are important for the resulting overall welfare gains. The baseline optimal tax reform is characterized by initial confiscation and/or subsidy of capital and labor income via taxation followed by a rather quick transition to the long-run values of taxes. How important is this short-run deviation from the long-run optimal taxes for the welfare consequences of the reform? In order to answer this question, we design a tax reform in which capital and labor income taxes move - without confiscation and subsidy - directly to their endogenous long-run values from the implementation date of the reform onwards.

Interestingly, we show that welfare gains for this "no confiscation/subsidy" tax reform increase with the pre-announcement horizon as opposed to the decrease observed in the baseline optimal pre-announced reform. In particular, we find that relative welfare gains increase by roughly 35 percent if the tax reform is pre-announced 4 years in advance. Moreover, we show that the level of welfare gains is very different for the baseline optimal and the "no confiscation/subsidy" reform in case of immediate implementation. By contrast, the level of welfare gains becomes very similar for 4 years pre-announcement. Despite this, however, the underlying structure of taxes in both reforms appears still to be very different. For 4 years pre-announcement, the first freely chosen capital tax in the baseline optimal tax reform is still 178 percent. By contrast, the "no confiscation/subsidy" reform moves straight to zero percent capital taxes. The resulting loss of revenues in the "no confiscation/subsidy" reform is made up for by moving to moderately higher steady state labor taxes of 30 percent compared to 28 percent in the baseline optimal tax reform.

Therefore, our results indicate that confiscation and subsidy of capital and labor income is not important for the level of welfare gains that arise from an optimal tax reform which is sufficiently pre-announced in advance of its implementation. Finally, we show that our results prevail qualitatively even if the government has no access to government debt.

5.5 Tables and Figures

Table 5.1: Calibration of the Competitive Equilibrium Steady State

Variable	Value	Description	Restriction
$\bar{\tau}^n$	0.235	Labor tax rate	Data
$\bar{\tau}^k$	0.514	Capital tax rate	Data
$\bar{\tau}^c$	0.057	Consumption tax rate	Data
$\bar{g}/\bar{y}$	0.162	Government consumption to output ratio	Data
$\bar{b}/\bar{y}$	0.509	Government debt to output ratio	Data
$\bar{k}/\bar{y}$	2.6	Private capital to output ratio	Data
$\bar{k}^g/\bar{y}$	0.6	Public capital to output ratio	Data

Table 5.2: Parameterizing the Competitive Equilibrium Steady State

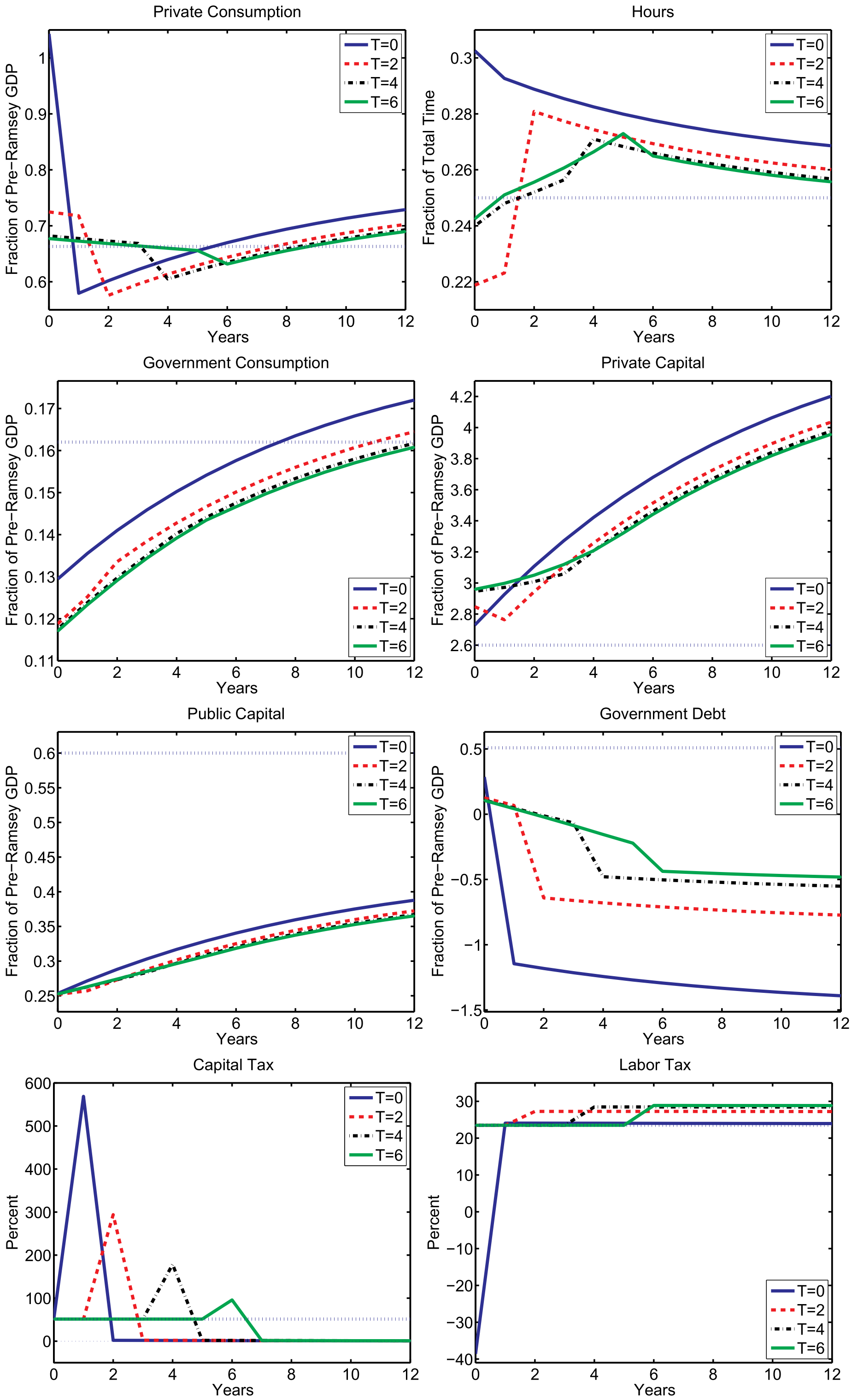
Variable	Value	Description	Restriction
α	0.323	Priv. consumption weight in utility	$\bar{n} = 0.25$
χ	0.2443	Det. weight of gov. cons. in utility	$\frac{u_{\bar{g}}}{u_{\bar{c}}} = 1$
σ	1.00	Det. intertemp. elast. of subst.	$-\frac{u_{\bar{c}}}{u_{\bar{c}\bar{c}}\bar{c}} = 1$
θ_k	0.36	Private capital share on production	Data
θ_n	0.64	Labor share on production	Data
θ_g	0.034	Public capital share on production	Data
δ	0.0542	Depreciation rate of private capital	Data
δ_g	0.0567	Depreciation rate of public capital	Data

Table 5.3: Data, Competitive Equilibrium and Ramsey Reform Steady States

Variable	Data	Comp. Equilib.	Tax Reforms						
			Baseline		Baseline (τ^k Bound)		No confiscation/subsidy		Base/No conf-sub (Fixed Debt)
$\bar{\tau}^k$	0.514	0.514	0.00		0.00		0.00		0.00
$\bar{k}/\bar{y}$	2.60	2.60	3.783		3.783		3.783		3.783
$\bar{k}^g/\bar{y}$	0.60	0.60	0.348		0.348		0.348		0.348
			$T=0$	$T=4$	$T=0$	$T=4$	$T=0$	$T=4$	
$\bar{\tau}^n$	0.235	0.235	0.239	0.284	0.276	0.286	0.318	0.301	0.348
$\bar{b}/\bar{y}$	0.509	0.509	-1.185	-0.503	-0.626	-0.480	0.004	-0.248	0.459
$\bar{c}/\bar{y}$	0.675	0.663	0.627	0.628	0.628	0.628	0.629	0.629	0.630
$\bar{g}/\bar{y}$	0.162	0.162	0.148	0.147	0.147	0.147	0.146	0.147	0.145
$\bar{n}$	0.25	0.25	0.260	0.248	0.250	0.247	0.239	0.243	0.230
$\bar{y}$	-	0.397	0.500	0.476	0.480	0.475	0.457	0.467	0.440

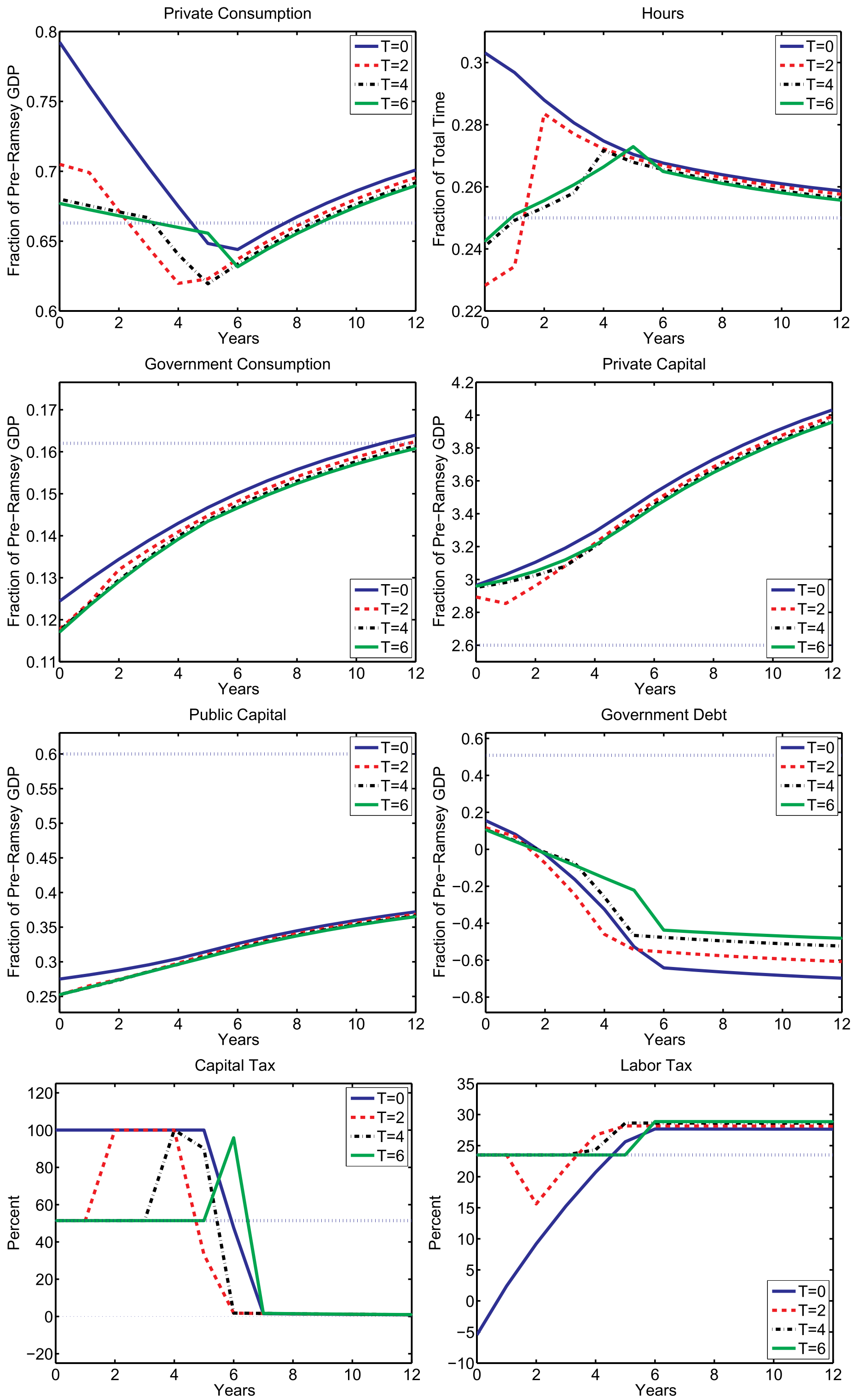
Notes: The table provides a comparison of the data, the competitive equilibrium steady state and the tax reform steady states. "Baseline" refers to the optimal capital and labor income tax reform. "Baseline (τ^k Bound)" means the optimal baseline reform with an upper bound on capital taxes. "No confiscation/subsidy" is the reform when the government moves taxes - without confiscation and subsidy - to their endogenous long-run values from the implementation date onwards. The last column shows the steady states for the reforms with fixed government debt. T denotes the pre-announcement horizon.

