ESSAYS ON MACROECONOMICS AND INEQUALITY

Inaugural-Dissertation
zur Erlangung des akademischen Grades
eines Doktors der Wirtschaftswissenschaft
des
Fachbereichs Wirtschaftswissenschaft
der Freien Universität Berlin

vorgelegt von
Diplom-Volkswirt
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Juni 2018

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Tag der Disputation: 18.07.2018

Für meine Eltern.

Danksagung

Ich möchte mich zuallererst bei meinem Betreuer Philipp Engler für seine Freundlichkeit, Hilfsbereitschaft und unendliche Geduld während all der Jahre bedanken. Ich bedanke mich zutiefst dafür, dass er bei Problemen jeglicher Art immer schnell zur Stelle war und ich mir seiner Unterstützung jederzeit gewiss sein konnte. Außerdem will ich mich bei ihm für sein Engagement in unserem gemeinsamen Projekt, Kapitel 3 dieser Dissertation, bedanken.

Ebenso bin ich Irwin Collier zu tiefem Dank verpflichtet. Ich bedanke mich bei ihm für seine Bereitschaft, die Betreuung und Begutachtung meiner Dissertation mit Selbstverständlichkeit zu übernehmen. Außerdem muss ich mich bei ihm für die Ausübung seiner Funktion als mein Vorgesetzter am John-F.-Kennedy-Institut bedanken. Herr Collier hat mir von Anfang an viel Vertrauen entgegengebracht, sich bei auftretenden Problemen immer spontan Zeit genommen und mir großen Freiraum bei der Durchführung meiner beruflichen Aufgaben gelassen.

Als nächstes gilt mein Dank Kerstin Brunke und Simon Jurkatis. Kerstin Brunke für die hervorragende Zusammenarbeit am Institut, ein offenes Ohr und ihren ansteckenden Optimismus. Simon Jurkatis für seinen Einsatz in unserem gemeinsamen Projekt, Kapitel 2 dieser Dissertation, und wertvollen freundschaftlichen Rat und Zuspruch über all die Jahre.

Ebenso bedanke ich mich bei allen früheren und jetzigen Mitarbeitern am Institut für das sehr angenehme Arbeitsklima. Außerdem möchte ich mich bei den folgenden (Post)Doktoranden dafür bedanken, dass sie einen Teil dieser langen Strecke mit mir zurückgelegt haben: Marc Adam, Martin Hud, Holger Lüthen, Katharina Knoll, Dominic Quint, Davud Rostam-Afschar, Julia Püschel und Alexander Wulff.

Zu guter Letzt gilt mein besonderer Dank meiner Familie und meinen Freunden. Ich bedanke mich bei meinem Bruder Alex, meiner Schwägerin Irene, meiner Nichte Maya und meinen Freunden Björn und Heidi ein nicht wegzudenkender Teil meines Orbits zu sein. Meine Eltern, Barbara und Joachim, waren immer und in jeder Hinsicht meine wichtigsten Unterstützer. Besonders in den schwierigen Momenten war ihre Liebe von unschätzbarem Wert. Ihnen gilt mein allergrößter Dank.

Koautorenschaften und Publikationen

Die vorliegende kumulative Dissertation besteht aus drei Forschungsaufsätzen (Kapitel 2-4 der Dissertation).

Das zweite Kapitel der Dissertation ("Gini Decompositions and Gini Elasticities: on Measuring the Importance of Income Sources and Population Subgroups for Income Inequality") wurde in Koautorenschaft mit Simon Jurkatis verfasst (Eigenanteil an Konzeption, Durchführung und Berichtsabfassung: 50 Prozent). Das Kapitel wurde im Jahr 2014 als Diskussionspapier am Fachbereich Wirtschaftswissenschaft veröffentlicht.[1] Die offizielle Literaturangabe lautet:

Jurkatis, S., Strehl, W., 2014. Gini decompositions and Gini elasticities: On measuring the importance of income sources and population subgroups for income inequality. Discussion Paper Economics 2014/22, School of Business and Economics, Free University Berlin.

Das dritte Kapitel der Dissertation ("The Macroeconomic Effects of Progressive Taxes and Welfare") wurde in Koautorenschaft mit Philipp Engler verfasst (Eigenanteil an Konzeption, Durchführung und Berichtsabfassung: 50 Prozent). Das Kapitel wurde im Jahr 2016 in etwas abgeänderter Form als Diskussionspapier am Fachbereich Wirtschaftswissenschaft und am DIW Berlin veröffentlicht.[2] Die offiziellen Literaturangaben lauten:

Engler, P., Strehl, W., 2016. The Macroeconomic Effects of Progressive Taxes and Welfare. Discussion Paper Economics 2016/23, School of Business and Economics, Free University Berlin.