Figure 5.1: Baseline Tax Reform



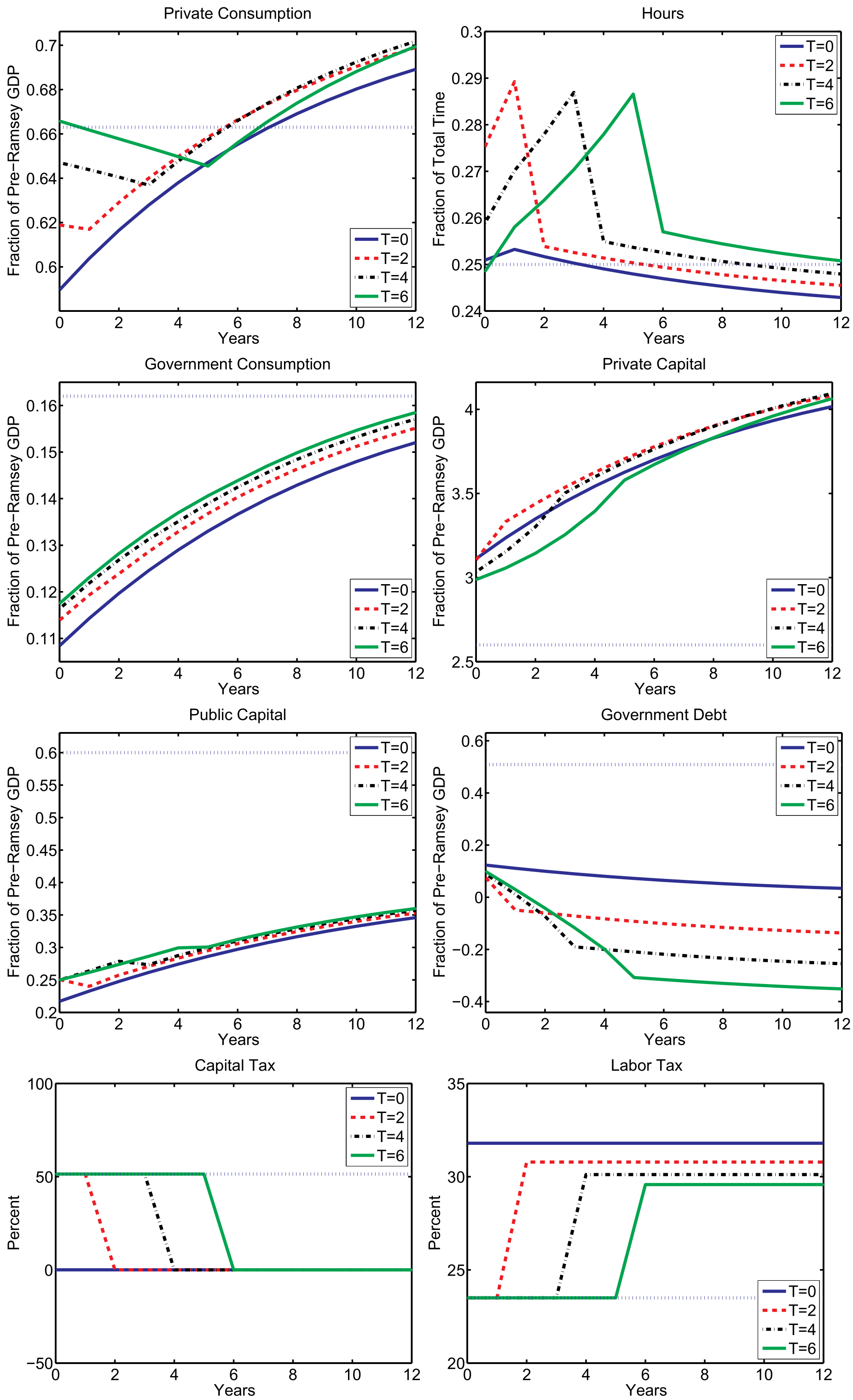
Notes: Baseline tax reform for different pre-announcement periods. (horizontal line: competitive equilibrium steady state).

Figure 5.2: Baseline Tax Reform with Upper Bound on Capital Taxes



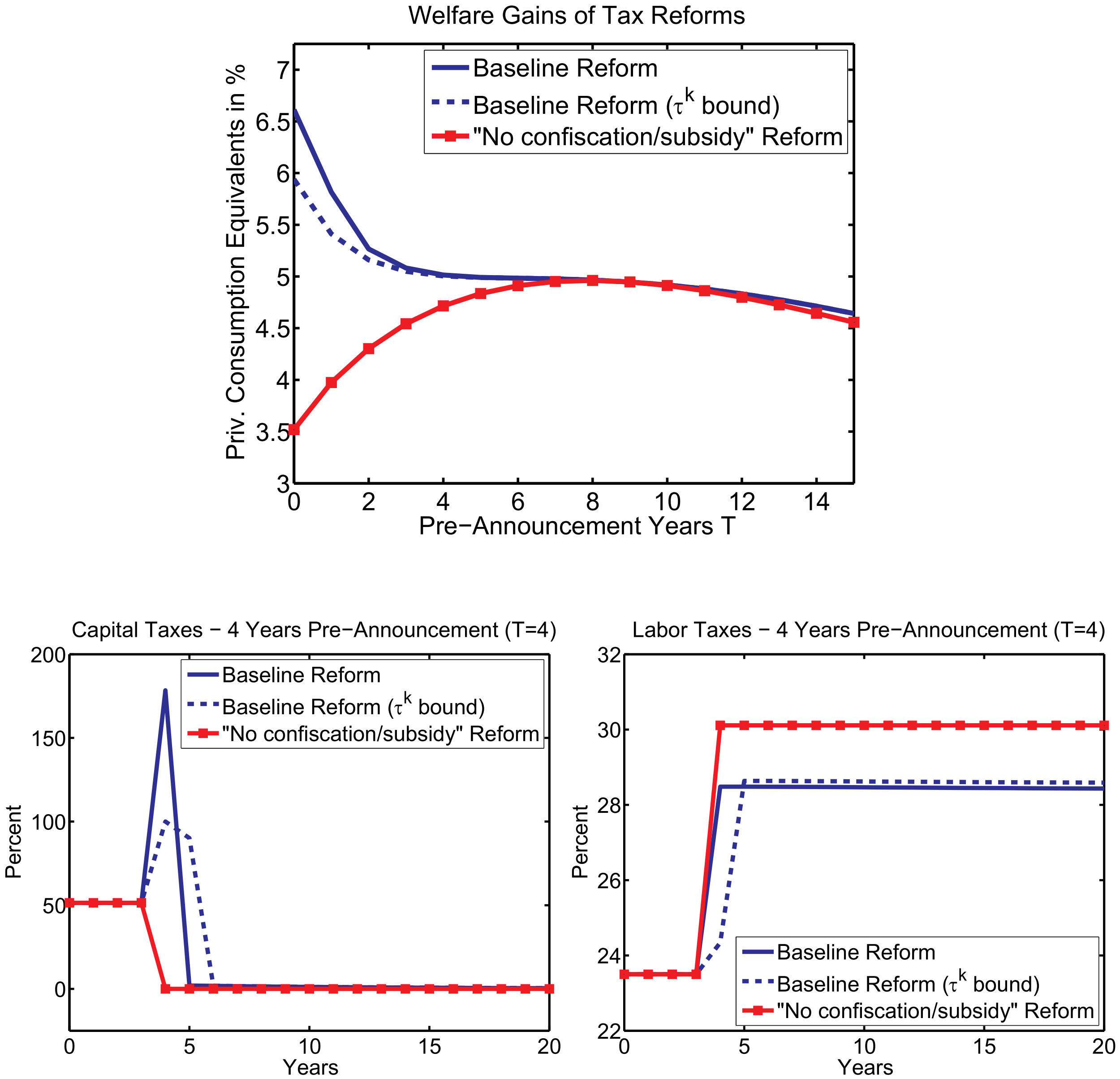
Notes: Baseline tax reform with upper bound on capital taxes for different pre-announcement periods. (horizontal line: competitive equilibrium steady state).

Figure 5.3: "No confiscation/subsidy" Tax Reform



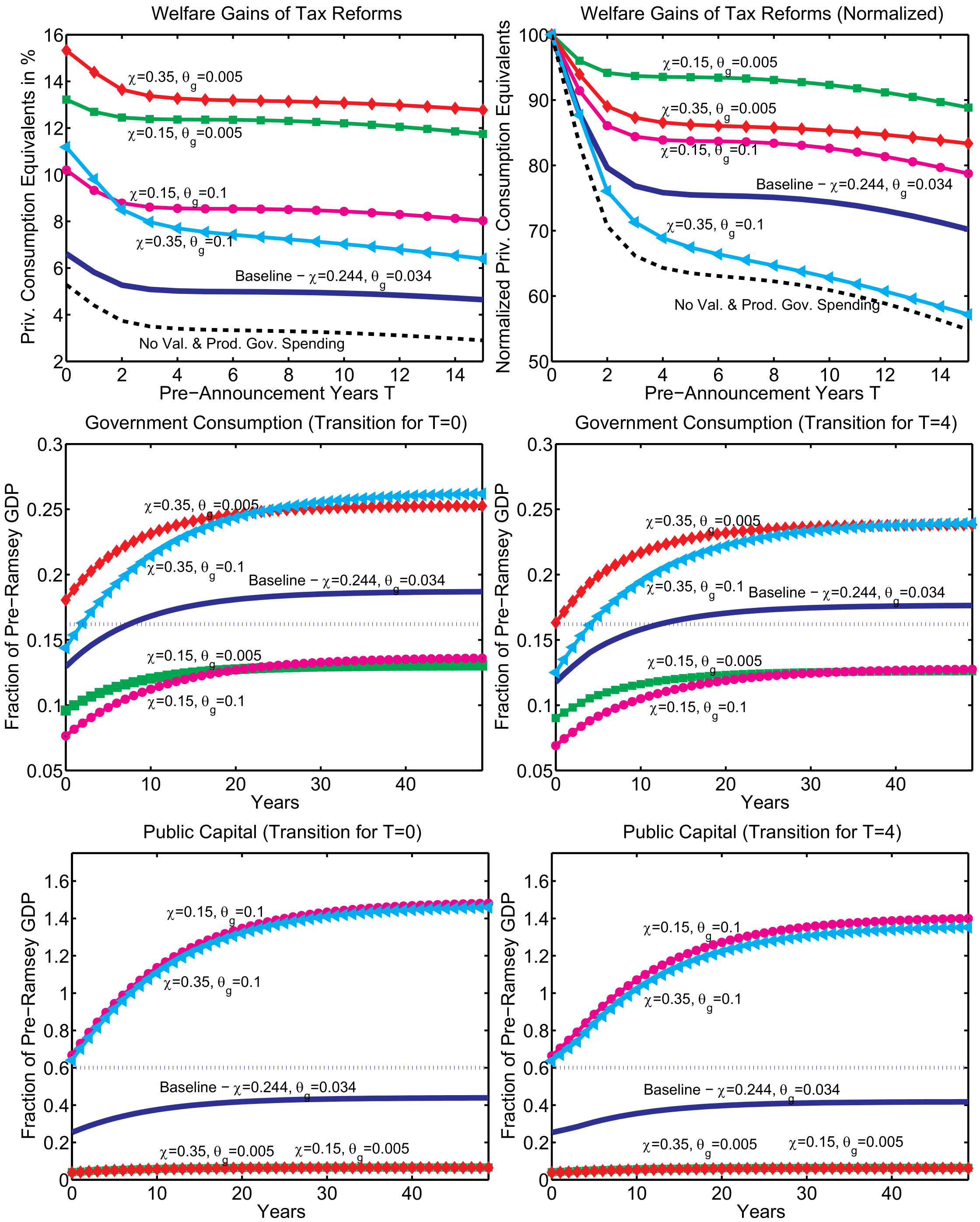
Notes: "No confiscation/subsidy" tax reform for different pre-announcement periods. (horizontal line: competitive equilibrium steady state).

Figure 5.4: Welfare Gains and Taxes of Baseline and "no confiscation/subsidy" Tax Reforms



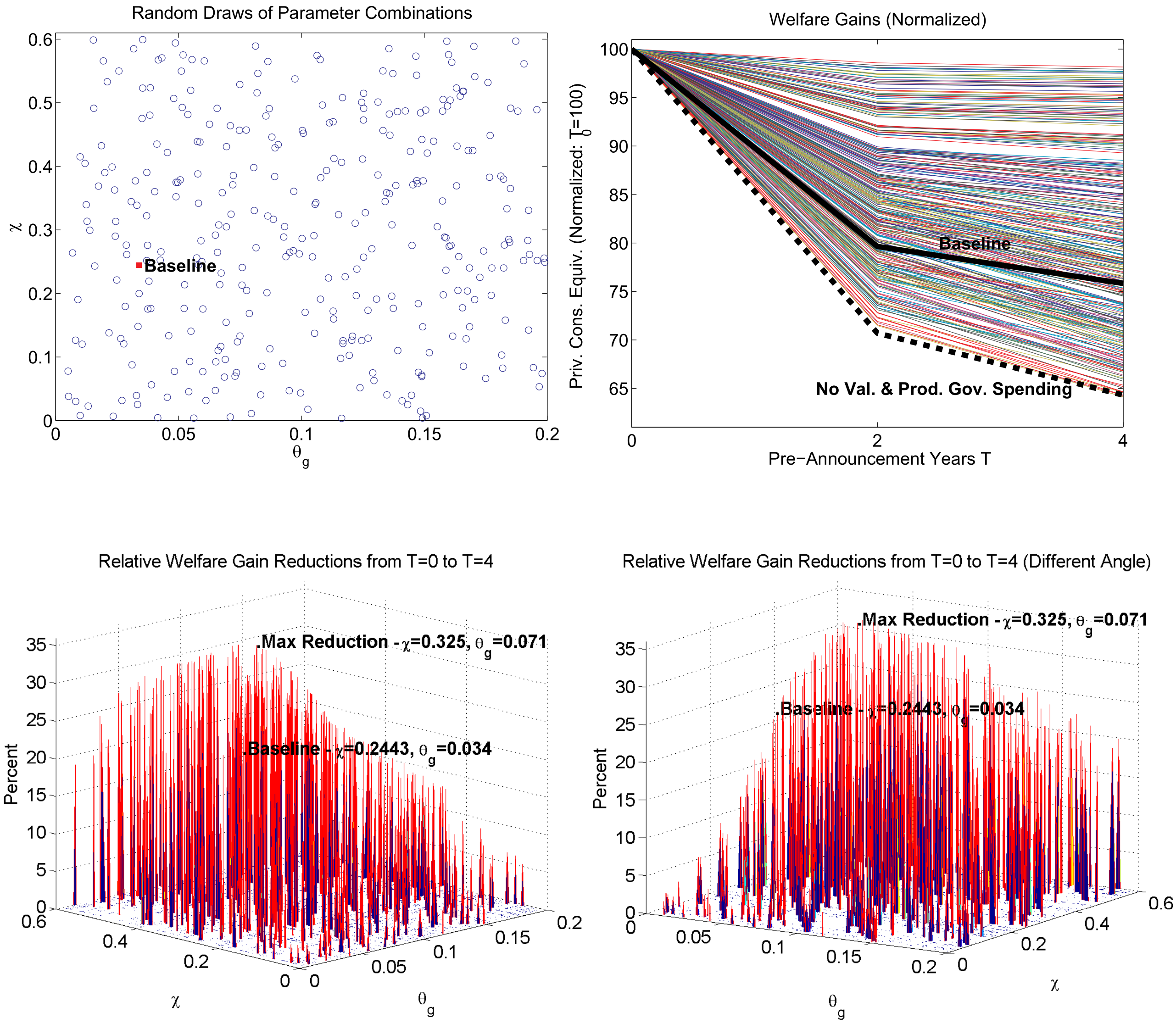
Notes: The upper panel plots welfare gains measured in permanent increases of private consumption for the baseline tax reform, the baseline tax reform with an upper bound on capital taxes as well as for the "no confiscation/subsidy" tax reform. In the latter reform, the government moves taxes - without confiscation and subsidy - directly to the endogenous long-run taxes from the implementation date onwards. The lower left panel depicts the transition of capital taxes whereas the lower right panel plots the transition of labor taxes in case of 4 years pre-announcement for all three reforms. While welfare is rather similar for T=4 in all three reforms, the tax structure appears to be very different.