Engler, P., Strehl, W., 2016. The Macroeconomic Effects of Progressive Taxes and Welfare. Discussion Papers of DIW Berlin 1626, DIW Berlin, German Institute for Economic Research.

Das vierte Kapitel ("Revisiting the Progressive Consumption Tax: a Business Cycle Perspective") wurde in Alleinautorenschaft verfasst (Eigenanteil an Konzeption, Durchführung und Berichtsabfassung: 100 Prozent). Zum Zeitpunkt der Einreichung der Dissertation wurde das Kapitel weder als Diskussionspapier noch als Fachartikel veröffentlicht.

[1] Eine frühere Version des Kapitels wurde unter dem Titel "Dos and Don'ts of Gini Decompositions" als BDPEMS Working Paper 2013-03 veröffentlicht.

[2] Eine frühere Version des Kapitels wurde außerdem unter dem Titel "Progressive Taxation and Monetary Policy in a Currency Union" als Beitrag zur Jahrestagung des Vereins für Socialpolitik 2015: Ökonomische Entwicklung - Theorie und Politik - Session: Monetary Unions, No. E01-V3 veröffentlicht.

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1. Introduction

Government policies such as progressive taxes, unemployment benefits, or public pensions have an important redistributive element. They also have well-known macroeconomic side effects. Take, for example, the progressive tax system. It imposes relatively higher tax rates on wealthy individuals and thereby *reduces economic inequality*. But it is also thought to operate as a so-called *automatic fiscal stabilizer*: by e.g. reducing the volatility of disposable income relative to the volatility of market income, it automatically stabilizes aggregate demand and therefore output and employment (Brown, 1955).

The topics of economic inequality and fiscal stabilization policy have received increasing attention by academics, policymakers, and the general public in recent years. Rising income and wealth inequality has been observed within most developed countries for a couple of decades now (see e.g. OECD, 2011; Alvaredo et al., 2018), and the subject features prominently in the political debate. Public interest in the topic probably culminated in 2013/14 with the publication of Thomas Piketty's *Capital in the Twenty-First Century* (Piketty and Goldhammer, 2014). Economists have pointed out many reasons for the increase in economic inequality such as (skilled-biased) technological change, globalization, winner-take-all markets, or changes in labor market institutions, to name but a few (see e.g. OECD, 2011; CBO, 2011). Equally numerous have been the proposed policy measures to address the problem of widening economic inequality. Among the more conventional measures put forth would be e.g. a significant increase in the top tax rate (Piketty et al., 2011). More novel and radical measures would be for instance the introduction of a global wealth tax (Piketty and Goldhammer, 2014) or the replacement of the income tax with a progressive consumption or expenditure tax (see e.g. Frank, 2011b; Rogoff, 2014; Arrow, 2015). Most certainly, the rise of artificial intelligence will not make the topic of economic inequality lose any of its significance in the foreseeable future (Korinek and Stiglitz, 2017).

In the wake of the financial crisis of 2007/08 and the ensuing Great Recession, the former according to some economists at least partly caused by rising economic inequality (see e.g. Rajan, 2010), there has likewise been an increasing interest in the topic of fiscal stabilization policy. During the preceding "Great Moderation", a period of reduced macroeconomic volatility in many developed countries beginning in the 1980s, a widely held view among academics and policymakers was that monetary policy could be relied upon to do the job of macroeconomic stabilization, with fiscal policy at best playing a minor role (Blanchard et al., 2010). The financial crisis has demonstrated, however, that big macroeconomic shocks might push the central bank's policy rate to the zero lower bound and thereby render conventional monetary policy ineffective.[1] Thus, on the one hand, besides extensively discussing the effectiveness of unconventional monetary policies[2], economists have reconsidered the role of discretionary fiscal policy.[3] DeLong and Summers (2012) for instance argue that although the case for discretionary fiscal policy is weak in normal times, in line with the pre-crisis conventional wisdom (Taylor, 2000), there is a role for such policy in a depressed economy where interest rates are at the zero lower bound and where hysteresis effects are present. According to Furman (2016), a "New View" has emerged that sees fiscal policy as an essential stabilization tool in a world of low interest rates and low economic growth.[4] On the other hand, also having been neglected for some time, automatic fiscal stabilizers received renewed attention by academics and policymakers.[5] IMF economists (Baunsgaard and Symansky, 2009; Debrun and Kapoor, 2010), for instance, have stressed the timely and—equally significant—self-correcting response of automatic stabilizers to economic disturbances and raise the question of how these important tools can be enhanced further without economic efficiency losses. In a widely cited contribution, Blanchard et al. (2010) argue that the design of better automatic stabilizers offers one of the most promising ways to reduce macroeconomic fluctuations.[6]

This dissertation contributes to the growing literature on economic inequality and automatic fiscal stabilizers. It consists of three self-contained papers. The first paper (Chapter 2), co-authored with Simon Jurkatis, deals with the measurement and

[1] An impaired financial system additionally hampers the standard monetary policy transmission mechanism.