Figure 5.5: Sensitivity Analysis



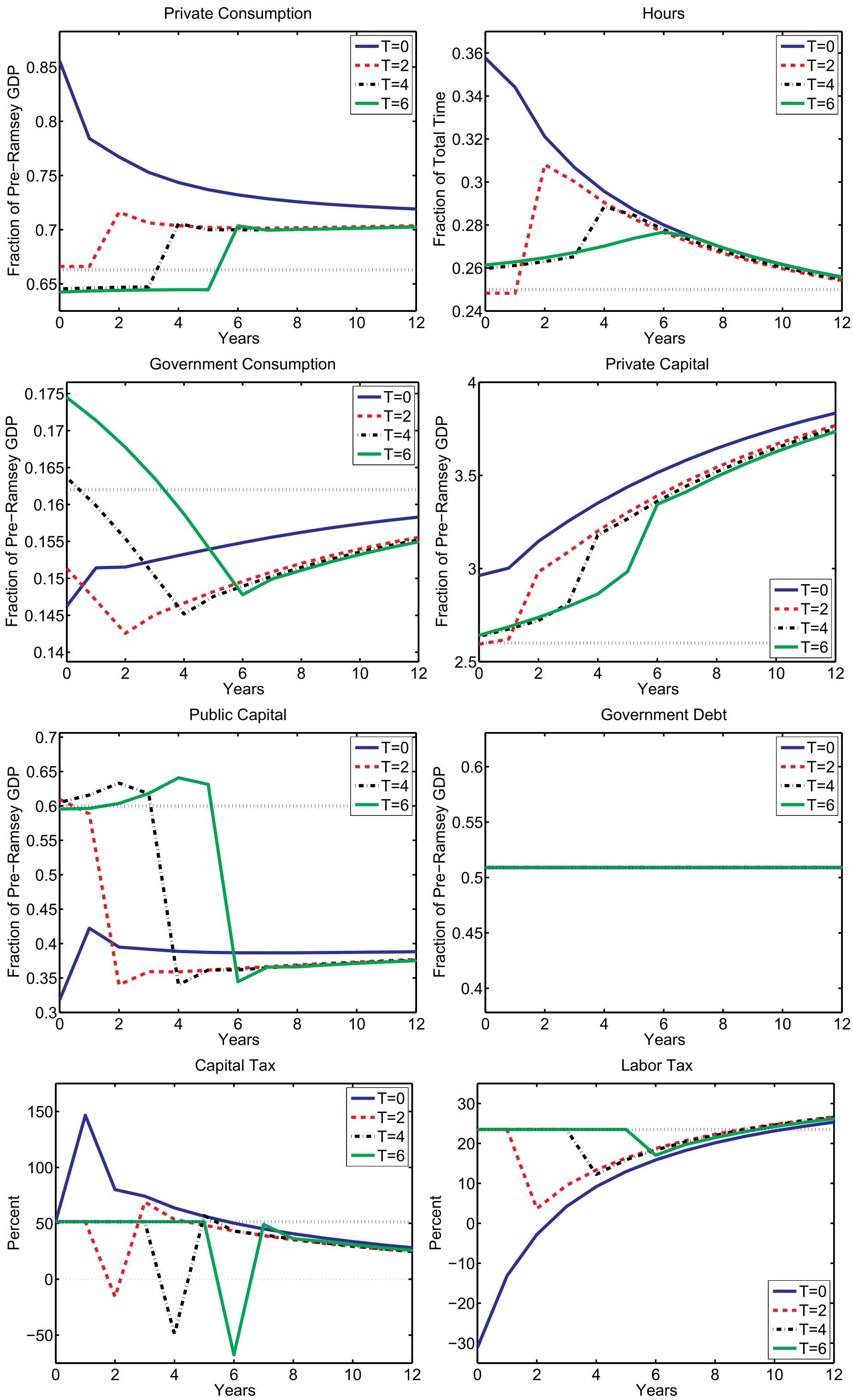
Notes: Sensitivity analysis. The upper panel plots the level of welfare gains as well as the normalized welfare gains (T=0 equals 100) for the baseline tax reform for different pre-announcement periods and different parameters χ and θ_g. "No Val. & Prod. Gov. Spending" corresponds to the model with no valuation and fixed government consumption and no productive public capital. The mid panel plots government consumption and the lower panel plots public capital for T=0 and T=4. The horizontal lines in the mid and lower panel are the competitive equilibrium steady states.

Figure 5.6: Sensitivity Analysis: Random Parameter Draws



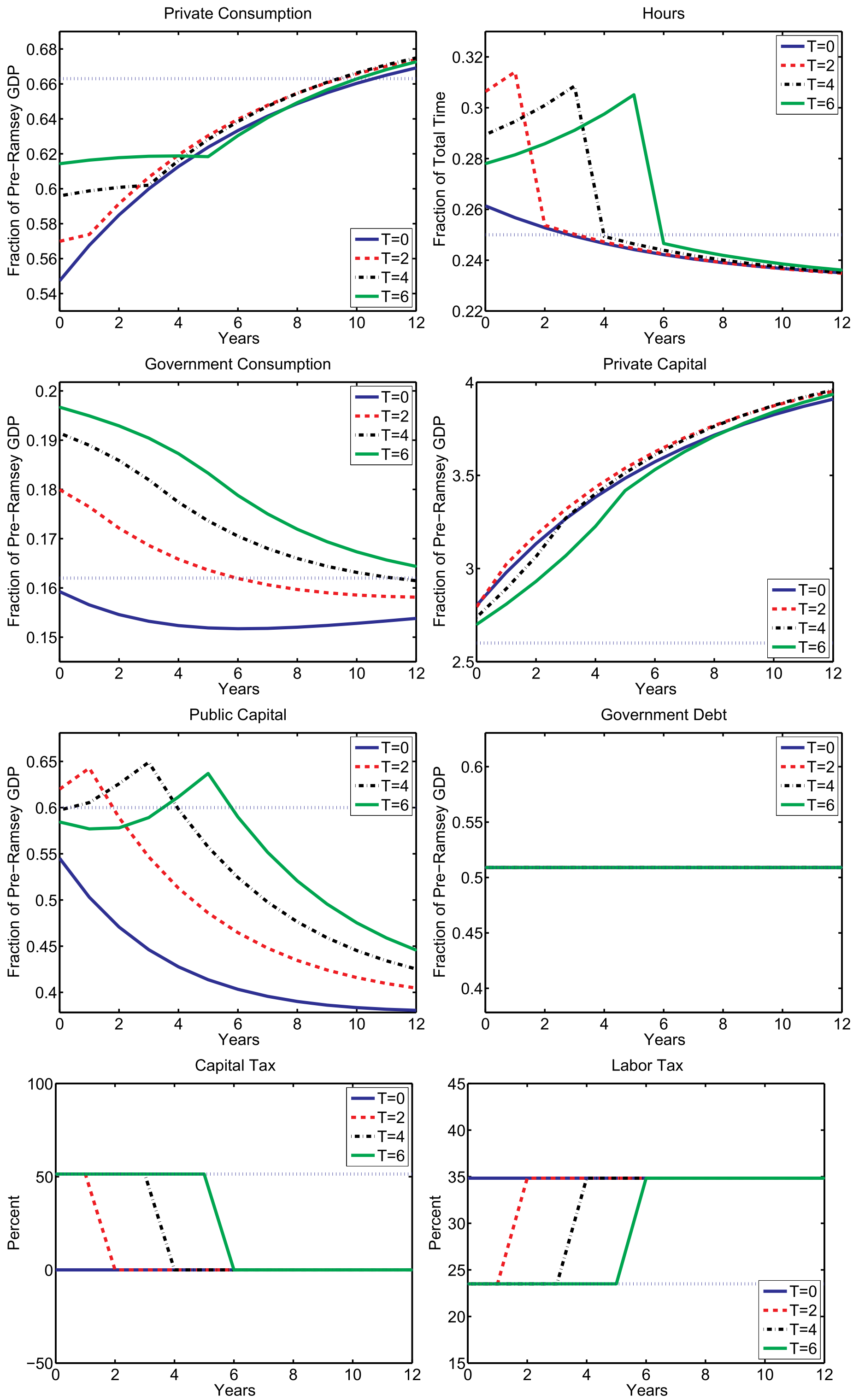
Notes: The upper left panel shows random parameter combinations of θ_g and χ that result from drawing both parameters from the following uniform distributions: $\theta_g \sim U[0.00001, 0.2]$ and $\chi \sim U[0.00001, 0.6]$. Total number of draws: 329. The upper right panel shows the resulting welfare gains for each random parameter combination for pre-announcement horizons $T \in \{0, 2, 4\}$. The bold black solid line shows our baseline parameterization and the bold black dashed line represents the model with non-valued and fixed government consumption and no productive public capital. In order to facilitate comparison with respect to the welfare losses of pre-announcement, we normalize all welfare gains such that they equal 100 for $T = 0$. Finally, the lower two panels depict the reductions of relative welfare gains that are due to moving from $T = 0$ (immediate reform) to $T = 4$ (4 years pre-announced reform) for all random parameter combinations and from different angles.

Figure 5.7: Baseline Tax Reform with Fixed Debt



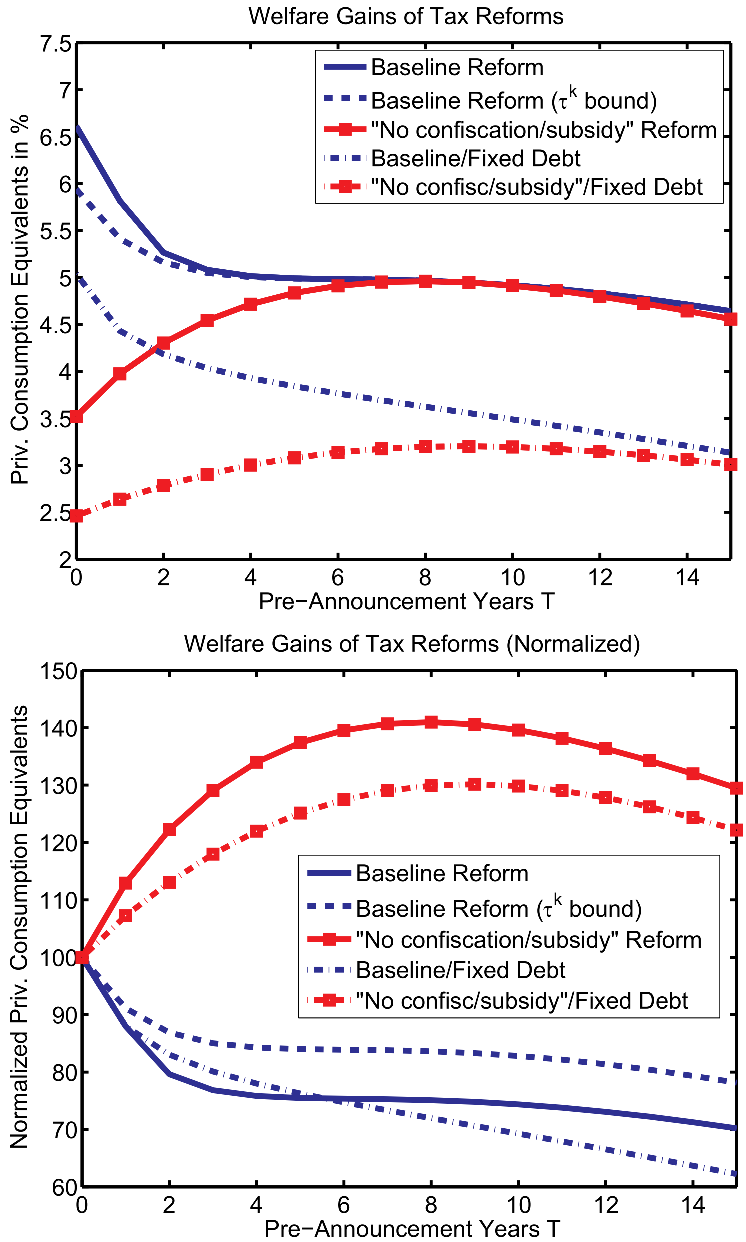
Notes: Baseline tax reform with fixed debt and different pre-announcement periods. (horizontal line: competitive equilibrium steady state).

Figure 5.8: "No confiscation/subsidy" Tax Reform with Fixed Debt



Notes: "No confiscation/subsidy" tax reform with fixed debt and different pre-announcement periods. (horizontal line: competitive equilibrium steady state).

Figure 5.9: Welfare Gains of Tax Reforms with and without Fixed Debt



Notes: The upper panel plots welfare gains measured in permanent increases of private consumption for the baseline tax reform, the baseline tax reform with an upper bound on capital taxes as well as for the "no confiscation/subsidy" tax reform. Further, the plot also depicts welfare gains of the baseline optimal tax reform as well as the "no confiscation/subsidy" tax reform with fixed government debt. The lower panel plots the corresponding welfare gains where we have normalized consumption equivalents to 100 for $T = 0$ *in all reforms that we consider.*

Bibliography

A. B. Abel and B. S. Bernanke. *Macroeconomics*. Addison-Wesley, 3rd edition, 1998.

J. Agell and M. Persson. On the analytics of the dynamic laffer curve. *Journal Of Monetary Economics*, 48:397–414, 2001.

S. R. Aiyagari. Optimal capital income taxation with incomplete markets, borrowing constraints, and constant discounting. *Journal Of Political Economy*, 103(6):1158–1175, 1995.

S. Albanesi and C. Sleet. Dynamic optimal taxation with private information. *Review Of Economic Studies*, 73(1):1–30, 2006.

A. Alesina and D. Rodik. Distributive politics and economic growth. *Quarterly Journal Of Economics*, 109(2):465–490, 1994.

A. Alesina, E. Glaeser, and B. Sacerdote. Work and leisure in the US and Europe: Why so different? *NBER Macroeconomic Annual 2005*, 2005.

D. Altig, L. J. Christiano, M. Eichenbaum, and J. Linde. Firm-specific capital, nominal rigidities and the business cycle. Manuscript, 2004.

R. A. Amano and T. S. Wirjanto. Government expenditures and the permanent income model. *Review Of Economic Dynamics*, 1:719–730, 1998.

J. Andres, D. J. Lopez-Salido, and E. Nelson. Sticky price models and the natural rate hypothesis. *Journal Of Monetary Economics*, 52(5):1025–1053, 2005.

G. Ascari. Staggered prices and trend inflation: Some nuisances. *Review Of Economic Dynamics*, 7(3):642–667, 2004.

G. Ascari and N. Rankin. Staggered wages and output dynamics under disinflation. *Journal Of Economic Dynamics And Control*, 26:653–680, 2002.

D. A. Aschauer. Is public expenditure productive? *Journal Of Monetary Economics*, 23:177–200, 1989.

A. Atkeson, V. V. Chari, and P. J. Kehoe. Taxing capital income: A bad idea. *Federal Reserve Bank Of Minneapolis Quarterly Review*, 23(3):3–17, 1999.

D. K. Backus, P. J. Kehoe, and F. E. Kydland. International business cycles: Theory and evidence. *Frontiers Of Business Cycle Research, Ed. Thomas F. Cooley, Princeton University Press*, pages 331–356, 1995.

L. Ball. Credible disinflation with staggered price setting. *American Economic Review*, 84:282–289, 1994.

M. Baxter and R. G. King. Fiscal policy in general equilibrium. *American Economic Review*, 82(3):315–334, 1993.

J. P. Benassy. Output and inflation dynamics under price and wage staggering: Analytical results. *Annales DÉconomie Et De Statistique*, 63:1–30, 2003.

J. Benhabib and A. Rustichini. Optimal taxes without commitment. *Journal Of Economic Theory*, 77, 231–259 1997.

M. Bils and P. Klenow. Some evidence on the importance of sticky prices. *Journal Of Political Economy*, 112:947–985, 2004.

O. Blanchard. The economic future of europe. *Journal Of Economic Perspectives*, 18(4):3–26, 2004.

R. A. Braun and H. Uhlig. The welfare enhancing effects of a selfish government in the presence of uninsurable, idiosyncratic risk. *Humboldt University SFB 649 Discussion Paper*, (2006-070), 2006.

N. Bruce and S. J. Turnovsky. Budget balance, welfare, and the growth rate: Dynamic scoring of the long run government budget. *Journal Of Money, Credit And Banking*, 31:162–186, 1999.

G. Calvo. Staggered prices in a utility-maximizing framework. *Journal Of Monetary Economics*, 12:383–398, 1983.

D. Carey and J. Rabesona. Tax ratios on labour and capital income and on consumption. *OECD Economic Studies*, (35), 2002.

C. D. Caroll. Macroeconomic expectations of households and professional forecasters. *Quarterly Journal Of Economics*, 118(1):269–298, 2003.

S. P. Cassou and K. J. Lansing. Tax reform with useful public expenditures. *Journal Of Public Economic Theory*, 8(4):631–676, 2006.

L. Cespedes, M. Kumhof, and E. Parrado. Pricing policies and inflation inertia. *IMF Working Papers*, (03/87), 2003.

C. Chamley. Optimal taxation of capital income in general equilibrium with infinite lives. *Econometrica*, 54(3):607–622, 1986.

V. V. Chari and P. J. Kehoe. Optimal fiscal and monetary policy. *J.B. Taylor And M.Woodford, Eds., Handbook Of Macroeconomics, Amsterdam: North-Holland*, 1: 1671–745, 1999.

V. V. Chari, L. J. Christiano, and P. J. Kehoe. Optimal fiscal policy in a business cycle model. *Journal Of Political Economy*, 102(4):617–652, 1994.

V. V. Chari, L. J. Christiano, and P. J. Kehoe. Policy analysis in business cycle models. *Thomas F. Cooley, Ed., Frontiers Of Business Cycle Research, Princeton, New Jersey: Princeton University Press*, pages 357–91, 1995.

V. V. Chari, P. J. Kehoe, and E. R. Mcgrattan. Sticky price models of the business cycle: Can the contract multiplier solve the persistence problem? *Econometrica*, 68:1151–1180, 2000.

L. J. Christiano and M. Eichenbaum. Current real-business-cycle theories and aggregate labor-market fluctuations. *American Economic Review*, 82:430–50, 1992.

L. J. Christiano, M. Eichenbaum, and C. Evans. Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal Of Political Economy*, 113(1): 1–45, February 2005.

R. Clarida, J. Gali, and M. Gertler. The science of monetary policy: A new keynesian perspective. *Journal Of Economic Literature*, 37:1661–1707, 1999.

R. Clarida, J. Gali, and M. Gertler. A simple framework for international monetary policy analysis. *Journal Of Monetary Economics*, 49(5):879–904, 2002.

O. Coibion. Inflation inertia in sticky information models. *Contributions In Macroeconomics*, 6(1), 2006a.

O. Coibion. Testing the sticky information phillips curve. 2006b. Manuscript.

O. Coibion and Y. Gorodnichenko. Strategic interaction among heterogeneous price setters in an estimated DSGE model. Manuscript, 2006.

F. Collard and H. Dellas. Sticky information. 2006. Manuscript.

T. F. Cooley and E.C. Prescott. Economic growth and business cycles. *Frontiers Of Business Cycle Research (Ed. Thomas F. Cooley), Princeton University Press*, pages 1–38, 1995.

I. Correia, J. C. Neves, and S. Rebelo. Business cycles in a small open economy. *European Economic Review*, 39:1089–1113, 1995.

M. B. Devereux and J. Yetman. Predetermined prices and the persistent effects of money on output. *Journal Of Money, Credit, And Banking*, 35(5):729–741, 2003.

D. Domeij and M. Floden. The labor-supply elasticity and borrowing constraints: Why estimates are biased. *Review Of Economic Dynamics*, 9:242–262, 2006.

D. Domeij and P. Klein. Pre-announced optimal tax reform. *Macroeconomic Dynamics*, 9(2):150–169, 2005.

B. Dominguez. On the time-inconsistency of optimal capital taxes. *Forthcoming Journal Of Monetary Economics*, 2006a.

B. Dominguez. Public debt and optimal taxes without commitment. *Forthcoming Journal Of Economic Theory*, 2006b.

J. Dovern, J. Doekpe, U. Fritsche, and J. Slacalek. Sticky information phillips curves: European evidence. *DIW Discussion Papers*, (615), 2006.

B. Dupor and T. Tsuruga. Sticky information: The impact of different information updating assumptions. *Journal Of Money, Credit And Banking*, 37(6): 1143–1152, 2005.

B. Dupor, T. Kitamura, and T. Tsuruga. Do sticky prices need to be replaced with sticky information? Manuscript, 2006.

B. Eichengreen. The capital levy in theory and practice. *R. Dornbusch And M. Draghi, Eds., Public Debt Management: Theory And History, Cambridge University Press*, pages 191–220, 1990.

A. Erosa and M. Gervais. Optimal taxation in infinitely-lived agent and overlapping generations models: A review. *Economic Quarterly, Federal Reserve Bank Of Richmond*, 87(2), 2001.

M. Feldstein and C. Horioka. Domestic saving and international capital flows. *The Economic Journal*, 90:314–329, 1980.

S. Fischer. Long-term contracts, rational expectations, and the optimal money supply rule. *Journal Of Political Economy*, 85(1):191–205, 1977.

M. Floden and J. Linde. Idiosyncratic risk in the United States and Sweden: Is there a role for government insurance? *Review Of Economic Dynamics*, 4: 406–437, 2001.

J. Gali. New perspectives on monetary policy, inflation and the business cycle. *Advances In Economic Theory, Edited By: M. Dewatripont, L. Hansen, And S. Turnovsky, Cambridge University Press*, 3:151–197, 2003.

J. Gali and M. Gertler. Inflation dynamics: A structural econometric approach. *Journal Of Monetary Economics*, 44(2):195–222, 1999.

J. Gali and T. Monacelli. Monetary policy and exchange rate volatility in a small open economy. *Review Of Economic Studies*, 72:707–734, 2005.

J. Gali, M. Gertler, and D. J. Lopez-Salido. European inflation dynamics. *European Economic Review*, 45(7):1237–1270, 2001.

J. Gali, M. Gertler, and D. J. Lopez-Salido. Robustness of the estimates of the hybrid new keynesian phillips curve. *Journal Of Monetary Economics*, 52:1107–1118, 2005.

T. Garcia-Mila, A. Marcet, and E. Ventura. Supply-side interventions and redistribution. Manuscript, 2001.

C. Giannitsarou. Supply-side reforms and learning dynamics. *Journal Of Monetary Economics*, 53(2):291–309, 2006.

M. P. Giannoni and M. Woodford. Optimal inflation targeting rules. *B. S. Bernanke And M. Woodford, Eds. Inflation Targeting, University Of Chicago Press*, 2003.

M. Golosov and R. E. Lucas. Menu costs and phillips curves. NBER Working Paper, 2003.

M. Golosov and A. Tsyvinski. Designing optimal disability insurance: A case for asset testing. *Journal Of Political Economy*, 114(2):257–269, 2006.

M. Golosov, N. Kocherlakota, and A. Tsyvinsky. Optimal indirect and capital taxation. *Review Of Economic Studies*, 70(3):569–588, 2003.

M. Golosov, A. Tsyvinski, and I. Werning. New dynamic public finance: A users guide. *NBER Macroeconomic Annual*, 2006.

P. Gomme and P. Rupert. Theory, measurement and calibration of macroeconomic models. Federal Reserve Bank Of Cleveland,Working Paper, 2005.

M. Goodfriend and R. G. King. The new neoclassical synthesis and the role of monetary policy. *NBER Macroeconomic Annual 1997, Eds. Ben S. Bernanke And Julio J. Rotemberg, Cambridge And London:* MIT *Press*, pages 231–283, 1997.

J. Greenwood, Z. Hercowitz, and G. Huffman. Investment, capacity utilization, and the real business cycles. *American Economic Review*, (78):402–417, 1988.

J. Gruber. A tax-based estimate of the elasticity of intertemporal substitution. NBER Working Paper, 2006.

R. E. Hall. Intertemporal substitution of consumption. *Journal Of Political Economy*, 96(2):339–357, 1988.

J. Hassler, K. Storesletten, and F. Zilibotti. Dynamic political choice in macroeconomics. *Journal Of The European Economic Association*, 1(2-3):543–552, 2003.

J. Hassler, P. Krusell, K. Storesletten, and F. Zilibotti. On the optimal timing of capital taxes. Manuscript, 2004.

J. Hassler, P. Krusell, K. Storesletten, and F. Zilibotti. The dynamics of government. *Journal Of Monetary Economics*, 52(7):1331–1358, 2005.

J. Hassler, K. Storesletten, and F. Zilibotti. Democratic public good provision. *Forthcoming Journal Of Economic Theory*, 2006.

C. L. House and M. D. Shapiro. Phased-in tax cuts and economic activity. *Forthcoming American Economic Review*, 2006.

P. N. Ireland. Supply-side economics and endogenous growth. *Journal Of Monetary Economics*, 33:559–572, 1994.

L. E. Jones, R. E. Manuelli, and P. E. Rossi. Optimal taxation in models of endogenous growth. *Journal Of Political Economy*, 101(3):485–517, 1993.

M. Jonsson and P. Klein. Tax distortions in Sweden and the United States. *European Economic Review*, 47:711–729, 2003.

M. Jonsson and P. Klein. Accounting for the relationship between money and interest rates. *Macroeconomic Dynamics*, 10(4):545–571, 2006.

K. L. Judd. Redistributive taxation in a simple perfect foresight model. *Journal Of Public Economics*, 28:59–83, 1985a.

K. L. Judd. Short-run analysis of fiscal policy in a simple perfect foresight model. *Journal Of Political Economy*, 93(2):298–319, 1985b.

K. L. Judd. The welfare cost of factor taxation in a perfect-foresight model. *Journal Of Political Economy*, 95(4):675–709, 1987a.

K. L. Judd. A dynamic theory of factor taxation. *American Economic Review Papers And Proceedings*, 77(2):42–48, 1987b.

M. Julliard. Dynare. http://www.cepremap.cnrs.fr/dynare/, 2006.

H. Kahn and Z. Zhu. Estimates of the sticky-information phillips curve for the United States. *Journal Of Money, Credit And Banking*, 38(1):195–208, 2006.

B. D. Keen. Sticky price and sticky information price setting models: What is the difference? *Forthcoming Economic Inquiry*, 2005.

M. Kiley. A quantitative comparison of sticky-price and sticky-information models of price setting. Manuscript, 2005.

J. Kim and S. H. Kim. Welfare effects of tax policy in open economies: Stabilization and cooperation. Manuscript, 2004.

M. S. Kimball and M. D. Shapiro. Labor supply: Are the income and substitution effects both large or small? Manuscript, 2003.

R. S. King and S. T. Rebelo. Resuscitating real business cycles. *Handbook Of Macroeconomics, Edited By J. B. Taylor And M. Woodford, Amsterdam: Elsevier*, 1B: 927–1007, 1999.

P. Klein and J. V. Rios-Rull. Time-consistent optimal fiscal policy. *International Economic Review*, 44(4):1217–1245, 2003.

P. Klein, P. Krusell, and J. V. Rios-Rull. Time-consistent public expenditures. Manuscript, 2004.

T. J. Kniesner and J. P. Ziliak. The effect of income taxation on consumption and labor supply. Manuscript, 2005.

N. Kocherlakota. Zero expected wealth taxes: A mirrlees approach to dynamic optimal taxation. *Econometrica*, 73(5):1587–1621, 2005.

N. Kocherlakota. Advances in dynamic optimal taxation. *Advances In Economics And Econometrics: Theory And Applications, Ninth World Congress*, I:269–299, 2006.

O. Korenok. Empirical comparison of sticky prices and sticky information models. Manuscript, 2004.

O. Korenok and N. R. Swanson. How sticky is sticky enough? A distributional and impulse response analysis of new keynesian DSGE models. *Forthcoming Journal Of Money, Credit And Banking*, 2006.

P. Krusell and J. V. Rios-Rull. Vested interests in a positive theory of stagnation and growth. *Review Of Economic Studies*, 63(2):301–329, 1996.

P. Krusell and J. V. Rios-Rull. On the size of US government: Political economy in the neoclassical growth model. *American Economic Review*, 43:699–735, 1999.

P. Krusell, V. Quadrini, and J. V. Rios-Rull. Are consumption taxes really better than income taxes? *Journal Of Monetary Economics*, 37:475–504, 1996.

P. Krusell, V. Quadrini, and J. V. Rios-Rull. Politico-economic equilibrium and economic growth. *Journal Of Economic Dynamics And Control*, 21:243–272, 1997.