[2] See e.g. Gertler and Karadi (2011) and Woodford (2012) for two influential theoretical contributions and Joyce et al. (2012) for a review of the empirical literature on the economic effects of the unconventional monetary policies. See also Den Haan (2016) for a summary of the diverging opinions on this controversial subject.

[3] See e.g. Hebous (2011) for an extensive review of the literature.

[4] Nonetheless, discretionary fiscal policy remains a somewhat controversial issue. See e.g. Parker (2011), Ramey (2011), and Taylor (2011) for differing views regarding the effectiveness of discretionary fiscal policy.

[5] According to Blanchard (2006), "very little work has been done on automatic stabilization [...] in the last 20 years".

[6] Recent academic papers on automatic stabilizers are e.g. Dolls et al. (2012), Mattesini and Rossi (2012), and McKay and Reis (2016a,b).

decomposition of income inequality, and focuses on the well-known Gini coefficient and its decomposition by income source and population subgroup. Simply put, this decomposition seeks to shed light on the importance of specific income sources (e.g. capital income) or population subgroups (e.g. ethnic groups) for total income inequality; naturally, it also lends itself to analyze the *distributional effects* of the government's tax (and transfer) policies. The paper addresses shortcomings in the existing Gini decomposition literature and proposes novel decomposition techniques. The second paper (Chapter 3), co-authored with Philipp Engler, and the third paper (Chapter 4) then deal theoretically, through the lens of a New Keynesian model framework, with the *macroeconomic effects* of the government's tax policies. Paper 2 looks at the progressive income tax and its (potential) automatic stabilization properties. It analyzes how and through which built-in mechanisms the tax system affects the economy's response to shocks and explores under what conditions the system is desirable from a welfare perspective. Paper 3 looks at the personal expenditure tax (PET), the most common formulation of a progressive consumption tax. The PET is an at least decades-old, but as yet unrealized alternative to the (progressive) income tax and has again received more attention recently. In the context of the ongoing inequality debate, proponents (e.g. Frank, 2010) have argued that a PET would allow to address the growing problem of economic inequality more efficiently, i.e. with less harmful effects on savings or work incentives, than measures based on the taxation of income or wealth. This paper discusses a different, so far neglected issue: the PET's effect on the business cycle. More precisely, it compares its automatic stabilization (and welfare) properties with those of the existing income tax and thus asks whether the PET is a promising alternative from a macroeconomic point of view.

In the following, the three papers of this doctoral dissertation will be reviewed in some more detail.

The first paper — **Chapter 2: Gini Decompositions and Gini Elasticities: on Measuring the Importance of Income Sources and Population Subgroups for Income Inequality** — is about the decomposition of the Gini coefficient. The essay confines itself to decomposition methods that are based on the framework of Rao (1969), a framework that decomposes the Gini into so-called "concentration coefficients". The economic inequality literature utilizes these techniques to understand the importance of specific income sources (e.g. capital or labor income) or population subgroups (e.g. ethnic or linguistic groups) for total income inequality; the techniques also lend themselves to the analysis of the distributional effects of government tax and transfer policies. The main contribution of this first paper is to help clarify the literature on this widely used Gini decomposition framework. More specifically, the essay points to both methodological errors and errors in the interpretation of the decomposition results. It stresses the importance of using the so-called "Gini elasticities" to assess the quantitative significance of an income source or population subgroup for overall income inequality. It proposes a self-consistent method to decompose the change in the Gini coefficient by income source and contributes to the multi-decomposition literature by deriving Gini elasticities from a two-dimensional decomposition by income source and population subgroup.