F. E. Kydland and E. C. Prescott. Time to build and aggregate fluctuations. *Econometrica*, 50:1345–1370, 1982.

J. P. Laforte. Pricing models: A bayesian DSGE approach for the US economy. Manuscript, 2005.

K. Lansing. Optimal fiscal policy in a business cycle model with public capital. *The Canadian Journal Of Economics*, 31(2):337–364, 1998.

E. M. Leeper and S-C. S. Yang. Dynamic scoring: Alternative financing schemes. NBER Working Paper, 2005.

E. M. Leeper and T. Yun. Monetary-fiscal policy interactions and the price level: Background and beyond. NBER Working Paper, 2005.

L. Ljungqvist and T. J. Sargent. *Recursive Macroeconomic Theory*. MIT Press, 2nd edition, 2004.

L. Ljungqvist and T. J. Sargent. Do taxes explain european employment? Indivisible labor, human capital, lotteries, and savings. Manuscript, 2006.

R. E. Lucas. Expectations and the neutrality of money. *Journal Of Economic Theory*, 4:103–124, 1972.

R. E. Lucas. Some international evidence on output-inflation tradeoffs. *American Economic Review*, 63:326–334, 1973.

R. E. Lucas. Supply-side economics: An analytical review. *Oxford Economic Papers, New Series*, 42(2):239–316, 1990.

R. E. Lucas. Inflation and welfare. *Econometrica*, 68(2):247–274, 2000.

S. Ludvigson. The macroeconomic effects of government debt in a stochastic growth model. *Journal Of Monetary Economics*, 38:25–45, 1996.

B. Mackowiak and M. Wiederholt. Optimal sticky prices under rational inattention. Manuscript, 2006.

G. N. Mankiw and R. Reis. Sticky information versus sticky prices: A proposal to replace the new keynesian phillips curve. *Quarterly Journal Of Economics*, 117(4):1295–1328, November 2002.

G. N. Mankiw and R. Reis. Sticky information: A model of monetary nonneutrality and structural slumps. *Knowledge, Information, And Expectations In Modern Macroeconomics: In Honor Of Edmund S. Phelps, Edited By P. Aghion, R. Frydman, J. Stiglitz And M. Woodford, Princeton University Press*, 2003.

G. N. Mankiw and R. Reis. Pervasive stickiness. *American Economic Review Papers And Proceedings*, 96(2), 2006a.

G. N. Mankiw and R. Reis. Sticky information in general equilibrium. *Forthcoming Journal Of The European Economic Association*, 2006b.

G. N. Mankiw and M. Weinzierl. Dynamic scoring: A back-of-the-envelope guide. *Forthcoming Journal Of Public Economics*, 2005.

G. N. Mankiw, R. Reis, and J. Wolfers. Disagreement about inflation expectations. *NBER Macroeconomics Annual 2003,* MIT *Press*, 2004.

A. Marcet and R. Marimon. Recursive contracts. Manuscript, 1998.

E. R. McGrattan. The macroeconomic effects of distortionary taxation. *Journal Of Monetary Economics*, 33(3):573–601, 1994.

E. R. McGrattan and R. Rogerson. Changes in hours worked, 1950-2000. *Quarterly Review, Federal Reserve Bank Of Minneapolis*, July 2004.

E. G. Mendoza and L. L. Tesar. The international ramifications of tax reforms: Supply-side economics in a global economy. *American Economic Review*, 88: 402–417, 1998.

E. G. Mendoza, A. Razin, and L. L. Tesar. Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption. *Journal Of Monetary Economics*, 34:297–323, 1994.

M. Merz. Search in the labor market and the real business cycle. *Journal Of Monetary Economics*, 36, 269–300 1995.

J. A. Mirrlees. An exploration in the theory of optimum income taxation. *Review Of Economic Studies*, 38(2):175–208, 1971.

G. Moscarini. Limited information capacity as a source of inertia. *Journal Of Economic Dynamics And Control*, 28:2003–2035, 2004.

A. Novales and J. Ruiz. Dynamic laffer curves. *Journal Of Economic Dynamics And Control*, 27:181–206, 2002.

M. Paustian and E. Pytlarczyk. Sticky contracts or sticky information? Evidence from an estimated Euro area DSGE model. Manuscript, 2006.

J. Pencavel. Labor supply of men: A survey. *Handbook Of Labor Economics, O. Ashenfelter And R. Layard, Eds., North-Holland, Amsterdam*, 1, 1986.

T. Persson and G. Tabellini. Is inequality harmful for growth? *American Economic Review*, 84(3):600–621, 1994.

C. Phelan and E. Stacchetti. Sequential equilibria in a Ramsey tax model. *Econometrica*, 69:1491–1518, 2001.

E. S. Phelps. *Microeconomic Foundations Of Employment And Inflation Theory*, chapter Introduction: The New Microeconomics In Employment And Inflation Theory. Norton, 1970.

E. C. Prescott. Prosperity and depression. *American Economic Review*, 92:1–15, 2002.

E. C. Prescott. Why do americans work so much more than europeans? *Quarterly Review, Federal Reserve Bank Of Minneapolis*, July 2004.

E. C. Prescott. Nobel lecture: The transformation of macroeconomic policy and research. *Journal Of Political Economy*, 114(2):203–235, 2006.

F. P. Ramsey. A contribution to the theory of taxation. *The Economic Journal*, 37: 47–61, 1927.

R. Reis. Inattentive consumers. *Forthcoming Journal Of Monetary Economics*, 2004.

R. Reis. Inattentive producers. *Review Of Economic Studies*, 73(3):793–821, 2006.

J. Rotemberg and M. Wodford. An optimization-based econometric framework for the evaluation of monetary policy. *NBER Macroeconomics Annual 1997*, pages 297–346, 1997.

A. M. Sbordone. Prices and unit labor costs: A new test of price stickiness. *Journal Of Monetary Economics*, 49:265–292, 2002.

S. Schmitt-Grohe and M. Uribe. Balanced-budget rules, distortionary taxes, and aggregate instability. *Journal Of Political Economy*, 105(5):976–1000, 1997.

C. A. Sims. Implications of rational inattention. *Journal Of Monetary Economics*, 50:665–690, 2003.

C. A. Sims. Rational inattention: A research agenda. Manuscript, 2006.

F. Smets and R. Wouters. An estimated dynamic stochastic general equilibrium model of the Euro area. *Journal Of The European Economic Association*, 1(5): 1123–1175, 2003.

N. L. Stokey and S. T. Rebelo. Growth effects of flat-rate taxes. *Journal Of Political Economy*, 103:519–550, 1995.

M. Trabandt. Sticky information vs. sticky prices: A horse race in a DSGE framework. *Humboldt University SFB 373 Discussion Paper*, (2003-41), 2003.

M. Trabandt. Optimal pre-announced tax reforms under valuable and productive government spending. Manuscript, 2006.

M. Trabandt and H. Uhlig. How far are we from the slippery slope? The laffer curve revisited. *Humboldt University SFB 649 Discussion Paper*, (2006-23), 2006.

H. Uhlig. A toolkit for analyzing nonlinear dynamic stochastic models easily. *Computational Methods For The Study Of Dynamic Economies, Eds. R. Marimon And A. Scott, Oxford University Press, Oxford*, pages 30–61, 1999.

H. Uhlig. Do technology shocks lead to a fall in total hours worked? *Journal Of The European Economic Association*, 2(2-3):361–371, 2004.

C. Walsh. *Monetary Theory And Policy*. MIT Press, 2nd edition, 2003.

P. Wang and Y. Wen. Solving linear difference systems with lagged expectations by a method of undetermined coefficients. Manuscript, 2006.

J. Wanniski. Taxes, revenues, and the laffer curve. *The Public Interest*, Winter 1978.

M. Woodford. Control of the public debt: A requirement for price stability? NBER Working Paper, 1996.

M. Woodford. *Imperfect Common Knowledge And The Effect Of Monetary Policy, In: Knowledge, Information, And Expectations In Modern Macroeconomics: In Honor Of Edmund S. Phelps*. Princeton University Press, 2002.

M. Woodford. Interest and prices: Foundations of a theory of monetary policy. *Princeton University Press*, 2003.

N. Yanagawa and H. Uhlig. Increasing the capital income tax may lead to faster growth. *European Economic Review*, 40:1521–1540, 1996.

T. Yun. Nominal price rigidity, money supply endogeneity, and business cycles. *Journal Of Monetary Economics*, 37:345–370, 1996.

A Appendix to Chapter 3

A.1 The DSGE Framework

We obtain the following set of log-linearized equilibrium conditions. Hat variables denote percentage deviations of variables from steady state. The consumer Euler equation can be manipulated to obtain an intertemporal "New IS" curve,

$$\hat{x}_t = E_t[\hat{x}_{t+1}] - \frac{s_c}{\sigma}\left[\hat{R}_t - E_t[\hat{\pi}_{t+1}] - \hat{rr}_t^f\right] \tag{A.1}$$

where $E_t[\hat{\pi}_{t+1}]$ is the expected gross inflation rate, $\hat{x}_t$ denotes the output gap, defined as the difference between the distorted and the flexible price - full information output, $\hat{R}_t$ is the nominal interest rate, $\hat{rr}_t^f$ denotes the flexible price - full information real interest rate and s_c is the steady state consumption to output ratio. Using the optimality conditions of the household, real money demand, $\hat{m}_t$, in this economy can be derived as a function of the output gap, exogenous disturbances for technology, $\hat{z}_t$, and government expenditures, $\hat{g}_t$, and the nominal interest rate,

$$\hat{m}_t = \frac{\sigma}{s_c \nu}\hat{x}_t + \frac{\sigma}{s_c \nu \varphi}\hat{z}_t - \gamma_g \hat{g}_t - \frac{1}{\nu(\bar{R}-1)}\hat{R}_t \tag{A.2}$$

where $\varphi = \frac{\omega + \sigma s_c^{-1}}{1+\omega}$, $\omega = \frac{\phi}{\alpha} + \frac{1}{\alpha} - 1$ and $\gamma_g = \frac{\sigma(1-s_c)}{s_c \nu}\left(1 - \frac{\sigma s_c^{-1}}{\omega + \sigma s_c^{-1}}\right)$. Expressing nominal money supply in real terms, real money supply in our economy is given as

$$\hat{m}_t = \hat{m}_{t-1} - \hat{\pi}_t + \hat{\xi}_t \tag{A.3}$$

where $\hat{\xi}_t$ denotes money growth. Solving for the flexible price - full information allocations of the economy yields the flexible price - full information real interest rate which can be expressed as

$$r\hat{r}_t{}^f = \mu_{rg}\hat{g}_t + \mu_{rz}\hat{z}_t \tag{A.4}$$

with $\mu_{rg} = \frac{\sigma(\rho_g-1)}{s_c}\left(\frac{\sigma(1-s_c)}{s_c\omega+\sigma} + s_c - 1\right)$ and $\mu_{rz} = \frac{\sigma(1+\omega)(\rho_z-1)}{s_c\omega+\sigma}$. Finally, we collect the log-linearized exogenous stochastic processes for technology, $\hat{z}_t = \rho_z\hat{z}_{t-1} + \epsilon_{z,t}$, for money growth, $\hat{\xi}_t = \rho_\xi\hat{\xi}_{t-1} + \epsilon_{\xi,t}$ and for government expenditures, $\hat{g}_t = \rho_g\hat{g}_{t-1} + \epsilon_{g,t}$.

A.2 A 2-Years Announced Disinflation

In order to model a 2-years (8 quarters) announced disinflation we proceed as follows. We replace money growth, $\hat{\xi}_t$, in the real money supply equation (A.3) in the log-linearized system of equations by the auxiliary variable $\hat{\xi}_t^{a8}$. Moreover, we make no more use of the exogenous money growth process in the system of equations. Instead, we add the following auxiliary variables to our system of equilibrium equations:

$$\hat{\xi}_t^{a8} = \hat{\xi}_{t-1}^{a7} \tag{A.5}$$

$$\hat{\xi}_t^{a7} = \hat{\xi}_{t-1}^{a6} \tag{A.6}$$

$$\vdots$$

$$\hat{\xi}_t^{a1} = \hat{\xi}_{t-1}^{a0} \tag{A.7}$$

$$\hat{\xi}_t^{a0} = \rho_\xi\hat{\xi}_{t-1}^{a0} + \epsilon_{\xi,t}. \tag{A.8}$$

This structure implies that an innovation in say $\hat{\xi}_t^{a0}$ in period $t = 0$ is fully observed by the households, sticky price firms and sticky information firms that just had an information update. However, it takes 2 years (8 quarters) until $\hat{\xi}^{a8}$ changes in the real money demand equation in the system of equations. Thus, the innovation in $\hat{\xi}_t^{a0}$ in period $t = 0$ can be interpreted as an announcement that 2 years later money growth will be changed. Again, we use Uhlig (1999) and our solution procedure described in section 3.2.7 to solve for the recursive equilibrium law of motion.