The second paper — **Chapter 3: The Macroeconomic Effects of Progressive Taxes and Welfare** — studies the tax system from a macroeconomic perspective. It adds to the theoretical literature on automatic fiscal stabilizers by analyzing the business cycle and welfare effects of a progressive tax on wages in a New Keynesian dynamic stochastic general equilibrium (DSGE) model. Compared to the existing literature (Mattesini and Rossi, 2012), the investigation is conducted in a non-linear setting and also features so-called "rule-of-thumb" households. The non-linearity allows examining the effects of the progressive tax on both the volatility and the level of macroeconomic variables; the existence of rule-of-thumb households that base their consumption decision on disposable income adds the traditional demand-side stabilization channel of the tax system to the analysis, the latter being absent in modern DSGE models with only intertemporally optimizing or so-called "Ricardian" households (and that therefore solely capture the supply-side stabilization channel). The key takeaways are the following: the paper first finds that the progressive tax indeed stabilizes output and on this view acts as an automatic fiscal stabilizer for the macroeconomy; it also finds, however, that the tax leads to welfare improvements only in a limited number of cases. Crucial for the results is the progressive tax system's effect on the volatility and average value of price inflation. Overall, the findings suggest that the case for progressive taxes is difficult to make from a business cycle perspective only, at least through the lens of the employed New Keynesian model.

The third paper — **Chapter 4: Revisiting the Progressive Consumption Tax: a Business Cycle Perspective** — examines the personal expenditure tax (PET), the most prominent version of a progressive consumption tax. The PET has a long intellectual tradition in economics, and the merits and demerits of this alternative to the personal income tax have been discussed at length. What has been missing in the literature so far, however, is a systematic account of its effect on the business cycle. This third paper therefore seeks to contribute to the theoretical literature on the PET and the wider literature on fiscal stabilizers by analyzing the PET's automatic stabilization properties in a modern business cycle model. To this effect, it introduces a highly stylized PET into a standard New Keynesian DSGE model, derives a log-linear version of the latter, and draws a comparison with the existing (progressive) income tax. The paper finds that the PET considerably changes the economy's response to shocks. Furthermore, the paper finds that the PET yields welfare gains, relative to the income tax, for all the demand shocks considered. The PET yields welfare losses, however, under a technology shock.

2. Gini Decompositions and Gini Elasticities: on Measuring the Importance of Income Sources and Population Subgroups for Income Inequality*

2.1. Introduction

> *"... the disaggregation of the Gini coefficient is probably the most misused and misunderstood concept in the income inequality literature."*
>
> - Podder and Chatterjee (2002, p.3)

Gini decompositions have been proposed early on to analyze the role of different income sources (e.g. capital income or government transfers) or population subgroups (e.g. different ethnical, geographical or generational groups) for overall income inequality (Bhattacharya and Mahalanobis, 1967; Rao, 1969). Yet, despite the extensive use of Gini decompositions in the income inequality literature, mistakes continue to be made when it comes to the interpretation of decomposition results, and misleading methods of decomposition do not stand corrected. The consequences of misinterpretations or misleading methods cannot be overstated, as Gini decomposition results may be used by policymakers to understand underlying trends in the distribution of income and, most relevantly, to assess different tax and transfer policies in terms of their effectiveness to reduce overall income inequality.[1]

*This paper was written in collaboration with Simon Jurkatis.

[1] To give one example, falsely attributing an increase in inequality, as measured by the Gini coefficient, to changes in the distribution of capital income, as opposed to changes in wage income, may lead to wrong conclusions about redistributional measures enacted in the past and/or to misdirecting policy recommendations to counteract the increase in inequality.

This paper critically assesses Gini decompositions by income sources and population subgroups within the framework of Rao (1969)—a framework which has been widely used in the income inequality literature (for recent applications, see e.g. Podder and Chatterjee, 2002; Chatterjee and Podder, 2007; Davis et al., 2010; Mussini, 2013). In this framework the Gini is disaggregated into the income sources' (or subgroups') so-called concentration coefficients[2], each coefficient being weighted by the share of the respective income source (or subgroup income) in total income. Generally speaking, such decompositions aim at providing an understanding of the importance of an income source or population subgroup for total income inequality. In this paper we show which questions can and cannot be addressed by the Gini decompositions proposed within Rao's (1969) framework. In addition to this assessment of the existing methods, we provide a new method to decompose the change in the Gini coefficient by income sources and derive Gini elasticities from a simultaneous decomposition by income sources and population subgroups, adding to the recent trend of multi-decompositions (Mussard, 2004; Mussard and Richard, 2012; Mussard and Savard, 2012; Mussini, 2013).