B Appendix to Chapter 4

B.1 Stationary Equilibrium

We detrend all variables that are non-stationary by the balanced growth path ψ^t with $\psi = \xi^{\frac{1}{1-\theta}}$, i.e. $c_t = \tilde{c}_t \psi^t$, $x_t = \tilde{x}_t \psi^t$, $y_t = \tilde{y}_t \psi^t$, $g_t = \tilde{g}_t \psi^t$, $s_t = \tilde{s}_t \psi^t$, $T_t = \tilde{T}_t \psi^t$, $k_{t-1} = \tilde{k}_{t-1} \psi^t$. All stationary variables like taxes, interest rates, hours worked and the cyclical component of technology γ_t are not detrended, i.e. $n_t = \tilde{n}_t$, $\gamma_t = \tilde{\gamma}_t$, $R_t = \tilde{R}_t$, $R_t^b = \tilde{R}_t^b$, $\tau_t^n = \tilde{\tau}_t^n$, $\tau_t^k = \tilde{\tau}_t^k$, $\tau_t^c = \tilde{\tau}_t^c$. The following equations describe the stationary equilibrium:

Households labor supply decision:

$$-\frac{U_{\tilde{n}}(t)}{U_{\tilde{c}}(t)\psi^t} = (1-\theta)\frac{1-\tilde{\tau}_t^n}{1+\tilde{\tau}_t^c}\frac{\tilde{y}_t}{\tilde{n}_t} \tag{B.1}$$

Households Euler equation for capital:

$$\beta E_t \left[\frac{U_{\tilde{c}}(t+1)}{U_{\tilde{c}}(t)} \frac{1+\tilde{\tau}_t^c}{1+\tilde{\tau}_{t+1}^c} \tilde{R}_{t+1} \right] = 1 \tag{B.2}$$

Households Euler equation for government bonds:

$$\beta E_t \left[\frac{U_{\tilde{c}}(t+1)}{U_{\tilde{c}}(t)} \frac{1+\tilde{\tau}_t^c}{1+\tilde{\tau}_{t+1}^c} \tilde{R}_{t+1}^b \right] = 1 \tag{B.3}$$

Capital accumulation equation:

$$\psi \tilde{k}_t = (1-\delta)\tilde{k}_{t-1} + \tilde{x}_t \tag{B.4}$$

Real return on capital:

$$\tilde{R}_t = (1-\tilde{\tau}_t^k)(\theta \frac{\tilde{y}_t}{\tilde{k}_{t-1}} - \delta) + 1 \tag{B.5}$$

Aggregate resource constraint:

$$\tilde{c}_t + \tilde{g}_t + \tilde{x}_t = \tilde{y}_t \tag{B.6}$$

Firms production function:

$$\tilde{y}_t = \tilde{\gamma}_t \tilde{k}_{t-1}^{\theta} \tilde{n}_t^{1-\theta} \tag{B.7}$$

Government tax revenues:

$$\tilde{T}_t = \tilde{\tau}_t^c \tilde{c}_t + (1-\theta)\tilde{\tau}_t^n \tilde{y}_t + \tilde{\tau}_t^k (\theta \frac{\tilde{y}_t}{\tilde{k}_{t-1}} - \delta)\tilde{k}_{t-1} \tag{B.8}$$

Government budget constraint:

$$\tilde{g}_t = \bar{b}(\psi - \tilde{R}_t^b) + \tilde{T}_t - \tilde{s}_t \tag{B.9}$$

Exogenous AR(1) processes:

$$\{\tilde{\tau}_t^c, \tilde{\tau}_t^n, \tilde{\tau}_t^k, \tilde{s}_t, \tilde{\gamma}_t\}_{t=0}^{\infty} \tag{B.10}$$

After assigning steady state values for tax rates, technology, transfers and debt, equations (B.1) to (B.9) determine the steady state for all other variables.

B.2 Log-linear Equations

Hat variables denote percentage deviations from steady state, i.e. $\hat{y}_t = \frac{y_t - \bar{y}}{\bar{y}}$. Breve variables denote absolute deviations from steady state, i.e. $\breve{\tau}_t^n = \tau_t^n - \bar{\tau}^n$. The following equations determine the log-linear dynamics of the model:

Households labor supply decision:

$$(1 + \sigma_{cn,n} + \sigma_{nn})\hat{n}_t = \hat{y}_t - (\sigma_{cc} + \sigma_{nc,c})\hat{c}_t - \frac{1}{1 - \bar{\tau}^n}\breve{\tau}_t^n - \frac{1}{1 + \bar{\tau}^c}\breve{\tau}_t^c \tag{B.11}$$

Households Euler equation for capital:

$$E_t\left[\hat{R}_{t+1} - \sigma_{cc}(\hat{c}_{t+1} - \hat{c}_t) - \sigma_{cn,n}(\hat{n}_{t+1} - \hat{n}_t) - \frac{1}{1 + \bar{\tau}_c}(\breve{\tau}_{t+1}^c - \breve{\tau}_t^c)\right] = 0 \tag{B.12}$$

Households Euler equation for government bonds:

$$E_t\left[\hat{R}_{t+1}^b - \sigma_{cc}(\hat{c}_{t+1} - \hat{c}_t) - \sigma_{cn,n}(\hat{n}_{t+1} - \hat{n}_t) - \frac{1}{1 + \bar{\tau}_c}(\breve{\tau}_{t+1}^c - \breve{\tau}_t^c)\right] = 0 \tag{B.13}$$

Capital accumulation equation:

$$\psi\hat{k}_t = (1 - \delta)\hat{k}_{t-1} + (\psi - 1 + \delta)\hat{x}_t \tag{B.14}$$

Real return on capital:

$$\bar{R}\hat{R}_t = \left(\bar{R} - 1 + \delta(1 - \bar{\tau}^k)\right)(\hat{y}_t - \hat{k}_{t-1}) - \frac{\bar{R} - 1}{1 - \bar{\tau}^k}\breve{\tau}_t^k \tag{B.15}$$

Aggregate resource constraint:

$$(1 - \xi - \frac{\bar{g}}{\bar{y}})\hat{c}_t + \frac{\bar{g}}{\bar{y}}\hat{g}_t + \xi\hat{x}_t = \hat{y}_t \tag{B.16}$$

Firms production function:

$$\hat{y}_t = \hat{\gamma}_t + \theta \hat{k}_{t-1} + (1-\theta)\hat{n}_t \tag{B.17}$$

Government tax revenues:

$$\begin{aligned} \frac{\bar{T}}{\bar{y}}\hat{T}_t &= (1-\xi-\frac{\bar{g}}{\bar{y}})(\bar{\tau}^c \hat{c}_t + \breve{\tau}^c_t) + (1-\theta)\breve{\tau}^n_t + (\bar{\tau}^n(1-\theta)+\bar{\tau}^k\theta)\hat{y}_t \\ &\quad + \left(\theta - \frac{\delta\xi}{\psi-1+\delta}\right)\breve{\tau}^k_t - \frac{\bar{\tau}^k\delta\xi}{\psi-1+\delta}\hat{k}_{t-1} \end{aligned} \tag{B.18}$$

Government budget constraint:

$$\frac{\bar{g}}{\bar{y}}\hat{g}_t = \frac{\bar{T}}{\bar{y}}\hat{T}_t - \frac{\bar{b}}{\bar{y}}\bar{R}^b\hat{R}^b_t - \frac{\bar{s}}{\bar{y}}\hat{s}_t \tag{B.19}$$

Exogenous AR(1) processes:

$$\{\breve{\tau}^c_t, \breve{\tau}^n_t, \breve{\tau}^k_t, \hat{s}_t, \hat{\gamma}_t\}_{t=0}^{\infty}$$

with $\sigma_{cc} = \frac{-U_{\bar{c}\bar{c}}\bar{c}}{U_{\bar{c}}}$, $\sigma_{cn,n} = \frac{-U_{\bar{c}\bar{n}}\bar{n}}{U_{\bar{c}}}$, $\sigma_{nn} = \frac{U_{\bar{n}\bar{n}}\bar{n}}{U_{\bar{n}}}$, $\sigma_{nc,c} = \frac{U_{\bar{n}\bar{c}}\bar{c}}{U_{\bar{n}}}$ and $\xi = \frac{(\psi-1+\delta)\theta(1-\bar{\tau}^k)}{\bar{R}-1+\delta(1-\bar{\tau}^k)}$. Equations (B.11) to (B.19) plus the exogenous shocks determine the dynamics of the model which can be solved with Uhlig (1999).

In order to determine the dynamics of the models, we need the following 15 parameters respectively steady state variables:

$$\sigma_{cc}, \sigma_{cn,n}, \sigma_{nn}, \sigma_{nc,c}, \bar{\tau}^c, \bar{\tau}^n, \bar{\tau}^k, \psi, \delta, \theta, \bar{R}, \tfrac{\bar{g}}{\bar{y}}, \tfrac{\bar{T}}{\bar{y}}, \tfrac{\bar{b}}{\bar{y}}, \tfrac{\bar{s}}{\bar{y}}.$$ [1]

Some of these 15 parameters are free whereas others are tight down by the data or the model. Following tables 4.1 and 4.2 the data restricts $\bar{\tau}^c, \bar{\tau}^n, \bar{\tau}^k, \psi, \bar{R}, \delta, \theta$. Table 4.3 reveals that σ_{cc}, $\sigma_{cn,n}$, σ_{nn}, $\sigma_{nc,c}$ are functions of other parameters and

[1] Note that in equilibrium $R_t = R^b_t$ and thus $\bar{R} = \bar{R}^b$.

steady state variables. E.g., for C-D utility we obtain two new parameters - η and α. However, the parameter α must be used to pin down $\bar{n}_{us} = 0.25$ for the baseline calibration. It turns out that for the case of C-D utility only η is a free parameter. Likewise for POW and GHH, κ' and κ'' pin down $\bar{n}_{us} = 0.25$ so that free parameters in these cases are η', η'', ϕ' and ϕ''.

Once we know $\bar{n}$ in our models we can calculate $\bar{y}$ and hence from equations (B.4), (B.5), (B.6), (B.8) and (B.9), we can derive

$$\frac{\bar{g}}{\bar{y}} = \frac{1}{1+\tau_c}\left(\frac{\bar{b}}{\bar{y}}(\psi - \bar{R}) + \bar{\tau}^c(1-\xi) + (1-\theta)\bar{\tau}^n + \bar{\tau}^k(\theta - \frac{\delta\xi}{\psi - 1 + \delta}) - \frac{\bar{s}}{\bar{y}}\right) \tag{B.20}$$

and as well as

$$\frac{\bar{T}}{\bar{y}} = \frac{\bar{b}}{\bar{y}}(\bar{R} - \psi) + \frac{\bar{g}}{\bar{y}} + \frac{\bar{s}}{\bar{y}} \tag{B.21}$$

which pin down $\frac{\bar{g}}{\bar{y}}$ and $\frac{\bar{T}}{\bar{y}}$. However, our choice for $\bar{b}$ as well as $\bar{s}$ is restricted by the fact that for the baseline calibration $\frac{\bar{b}}{\bar{y}}$ as well as $\frac{\bar{s}}{\bar{y}}$ must match the data as given in table 4.1. To sum up, η, η', η'', ϕ' and ϕ'' are the only free parameters in our models. However, as outlined in section 4.2.3 we set η, η' and η'' such that the intertemporal elasticity of substitution is unity. In addition, we set ϕ' and ϕ'' such that $\frac{\partial \bar{T}^{US}_{C-D}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{POW}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{GHH}}{\partial \bar{\tau}^n}$. As a consequence of our calibration/parameterization discipline table 4.3 reveals that $\sigma_{cc}, \sigma_{cn,n}, \sigma_{nn}, \sigma_{nc,c}$ are identical for C-D and POW preferences for the US model. Hence, the dynamics are locally identical for these models. By contrast, for GHH preferences only $\sigma_{cc} = 1$ is identical with the other preference specifications and hence the dynamics will not be identical with the other preferences in general. However, implied by our calibration/parameterization discipline that $\frac{\partial \bar{T}^{US}_{GHH}}{\partial \bar{\tau}^n} = \frac{\partial \bar{T}^{US}_{C-D}}{\partial \bar{\tau}^n}$ we know that for labor income tax cuts the dynamics will be identical compared to the other preference specifications.

B.3 EU-15 Tax Rates and GDP Ratios

In order to obtain EU-15 tax rates and GDP ratios we proceed as follows. E.g., EU-15 consumption tax revenues can be expressed as:

$$\tau^c_{EU-15,t} c_{EU-15,t} = \sum_j \tau^c_{j,t} c_{j,t} \tag{B.22}$$

where j denotes each individual EU-15 country. Rewriting equation (B.22) yields the consumption weighted EU-15 consumption tax rate:

$$\tau^c_{EU-15,t} = \frac{\sum_j \tau^c_{j,t} c_{j,t}}{c_{EU-15,t}} = \frac{\sum_j \tau^c_{j,t} c_{j,t}}{\sum_j c_{j,t}}. \tag{B.23}$$

The numerator of equation (B.23) consists of consumption tax revenues of each individual country j whereas the denominator consists of consumption tax revenues divided by the consumption tax rate of each individual country j. Formally,

$$\tau^c_{EU-15,t} = \frac{\sum_j T^{Cons}_{j,t}}{\sum_j \frac{T^{Cons}_{j,t}}{\tau^c_{j,t}}}. \tag{B.24}$$

The dataset of Carey and Rabesona (2002) contains individual country data for consumption taxes. Further, the methodology of Mendoza, Razin, and Tesar (1994) allows to calculate implicit individual country consumption tax revenues so that we can easily calculate the EU-15 consumption tax rate $\tau^c_{EU-15,t}$. Likewise, applying the same procedure we calculate EU-15 labor and capital tax rates. Taking averages over time yields the tax rates we report in table 4.1.[2]

[2] Note that these tax rates are similar to those when calculating EU-15 tax rates from simply taking the arithmetic average of individual country tax rates. In this case, we would obtain $\bar{\tau}^n = 0.38$, $\bar{\tau}^k = 0.35$ and $\bar{\tau}^c = 0.19$.

In order to calculate EU-15 GDP ratios we proceed as follows. E.g., the GDP weighted EU-15 debt to GDP ratio can be written as:

$$\frac{b_{EU-15,t}}{y_{EU-15,t}} = \frac{\sum_j \frac{b_{j,t}}{y_{j,t}} y_{j,t}}{\sum_j y_{j,t}} \tag{B.25}$$

where b_j and y_j are individual country government debt and GDP. Likewise, we apply the same procedure for the EU-15 transfer to GDP ratio.[3] Taking averages over time yields the numbers reported in tables 4.1, 4.4, 4.5 and 4.6.

B.4 Analytical Characterization of the Slope of the Laffer Curve

In this section we derive an analytical characterization of the slope of the Laffer curve for unexpected and announced labor and capital tax cuts. We detrend all variables that are non-stationary by the balanced growth path ψ^t with $\psi = \xi^{\frac{1}{1-\theta}}$. Then, we log-linearize the equations that describe the equilibrium. Hat variables denote percentage deviations from steady state, i.e. $\hat{T}_t = \frac{T_t - \bar{T}}{\bar{T}}$. Breve variables denote absolute deviations from steady state, i.e. $\breve{\tau}_t^n = \tau_t^n - \bar{\tau}^n$. See appendix B.1 as well as appendix B.2 for a full representation of the stationary equilibrium equations as well as the the log-linearized equations. Without loss of generality we assume that all other exogenous processes are at their steady states, i.e. $\hat{\gamma}_t = 0$, $\breve{\tau}_t^c = 0$ and $\hat{s}_t = 0 \; \forall t$.

[3]Note again, that these GDP ratios are close to those when simply taking the arithmetic average. In this case, we would obtain an annual debt to GDP ratio of 55 % and a transfer to GDP ratio of 19 %.

B.4.1 Unexpected Tax Cuts

For unexpected tax cuts, we assume that capital and labor taxes evolve according to: $\breve{\tau}_t^k = \rho_{\tau^k}\breve{\tau}_{t-1}^k + \epsilon_t$ and $\breve{\tau}_t^n = \rho_{\tau^n}\breve{\tau}_{t-1}^n + \nu_t$. Using the log-linearized system of equations we can solve for the recursive equilibrium law of motion for $\hat{k}_t$ and $\hat{T}_t$ following Uhlig (1999). I.e.,

$$\hat{k}_t = \eta_{kk}\hat{k}_{t-1} + \pi\breve{\tau}_t^k + \nu\breve{\tau}_t^n \tag{B.26}$$

$$\hat{T}_t = \eta_{Tk}\hat{k}_{t-1} + \mu\breve{\tau}_t^k + \omega\breve{\tau}_t^n. \tag{B.27}$$

After some tedious manipulations we can express tax revenues $\hat{T}_t$ as follows:

$$\begin{aligned}\hat{T}_t = \eta_{Tk}\eta_{kk}^t\hat{k}_{-1} \quad &+ \quad \left[\frac{\eta_{Tk}\pi}{\eta_{kk}}\left(\frac{\rho_{\tau^k}^{t+1} - \eta_{kk}^{t+1}}{\rho_{\tau^k} - \eta_{kk}}\right) + \left(\mu - \frac{\eta_{Tk}\pi}{\eta_{kk}}\right)\rho_{\tau^k}^t\right]\breve{\tau}_0^k \\ &+ \quad \left[\frac{\eta_{Tk}\nu}{\eta_{kk}}\left(\frac{\rho_{\tau^n}^{t+1} - \eta_{kk}^{t+1}}{\rho_{\tau^n} - \eta_{kk}}\right) + \left(\omega - \frac{\eta_{Tk}\pi}{\eta_{kk}}\right)\rho_{\tau^n}^t\right]\breve{\tau}_0^n\end{aligned} \tag{B.28}$$

The coefficients in front of $\breve{\tau}_0^k$ and $\breve{\tau}_0^n$ can be interpreted as the slope of the Laffer curve. Suppose we consider permanent tax changes only, i.e. $\rho_{\tau^k} = \rho_{\tau^n} = 1$ and no initial deviation of capital, i.e. $\hat{k}_{-1} = 0$. Then, if $\|\eta_{kk}\| < 1$ we obtain:

$$\lim_{t\to\infty}\hat{T}_t \quad = \quad \left[\frac{\eta_{Tk}}{1-\eta_{kk}}\pi + \mu\right]\breve{\tau}_0^k + \left[\frac{\eta_{Tk}}{1-\eta_{kk}}\nu + \omega\right]\breve{\tau}_0^n \tag{B.29}$$

The coefficients in front of $\breve{\tau}_0^k$ and $\breve{\tau}_0^n$ characterize the slope of the long-run Laffer curve. Since the coefficients of the recursive equilibrium law of motion are very complicated functions of the model parameters we rely on numerical evaluations presented in tables 4.7 and 4.8 and figure 4.9.

B.4.2 5-Years-In-Advance Announced Tax Cuts

In order to model announced labor as well as capital tax cuts we replace $\check{\tau}_t^n$ and $\check{\tau}_t^k$ in the log-linearized system of equations in appendix B.2 by $\check{\tau}_t^{na20}$ and $\check{\tau}_t^{ka20}$. Further, we add the following auxiliary variables to our system of equilibrium equations. For capital taxes: $\check{\tau}_t^{ka20} = \check{\tau}_{t-1}^{ka19}$, $\check{\tau}_t^{ka19} = \check{\tau}_{t-1}^{ka18}$, ..., $\check{\tau}_t^{ka1} = \check{\tau}_{t-1}^{ka0}$ with $\check{\tau}_t^{ka0} = \rho_{\tau^{ka0}}\check{\tau}_{t-1}^{ka0} + \epsilon_t$. For labor taxes: $\check{\tau}_t^{na20} = \check{\tau}_{t-1}^{na19}$, $\check{\tau}_t^{na19} = \check{\tau}_{t-1}^{na18}$, ..., $\check{\tau}_t^{na1} = \check{\tau}_{t-1}^{na0}$ with $\check{\tau}_t^{na0} = \rho_{\tau^{na0}}\check{\tau}_{t-1}^{na0} + \nu_t$. This structure implies that an innovation in say $\check{\tau}_t^{ka0}$ in period $t = 0$ is fully observed by the individuals. However, it takes 20 periods (5 years) until $\check{\tau}_t^{ka20}$ changes in the respective equations of the system of equations. Thus, the innovation in $\check{\tau}_t^{ka0}$ in period $t = 0$ can be interpreted as an announcement that 5 years later capital taxes will be changed. Again, we use Uhlig (1999) to solve for the recursive equilibrium law of motion. I.e.,

$$\hat{k}_t = \eta_{kk}\hat{k}_{t-1} + \sum_{i=0}^{20}\pi_i\check{\tau}_t^{kai} + \sum_{i=0}^{20}\nu_i\check{\tau}_t^{nai} \tag{B.30}$$

$$\hat{T}_t = \eta_{Tk}\hat{k}_{t-1} + \sum_{i=0}^{20}\mu_i\check{\tau}_t^{kai} + \sum_{i=0}^{20}\omega_i\check{\tau}_t^{nai}. \tag{B.31}$$

After some tedious manipulations and using $\sum_{i=0}^{20}\pi_i\check{\tau}_{t-j}^{kai} = \sum_{i=0}^{20}\pi_i\check{\tau}_{t-j-i}^{ka0}$ as well as $\sum_{i=0}^{20}\pi_i\check{\tau}_{t-j}^{nai} = \sum_{i=0}^{20}\pi_i\check{\tau}_{t-j-i}^{na0}$, we can express tax revenues $\hat{T}_t$ as follows:

$$\begin{aligned}\hat{T}_t = \eta_{Tk}\eta_{kk}^t\hat{k}_{-1} \quad &+ \quad \frac{\eta_{Tk}}{\eta_{kk}}\sum_{j=0}^{t}\eta_{kk}^j\sum_{i=0}^{20}\pi_i\check{\tau}_{t-j-i}^{ka0} + \sum_{i=0}^{20}(\mu_i - \frac{\eta_{Tk}}{\eta_{kk}}\pi_i)\check{\tau}_{t-i}^{ka0} \\ &+ \quad \frac{\eta_{Tk}}{\eta_{kk}}\sum_{j=0}^{t}\eta_{kk}^j\sum_{i=0}^{20}\nu_i\check{\tau}_{t-j-i}^{na0} + \sum_{i=0}^{20}(\omega_i - \frac{\eta_{Tk}}{\eta_{kk}}\nu_i)\check{\tau}_{t-i}^{na0}\end{aligned} \tag{B.32}$$

with $\check{\tau}_t^{na0} = \rho_{\tau^{na0}}\check{\tau}_{t-1}^{na0} + \nu_t$ and $\check{\tau}_t^{ka0} = \rho_{\tau^{ka0}}\check{\tau}_{t-1}^{ka0} + \epsilon_t$. Equation (B.32) characterizes the slope of the Laffer curve for 5-years-in-advance announced capital and labor tax cuts. Suppose we consider permanent tax changes only, i.e. $\rho_{\tau^{ka0}} = \rho_{\tau^{na0}} = 1$ and no initial deviation of capital, i.e. $\hat{k}_{-1} = 0$. Then, if $\|\eta_{kk}\| < 1$ we obtain:

$$\lim_{t\to\infty} \hat{T}_t = \left[\frac{\eta_{Tk}}{1-\eta_{kk}} \sum_{i=0}^{20} \pi_i + \sum_{i=0}^{20} \mu_i\right] \check{\tau}_0^{ka0} + \left[\frac{\eta_{Tk}}{1-\eta_{kk}} \sum_{i=0}^{20} \nu_i + \sum_{i=0}^{20} \omega_i\right] \check{\tau}_0^{na0} \tag{B.33}$$

The coefficients in front of $\check{\tau}_0^{ka0}$ and $\check{\tau}_0^{na0}$ characterize the slope of the long-run Laffer curve. Note that since $\sum_{i=0}^{20} \pi_i = \pi$, $\sum_{i=0}^{20} \mu_i = \mu$, $\sum_{i=0}^{20} \nu_i = \nu$ and $\sum_{i=0}^{20} \omega_i = \omega$ the long-run slope of the Laffer curve is identical compared to the case of unexpected tax cuts (see equation (B.29)). Again, since the coefficients of the recursive equilibrium law of motion are very complicated functions of the model parameters we rely on numerical evaluations presented in tables 4.7 and 4.8 and figure 4.9.

C Appendix to Chapter 5

C.1 Ramsey Problem - First Order Conditions

C.1.1 First order conditions for periods $t > T$ (if $T = 0$) or $t \geq T$ (if $T \geq 1$)

$$
\begin{aligned}
c_t: \quad & U_c(t) + \phi \frac{U_{cc}(t)}{1+\tau_t^c}\left(Rev_t - g_t - s_t - k_t^g + (1-\delta_g)k_{t-1}^g\right) \\
& -\mu_t\left(U_{nc}(t)(1+\tau_t^c) + (1-\tau_t^n)U_{cc}(t)f_{n,t}\right) - \gamma_t + \omega_t\tau_t^c \\
& +\eta_t \frac{U_{cc}(t)}{1+\tau_t^c} - \eta_{t-1}\frac{U_{cc}(t)}{1+\tau_t^c}\Big((1-\tau_t^k)(f_{k,t}-\delta)+1\Big) = 0
\end{aligned} \tag{C.1}
$$

$$
\begin{aligned}
g_t: \quad & U_g(t) + \phi \frac{U_{cg}(t)}{1+\tau_t^c}\left(Rev_t - g_t - s_t - k_t^g + (1-\delta_g)k_{t-1}^g\right) - \phi\frac{U_c(t)}{1+\tau_t^c} \\
& -\mu_t\left(U_{ng}(t)(1+\tau_t^c) + (1-\tau_t^n)U_{cg}(t)f_{n,t}\right) - \gamma_t + \eta_t\frac{U_{cg}(t)}{1+\tau_t^c} \\
& -\eta_{t-1}\frac{U_{cg}(t)}{1+\tau_t^c}\Big((1-\tau_t^k)(f_{k,t}-\delta)+1\Big) = 0
\end{aligned} \tag{C.2}
$$

$$
\begin{aligned}
n_t: \quad & U_n(t) + \phi \frac{U_{cn}(t)}{1+\tau_t^c}\left(Rev_t - g_t - s_t - k_t^g + (1-\delta_g)k_{t-1}^g\right) \\
& -\mu_t\left(U_{nn}(t)(1+\tau_t^c) + (1-\tau_t^n)U_{cn}(t)f_{n,t} + (1-\tau_t^n)U_c(t)f_{nn,t}\right) \\
& +\gamma_t f_{n,t} + \omega_t\tau_t^n f_{nn,t}n_t + \omega_t\tau_t^n f_{n,t} + \omega_t\tau_t^k k_{t-1}f_{kn,t} + \eta_t\frac{U_{cn}(t)}{1+\tau_t^c} \\
& -\eta_{t-1}\frac{U_{cn}(t)}{1+\tau_t^c}\Big((1-\tau_t^k)(f_{k,t}-\delta)+1\Big) - \eta_{t-1}\frac{U_c(t)}{1+\tau_t^c}(1-\tau_t^k)f_{kn,t} = 0
\end{aligned} \tag{C.3}
$$

$$k_t: \quad -\mu_{t+1}\beta(1-\tau^n_{t+1})U_c(t+1)f_{nk,t+1} - \gamma_t + \gamma_{t+1}\beta\left(f_{k,t+1}+1-\delta\right)$$
$$+\omega_{t+1}\beta\left(\tau^n_{t+1}f_{nk,t+1}n_{t+1} + \tau^k_{t+1}f_{kk,t+1}k_t + \tau^k_{t+1}(f_{k,t+1}-\delta)\right)$$
$$-\beta\eta_t\frac{U_c(t+1)}{1+\tau^c_{t+1}}(1-\tau^k_{t+1})f_{kk,t+1} = 0 \tag{C.4}$$

$$Rev_t: \quad \phi\frac{U_c(t)}{1+\tau^c_t} - \omega_t = 0 \tag{C.5}$$

$$k^g_t: \quad -\phi\frac{U_c(t)}{1+\tau^c_t} + \beta\phi\frac{U_c(t+1)}{1+\tau^c_t}(1-\delta_g) - \mu_{t+1}\beta(1-\tau^n_{t+1})U_c(t+1)f_{nk^g,t+1}$$
$$-\gamma_t + \beta\gamma_{t+1}(f_{k^g,t+1}+1-\delta_g) + \beta\omega_{t+1}(\tau^n_{t+1}f_{nk^g,t+1}n_{t+1} + \tau^k_{t+1}k_tf_{kk^g,t+1})$$
$$-\eta_t\beta\frac{U_c(t+1)}{1+\tau^c_{t+1}}(1-\tau^k_{t+1})f_{kk^g,t+1} = 0 \tag{C.6}$$

$$\tau^k_t: \quad \omega_t(f_{k,t}-\delta)k_{t-1} + \eta_{t-1}\frac{U_c(t)}{1+\tau^c_t}(f_{k,t}-\delta) = 0 \tag{C.7}$$

$$\tau^n_t: \quad \mu_tU_c(t)f_{n,t} + \omega_tf_{n,t}n_t = 0 \tag{C.8}$$

$$\eta_t: \quad \beta\frac{U_c(t+1)}{1+\tau^c_{t+1}}\left((1-\tau^k_{t+1})(f_{k,t+1}-\delta)+1\right) - \frac{U_c(t)}{1+\tau^c_t} = 0 \tag{C.9}$$

$$\mu_t: \quad U_n(t)(1+\tau^c_t) + U_c(t)(1-\tau^n_t)f_{n,t} = 0 \tag{C.10}$$

$$\gamma_t: \quad c_t + g_t + k_t + k^g_t - f_t(k_{t-1}, n_t, k^g_{t-1}) - (1-\delta)k_{t-1}$$
$$-(1-\delta_g)k^g_{t-1} = 0 \tag{C.11}$$

$$\omega_t: \quad Rev_t - \tau^c_tc_t - \tau^n_tf_{n,t}n_t - \tau^k_t(f_{k,t}-\delta)k_{t-1} = 0 \tag{C.12}$$

$$\phi: \quad \sum_{t=0}^{\infty}\beta^t\frac{U_c(t)}{1+\tau^c_t}\left[Rev_t - g_t - s_t - k^g_t + (1-\delta_g)k^g_{t-1}\right] - \frac{U_c(0)}{1+\tau^c_0}b_{-1} = 0 \tag{C.13}$$