First, we examine the Gini decomposition by income sources. Specifically, we point to mistakes in the interpretation of the decomposition results obtained from the method of Podder (1993b). Podder (1993b) proposes a transformation of Rao's (1969) traditional decomposition by income sources to circumvent what is known as the violation of the property of uniform additions (Morduch and Sicular, 2002).[3] According to Podder (1993b), the transformation allows assessing whether the presence of an income source increases or decreases total income inequality. We show that the method, however, is generally not able to provide such an understanding. Instead, we find that the results obtained from this method are to be interpreted as the semi-elasticities of the Gini coefficient with respect to changes in the income sources.

Turning to the Gini trend decomposition by income sources, which examines the role of *changes* in income sources for the *change* in the Gini coefficient over time, we show that the method proposed by Podder and Chatterjee (2002) can lead to erroneous conclusions. For example, using Podder and Chatterjee's (2002) trend decomposition, one may conclude that a change in an income source caused total

[2]Roughly speaking, a concentration coefficient measures the relation of an income source (or the income of a population subgroup) with the rank of its recipients in total income, i.e. it indicates whether an income source (or the income of a subgroup) accrues mainly to relatively poor or rich households.

[3]This violation states that an equally distributed income source will have a zero contribution to total income inequality, though adding a constant income source to the existing income distribution would lower total income inequality.

income inequality to increase, when in fact the change contributed to a more equally distributed total income. We are able to provide a method that does not admit such unwanted conclusions. In particular, we show that changes in an income source over time can contribute to an increase in the Gini in two different ways: first, if the distribution of that income source changes in favor of relatively rich individuals (or households); second, if the share of that income source in total income increases while the distribution of the income source is more in favor of relatively rich individuals than that of total income (or, conversely, if the income share of that source decreases while its distribution is less in favor of relatively rich individuals than that of total income). It is that latter comparison of the distribution of an income source with the distribution of total income that is missing in the approach of Podder and Chatterjee (2002). The trend decomposition of Fei et al. (1978) provides a similar intuition as to the consequences of changes in income sources as our approach. Their method, however, is less practical when more than two income sources are considered.

Discussing the Gini decomposition by population subgroups, we focus on the approach of Podder (1993a). Equivalent to Podder (1993b), Podder (1993a) proposes a transformation of the Gini subgroup decomposition of Rao (1969), thus aiming at assessing whether the presence of the income of a subgroup increases or decreases overall income inequality. Again we show that the transformation does not allow drawing conclusions on the (dis)equalizing effect of the presence of the income of population subgroups.

We next discuss the Gini trend decomposition by population subgroups that emerged from the decomposition method of Rao (1969). The trend decomposition was put forth by Chatterjee and Podder (2007) and examines the role of the change in the income of the different subgroups for the change in the Gini coefficient. We show that their method, however, can lead to highly misleading conclusions as changes in the concentration coefficients cannot be mapped unambiguously to changes in the population subgroups.[4] In contrast to the trend decomposition by income sources, the ambiguous interpretation of changes in the subgroup concentration coefficients, unfortunately, does not allow for an insightful Gini trend decomposition within Rao's (1969) framework, as changes in the Gini would, inter alia, be explained by changes in the concentration coefficients.

Throughout the paper, we highlight the importance of Gini elasticities to analyze the role of income sources and population subgroups for overall income inequality within Rao's (1969) decomposition framework (see Lerman and Yitzhaki, 1985;

[4]For example, one may prematurely conclude that the relative income position of a population subgroup has worsened, although the opposite is the case.

Podder, 1993a). Gini elasticities measure the impact of marginal changes in income sources (or in the income of population subgroups) on the Gini coefficient. Even though Gini elasticities thus aim at a quite different understanding than the contributions of income sources to total income inequality traditionally derived from the decomposition methods, in light of the non-interpretability result of Shorrocks (1988) and our assessment of Podder's (1993b) decomposition by income sources, we stress that Gini elasticities provide a valuable tool—or are arguably even to be preferred—to assess the importance of income sources for overall income inequality in a Gini decomposition framework.[5] Given our assessment of Podder's (1993a) Gini subgroup decomposition, we derive the same conclusion for the use of Gini elasticities within the subgroup decomposition framework of Rao (1969).[6]

Recently proposed multi-decompositions merge decompositions by income source and population subgroup and are thus inevitably subject to Shorrocks' (1988) critique. Due to the unambiguous interpretability of Gini elasticities, they provide a useful extension to multi-decomposition frameworks. We add to the literature by deriving the Gini elasticity from a multi-decomposition within Rao's (1969) framework. This elasticity gives the percentage change in the Gini coefficient due to a marginal, percentage change in the mean of an income source of a particular population subgroup. The elasticity is thus particularly suitable for analyzing how changes in income sources differentiated across different subgroups (e.g. changes in government transfers targeted at specific regions of a country) affect total income inequality. Gini elasticities in a multi-decomposition framework have also been derived by Mussard and Richard (2012). Unlike our approach, however, their decomposition is only valid for non-overlapping subgroup populations.

The remainder of the paper is structured as follows. Section 2.2 discusses the

[5]The non-interpretability result of Shorrocks (1988) states that the contribution of an income source to overall income inequality derived from decompositions of a general class of inequality indices (including the Gini coefficient) does not admit an interpretation of what could be reasonably understood under the term "contribution" (see below). Gini elasticities and elasticities of other inequality indices (see Paul, 2004), on the other hand, are by definition straightforward interpretable. We may thus extend our statement to elasticities and decompositions of this general class of inequality indices.

[6]Note that numerous other decompositions of the Gini coefficient by population subgroup have been proposed (among others Yitzhaki, 1994; Dagum, 1997) and that we view the Gini elasticity derived from Rao's (1969) decomposition not as a substitute, but as a complement to these methods, depending on the specific research question. This said, the reader may be reminded of the discussion regarding the decomposability of the Gini by population subgroups (Mookherjee and Shorrocks, 1982; Cowell, 1988; Silber, 1989; Yitzhaki and Lerman, 1991; Lambert and Aronson, 1993) due to the failure of *subgroup consistency* (see Cowell, 2000, p. 123). Although this discussion is beyond the scope of this paper, we want to note that whatever caveat may be put forth the Gini elasticity provides a clear-cut interpretation, which is enhanced by the intuitive appeal of the Gini itself, and that deriving this elasticity from the decomposition framework of Rao (1969) is straightforward.

Gini decomposition and the corresponding trend decomposition by income sources. Section 2.3 discusses the Gini decomposition and Gini trend decomposition by population subgroups. Section 2.4 presents a simultaneous decomposition by income sources and population subgroups based on Rao (1969) and derives the Gini elasticity from this decomposition. Section 2.5 concludes.

2.2. Gini Decomposition by Income Sources

2.2.1. Explaining Income Inequality in Terms of Income Sources

The decomposition of the Gini coefficient by income sources was early developed by Rao (1969), followed by the contributions of Fei et al. (1978), Pyatt et al. (1980) and Lerman and Yitzhaki (1985). The objective of the decomposition is to explain total income inequality in terms of the underlying income sources. The contribution of an income source to total income inequality has been of particular interest.

Assume that individuals' (or households') total income Y is made up of $I \in \mathbb{N}$ number of components, such that $Y = \sum_i Y_i$ where Y_i is the income from source i. The Gini can then be expressed as

$$G = \sum_{i}^{I} S_i \, C_i, \tag{2.1}$$

where $S_i := \mu_i/\mu$ is the mean of income source i divided by the mean of total income and C_i is the concentration coefficient (also referred to as the 'pseudo Gini') associated with income source i.[7] The concentration coefficient is defined as one minus twice the area under the concentration curve, which plots the cumulative proportions of income source i against the cumulative proportions of the population ordered ascendingly according to their total income. That is, the concentration curve makes statements like: the poorest $p\%$ of the population receive $q\%$ of income source i. Hence, it should be obvious that $C_i \in [-1, 1]$, as the concentration curve may very well lie above the diagonal of the unit square, for example, if an income source is mostly received by relatively poor households.

Regarding the contribution of an income source to total inequality, Shorrocks (1988) establishes a very unsatisfactory impossibility result that relates to the question of how to interpret the term "contribution". He names four different concepts

[7] The concentration coefficient can be further decomposed into a "Gini correlation" and the Gini coefficient of income source i (see Pyatt et al., 1980; Lerman and Yitzhaki, 1985).

that can be principally understood as the contribution of an income source i to total income inequality: (a) the inequality due to income source i alone, (b) the reduction in inequality that would result if income source i would be eliminated, (c) the observed inequality if income source i would be the only source not distributed equally, and (d) the reduction in inequality that would result from eliminating the inequality in the distribution of income source i. He shows that in general no reasonable inequality index that can be expressed as $I(Y) = \sum_i \alpha_i$ (as in equation (2.1)) admits an interpretation of α_i in the sense of (a)-(d).[8]

Abandoning the wish of an interpretive assignment in terms of (a)-(d) to a decomposition method, one can divide equation (2.1) by the Gini coefficient to get

$$1 = \sum_i \frac{S_i\, C_i}{G} = \sum_i s_i, \tag{2.2}$$

and then to attribute the term $s_i := S_i C_i / G$ to income source i as its proportional contribution to total inequality (see e.g. Fields, 1979; Shorrocks, 1982; Silber, 1989; Achdut, 1996; Davis et al., 2010).