C.1.2 First order conditions for periods $1 \leq t \leq T-1$

$c_t, g_t, n_t, k_t, Rev_t, k_t^g, \eta_t, \mu_t, \gamma_t, \omega_t, \phi$: equations (C.1) to (C.6) as well as equations (C.9) to (C.13). In addition, the following first order conditions need to be changed to

$$\tau_t^k: \quad \omega_t(f_{k,t}-\delta)k_{t-1} + \eta_{t-1}\frac{U_c(t)}{1+\tau_t^c}(f_{k,t}-\delta) - \nu_t = 0 \tag{C.14}$$

$$\tau_t^n: \quad \mu_t U_c(t) f_{n,t} + \omega_t f_{n,t} n_t - \kappa_t = 0 \tag{C.15}$$

$$\nu_t: \quad \tau_t^k - \bar{\tau}^k = 0 \tag{C.16}$$

$$\nu_t: \quad \tau_t^n - \bar{\tau}^n = 0 \tag{C.17}$$

C.1.3 First order conditions for period $t = 0$ (if $T > 0$)

$k_t, Rev_t, k_t^g, \eta_t, \mu_t, \gamma_t, \omega_t, \phi, \tau_t^k, \tau_t^n, \nu_t, \kappa_t$: equations (C.4) to (C.6) as well as equations (C.9) to (C.13) and equations (C.14) to (C.17). Now, the following first order conditions need to be adjusted:

$$\begin{aligned} c_t: \quad & U_c(t) + \phi\frac{U_{cc}(t)}{1+\tau_t^c}\left(Rev_t - g_t - s_t - k_t^g + (1-\delta_g)k_{t-1}^g\right) \\ & -\mu_t\left(U_{nc}(t)(1+\tau_t^c) + (1-\tau_t^n)U_{cc}(t)f_{n,t}\right) - \gamma_t + \omega_t\tau_t^c \\ & +\eta_t\frac{U_{cc}(t)}{1+\tau_t^c} - \eta_{t-1}\frac{U_{cc}(t)}{1+\tau_t^c}\Big((1-\tau_t^k)(f_{k,t}-\delta)+1\Big) - \phi\frac{U_{cc}(0)}{1+\tau^c(0)}b_{-1} = 0 \end{aligned} \tag{C.18}$$

$$
\begin{aligned}
g_t: \quad & U_g(t) + \phi \frac{U_{cg}(t)}{1+\tau_t^c}\left(Rev_t - g_t - s_t - k_t^g + (1-\delta_g)k_{t-1}^g\right) - \phi \frac{U_c(t)}{1+\tau_t^c} \\
& -\mu_t \left(U_{ng}(t)(1+\tau_t^c) + (1-\tau_t^n)U_{cg}(t) f_{n,t}\right) - \gamma_t + \eta_t \frac{U_{cg}(t)}{1+\tau_t^c} \\
& -\eta_{t-1}\frac{U_{cg}(t)}{1+\tau_t^c}\left((1-\tau_t^k)(f_{k,t}-\delta)+1\right) - \phi \frac{U_{cc}(0)}{1+\tau^c(0)} b_{-1} = 0 \qquad \text{(C.19)}
\end{aligned}
$$

$$
\begin{aligned}
n_t: \quad & U_n(t) + \phi \frac{U_{cn}(t)}{1+\tau_t^c}\left(Rev_t - g_t - s_t - k_t^g + (1-\delta_g)k_{t-1}^g\right) \\
& -\mu_t \left(U_{nn}(t)(1+\tau_t^c) + (1-\tau_t^n)U_{cn}(t) f_{n,t} + (1-\tau_t^n)U_c(t) f_{nn,t}\right) \\
& +\gamma_t f_{n,t} + \omega_t \tau_t^n f_{nn,t} n_t + \omega_t \tau_t^n f_{n,t} + \omega_t \tau_t^k k_{t-1} f_{kn,t} + \eta_t \frac{U_{cn}(t)}{1+\tau_t^c} \\
& -\eta_{t-1}\frac{U_{cn}(t)}{1+\tau_t^c}\left((1-\tau_t^k)(f_{k,t}-\delta)+1\right) - \eta_{t-1}\frac{U_c(t)}{1+\tau_t^c}(1-\tau_t^k) f_{kn,t} \\
& -\phi \frac{U_{cn}(0)}{1+\tau^c(0)} b_{-1} = 0 \qquad \text{(C.20)}
\end{aligned}
$$

C.1.4 First order conditions for period $t = 0$ (if $T = 0$)

$c_t, g_t, n_t, k_t, Rev_t, k_t^g, \eta_t, \mu_t, \gamma_t, \omega_t, \phi, \tau_t^n$: equations (C.18) to (C.20), equations (C.4) to (C.6), equation (C.8) and equations (C.9) to (C.13).

Note that the Ramsey planner does not choose τ_0^k here in order to avoid the initial confiscation. Instead, for this case, we directly impose $\tau_0^k = \bar{\tau}^k$ in all equations listed above.

C.2 Solution Method for the Ramsey Model

We follow Domeij and Klein (2005) regarding the solution technique.[1] In particular, we make the system of equations derived in appendix C.1 finite dimensional

[1] We use MATLAB to solve the model. However, we are thankful to Paul Klein for sending example GAUSS code of the numerical solution technique used in Domeij and Klein (2005).

by assuming that the economy converges to the Ramsey steady state in finitely many periods. To that end, we choose 100 years as the finite time horizon. This implies that if time starts in $t = 0$ we know the terminal values of our state variables in period $t = 99$, i.e.

$$k_{99} = \bar{k}_{Ramsey}, k^g_{99} = \bar{k}^g_{Ramsey} \text{ and } \eta_{99} = \bar{\eta}_{Ramsey}.$$

In addition, since the economy reaches the Ramsey steady state at latest in the terminal period the three Euler equations for the terminal period $t = 99$ that look forward to the period $t = 100$ in the system of equations derived in the appendix C.1 are not longer required. This leaves us with a system of non-linear equations with as many equations as unknowns which we can solve with non-linear numerical solver.

In particular, using the derivations of appendix C.1 for, e.g. $T = 0$, we guess a value for the multiplier ϕ and then solve for the sequences of variables $\{c_t, n_t, g_t, Rev_t, \tau^n_t, \mu_t, \gamma_t, \omega_t\}^{99}_{t=0}$, $\{\tau^k_t\}^{99}_{t=1}$ and $\{k_t, k^g_t, \eta_t\}^{98}_{t=0}$ knowing that $k_{99} = \bar{k}_{Ramsey}$, $k^g_{99} = \bar{k}^g_{Ramsey}$ and $\eta_{99} = \bar{\eta}_{Ramsey}$. Hence, we have $8 \times 100 + 1 \times 99 + 3 \times 99$=1196 unknown variables. Given ϕ, appendix C.1 shows that for $T = 0$ in period 0 there are 11 equations and for periods $t = 1, .., 99$ there are 12 equations that determine the equilibrium. Thus, $12 \times 99 + 11$ minus the three Euler equations for the terminal period gives exactly 1196 equations. The case of $T > 0$ applies accordingly. We solve the system of non-linear equations using the `fsolve.m` function of `MATLAB` with a solution precision of $1e-8$. Technically, given the guess for the multiplier ϕ, we are able to calculate the Ramsey steady state which in turn serves as an initial guess, $\{\bar{c}_{Ramsey}, \bar{n}_{Ramsey}, \bar{g}_{Ramsey}, \bar{R}ev_{Ramsey}, \bar{\tau}^n_{Ramsey}, \bar{\mu}_{Ramsey}, \bar{\gamma}_{Ramsey}, \bar{\omega}_{Ramsey}\}^{99}_{t=0}$, $\{\bar{\tau}^k_{Ramsey}\}^{99}_{t=1}$, $\{\bar{k}_{Ramsey}, \bar{k}^g_{Ramsey}, \bar{\eta}_{Ramsey}\}^{98}_{t=0}$, for the above sequences of variables we wish to solve for.

Having obtained a potential solution, we check whether the intertemporal government budget constraint is satisfied with a precision of $1e-6$. If not, we update ϕ and repeat calculations until the desired solution precision is achieved. For a given pre-announcement horizon T it takes roughly one hour to solve the model with an up-to-date unix machine.

In order to check whether our solution represents the global maximum, we have done the following diagnostic checks. First, we have randomized our initial guess for the multiplier ϕ. In particular, we have drawn ϕ from a uniform distribution on the interval $[0,3]$.[2] Consider the case of e.g. $T=0$. Due to random draws for ϕ, the Ramsey steady states are randomized as well and hence the initial guess $\{\bar{c}_{Ramsey}, \bar{n}_{Ramsey}, \bar{g}_{Ramsey}, \bar{Rev}_{Ramsey}, \bar{\tau}^n_{Ramsey}, \bar{\mu}_{Ramsey}, \bar{\gamma}_{Ramsey}, \bar{\omega}_{Ramsey}\}_{t=0}^{99}$, $\{\bar{\tau}^k_{Ramsey}\}_{t=1}^{99}$, $\{\bar{k}_{Ramsey}, \bar{k}^g_{Ramsey}, \bar{\eta}_{Ramsey}\}_{t=0}^{98}$ for the sequences $\{c_t, n_t, g_t, Rev_t, \tau^n_t, \mu_t, \gamma_t, \omega_t\}_{t=0}^{99}$, $\{\tau^k_t\}_{t=1}^{99}$ and $\{k_t, k^g_t, \eta_t\}_{t=0}^{98}$ we wish to solve for is randomized as well. The case of $T>0$ applies accordingly. Given that the solution algorithm was able to find a solution, we always obtained the solution for the baseline and "no confiscation/subsidy" reforms discussed in the chapter.

Second, as a further check that our solution represents the global maximum we draw the multiplier ϕ from a uniform distribution on the interval $[0,3]$ and in addition perturb our initial guesses for the sequences of variables. In particular, we generate e.g. $\{\bar{c}_{rand} = \bar{c}_{Ramsey} \times \epsilon\}_{t=0}^{99}$ where ϵ is drawn form a uniform distribution on the interval $[0.5, 1.5]$.[3] Similarly, we perturb the other variables using al-

[2] In most of the solutions discussed in the chapter, ϕ took values below one. From that perspective, three as an upper bound is reasonably large. However, for values of ϕ larger than 3 it turns out that the solution algorithm has difficulties to calculate a solution at all.

[3] Hence, this implies that the initial guess is at most 50 percent smaller or larger than the Ramsey steady state. Note, however, that the Ramsey steady state itself varies considerably due to the random guesses for the multiplier ϕ. Hence, there is substantial random variation. However, for bounds lower than 0.5 or higher than 1.5 of the uniform distribution, the solution algorithm has difficulties to find a solution. Further, we have also attempted to examine randomly time varying initial guesses for each variable by e.g. drawing a randomly time varying initial sequence for consumption etc. However, the solution algorithm was not able to find a solution in this case.

ternative and independent draws for ϵ and formulate the following initial guess for the sequences of variables we wish to solve for: $\{\bar{c}_{rand}, \bar{n}_{rand}, \bar{g}_{rand}, \bar{R}ev_{rand}, \bar{\tau}^{n}_{rand}, \bar{\mu}_{rand}, \bar{\gamma}_{rand}, \bar{\omega}_{rand}\}_{t=0}^{99}$, $\{\bar{\tau}^{k}_{rand}\}_{t=1}^{99}$ and $\{\bar{k}_{rand}, \bar{k}^{g}_{rand}, \bar{\eta}_{rand}\}_{t=0}^{98}$ for $T = 0$. The case of $T > 0$ applies accordingly. Hence, this way, we have randomized our initial guess in two dimensions. First, the underlying Ramsey steady state is randomized by random draws of ϕ. Second, our initial guess for the sequences of variables itself consists now of random elements that are unrelated to e.g. the Ramsey steady state. Hence, we argue that our initial guesses display now a considerable degree of randomization. Nevertheless, given that the solution algorithm was able to find a solution, we did not find a single solution that generated higher utility respectively welfare gains for the baseline and "no confiscation/subsidy" reforms. In other words, the solution for the baseline and "no confiscation/subsidy" reforms discussed in the paper represent very likely the global maximum.

C.3 Welfare Calculations

In order to evaluate welfare consequences of the tax reforms we calculate permanent private consumption equivalents $\triangle_c^*$ that make the household indifferent between the competitive equilibrium steady state and the Ramsey allocation.

Taking transitional dynamics into account, private consumption equivalents $\triangle_c^*$ can be calculated as:

$$\sum_{t=0}^{\infty} \beta^t u\left((1+\triangle_c^*)\bar{c}, \bar{n}, \bar{g}\right) = \sum_{t=0}^{\infty} \beta^t u\left(c_{t,Ramsey}, n_{t,Ramsey}, g_{t,Ramsey}\right). \tag{C.21}$$

Given the preference specification of section 5.2.3 we can explicitly solve for private consumption equivalents that take transitional dynamics into account. Formally,

$$\triangle_c^* = \begin{cases} \exp[\frac{(1-\beta)(u_{Ramsey}^{trans}-u^{ss})}{\alpha}]-1 & \text{for } \sigma=1 \\ \left(\frac{(1-\sigma)(1-\beta)u_{Ramsey}^{trans}+1}{(1-\sigma)(1-\beta)u^{ss}+1}\right)^{\alpha(\sigma-1)}-1 & \text{for } \sigma\neq 1 \end{cases} \tag{C.22}$$

with the abbreviations $u_{Ramsey}^{trans} = \sum_{t=0}^{\infty} \beta^t u\left(c_{t,Ramsey}, n_{t,Ramsey}, g_{t,Ramsey}\right)$ and $u^{ss} = u\left(\bar{c}, \bar{n}, \bar{g}\right)$.

Selbständigkeitserklärung

Hiermit erkläre ich, die vorliegende Dissertation selbständig verfasst und nur die angegebene Literatur und Hilfsmittel verwendet zu haben. Wie an mehreren Stellen dieser Arbeit deutlich gemacht, ist Kapitel 4 eine gemeinsame Forschungsarbeit mit Prof. Harald Uhlig, Ph.D.

Mathias Trabandt

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