Shorrocks (1982) already suggested that s_i may not be a desirable measure of the proportional contribution of income source i, which was again forcefully pointed out by Podder (1993b) and Podder and Chatterjee (2002). Consider, for example, an income source which is equally distributed across households. The concentration coefficient of such an income source is zero and so its (proportional) contribution to total income inequality according to s_i. We know, however, that adding a constant to each household's income lowers total income inequality. The contribution of such an income source should thus be negative.[9] The failure of the Gini decomposition—as stated in equation (2.2)—in this respect is known as the violation of the *property of uniform additions* (Morduch and Sicular, 2002).

Motivated by this failure, Podder (1993b) suggests to transform equation (2.1) in

[8]Shorrocks (1988) provides four criteria that should be fulfilled by any reasonable inequality index, which are symmetry, the principal of transfers, the normalization restriction, and the continuity assumption (see Shorrocks (1988) for details).

[9]One may want to argue that whether the contribution of such an income source should indeed be negative depends on the baseline of the analysis. That an equally distributed income source should have a negative contribution to total income inequality implies that the baseline is given by the status quo (with positive income inequality). In a world of equally distributed income, on the other hand, an equally distributed income source would not contribute in any direction to total income inequality. Therefore, equation (2.2) simply takes such a hypothetical world as the baseline of the analysis. This argument, however, is self-contradictory. To see this, note that in a world with equally distributed income adding *any* income source that is not distributed equally will increase total income inequality. Yet, an income source that is (in the status quo) mostly received by relatively poor households has a negative contribution to total income inequality according to equation (2.2)—a contradiction.

a simple manner to get

$$0 = \sum_i S_i(C_i - G) = \sum_i \tilde{s}_i. \tag{2.3}$$

Although it is not possible to interpret the term $\tilde{s}_i := S_i(C_i - G)$ as the proportional contribution of source i to total income inequality, according to Podder (1993b), the sign of $C_i - G$ tells us whether the ith income source has an inequality decreasing or increasing effect on total inequality. Or, in the words of Podder (1993b): "the sign indicates if the presence of the k-th [here ith] component increases or decreases total inequality"(p. 53). That is, $C_i - G > 0$ "means that the presence of income from the ith source makes the total inequality higher than what it would be in the absence ... from that source" (Podder and Chatterjee, 2002, p. 7).

We will show that such an interpretation of equation (2.3) is misleading by means of a simple example. Consider a population with $n = 1, \dots, N$ individuals, sorted ascendingly in their income, y_n. Let the richest individual N receive only, say, capital income. The rest of the population earns labor income only. Clearly, $C_i - G$ is positive for capital income suggesting—according to the above interpretation—that in the absence of capital income the Gini coefficient should be smaller. However, it can be shown that if the initial (capital) income of the richest individual satisfies

$$y_N < \frac{(\sum_{n=1}^{N-1} y_n)^2}{\sum_{n=1}^{N-1}(N-1-n)y_n}, \tag{2.4}$$

the absence of this income would lead to an increase in the Gini coefficient contradicting the above interpretation of equation (2.3).[10] The intuition is clear: eliminating an income source i which is disproportionately received by relatively rich individuals, i.e. where $C_i - G > 0$, leads to an increase in total inequality when the worsening in the relative position of these individuals outweighs the improvement in the relative position of the remaining population.

So far we have reminded the reader that an intuitive interpretation of the (proportional) contribution of an income source is not possible in the Gini decomposition

[10] Recalling the definition of the Gini coefficient

$$G = \frac{2\sum_n n\, y_n}{N \sum_n y_n} - \frac{N+1}{N},$$

we derive this result by solving the inequality

$$\frac{\sum_n^N n y_n}{\sum_n^N y_n} < \frac{\sum_n^{N-1}(n+1)y_n}{\sum_n^{N-1} y_n}$$

for y_N.

framework and showed that the qualitative approach of Podder (1993b) is no feasible alternative—a most unsatisfactory conjuncture.[11] Yet, another possibility to assess the importance of an income source for total income inequality is given by the elasticity of an inequality index with respect to the mean of an income source, also called marginal effects. Lerman and Yitzhaki (1985) were the first to derive this expression within the Gini decomposition framework considered here. They show that the Gini elasticity is given by $\eta_i = S_i(C_i - G)/G$, which is the percentage change in the Gini coefficient due to a marginal, percentage increase in the mean of income source i (for an extension to other inequality indices see Paul, 2004).[12] Given the non-interpretability of (proportional) contributions and given that the elasticities provide, by definition, a clear-cut assessment we are inclined to conclude that these elasticities are to be preferred when examining the role of income sources for total income inequality.[13]

Before proceeding with the next section, two last remarks regarding the decomposition approach taken by Podder (1993b) are in order. First, the mistake of Podder (1993b) and Podder and Chatterjee (2002) is to interpret—based on the sign of $C_i - G$— the importance of an income source i for total income inequality in absolute terms. The sign of $C_i - G$ remains informative about the (dis)equalizing character of an income source when considering marginal changes since $\text{sgn}(\eta_i) = \text{sgn}(C_i - G)$.[14] Second, observe that $\tilde{s}_i = \eta_i G$. Hence, Podder's (1993b) transformation (2.3) yields the term $\tilde{s}_i$ as the semi-elasticity of the Gini with respect to the mean of income source i. That is, $\tilde{s}_i$ is the absolute change in the Gini due to a marginal, percentage increase in the mean of income source i.

[11]Recent research circumvents the non-interpretability problem by deriving the *expected* contribution of an income source to total income inequality similar to the Shapley value known from cooperative game theory (see Chantreuil and Trannoy, 2011; Shorrocks, 2013).

[12]Note that the sign of η_i is determined by the sign of $C_i - G$. The Gini elasticity is thus consistent with the property of uniform additions.

[13]The importance of examining marginal effects has also been stressed by Paul (2004) and Kimhi (2011). Paul (2004) argues that policy makers can affect income sources only at the margin and that, therefore, it is more important to know how marginal changes in income sources affect total income inequality than to know the proportional contributions of income sources. Reviewing decompositions of different inequality indices by income sources, Kimhi (2011) argues that marginal effects are more robust across decompositions of different inequality indices than proportional contributions.

[14]In fact, reducing capital income in the above example only slightly would reduce total income inequality.

2.2.2. Explaining Income Inequality Trends in Terms of Income Sources

We now turn to the decomposition of inequality *trends*. That is, we want to attribute the *change* in the Gini coefficient over time to *changes* in income sources. We again restrict our attention to the framework proposed by Rao (1969).

Fei et al. (1978) are the first to study how the change in the Gini can be traced back to changes in the shares and concentration coefficients of income sources. They start out with two income sources, labor and capital income, and show that any increase in the concentration coefficients increases the Gini. Further, they show that an increase in the share of an income source has a negative effect on the Gini if the concentration coefficient is smaller than that of the other income source.

Hence, to determine the effect of a change in the share of an income source on total income inequality Fei et al. (1978) highlight the importance of comparing the relative inequality of the two sources. Clearly, such a comparison becomes less tractable when splitting income into more than two sources. In fact, with a third income source, agricultural income, they summarize wage and labor income to non-agricultural income so that the analysis of the change in the Gini can be carried out as before. Yet, changes in capital and labor income become convoluted in the change in non-agricultural income, making the analysis less and less instructive the more income sources are added.

A different approach is taken by Podder and Chatterjee (2002). They analyze changes in the Gini coefficient by differentiating equation (2.1) with respect to time t, yielding

$$\dot{G} = \sum_i C_i \dot{S}_i + \sum_i S_i \dot{C}_i, \tag{2.5}$$

with $\dot{x} := \partial x / \partial t$. According to Podder and Chatterjee (2002), the term $C_i \dot{S}_i + S_i \dot{C}_i$ describes the contribution of income source i to the change in the Gini coefficient of total income, i.e. the change in the Gini that is due to the changes in the share and the concentration coefficient of the ith income source.[15] Specifically, such an interpretation implies that any increase in the share of an income source raises total inequality whenever its concentration coefficient is positive. However, this understanding contradicts the Gini elasticity η_i: a marginal increase in the share of an income source that has an equalizing effect according to the sign of $C_i - G$ should lower total income inequality.

[15] See the remarks referring to equation (16), Table 5 and Table 9 in Podder and Chatterjee (2002).

Instead of using equation (2.1), we propose to base the decomposition of the change in the Gini coefficient on equation (2.3). This approach allows for an interpretation that is consistent with the Gini elasticity and is still instructive when more than two income sources are considered.

Differentiating equation (2.3) with respect to time and rearranging terms, we obtain[16]

$$\dot{G} = \sum_i (C_i - G)\dot{S}_i + \sum_i S_i \dot{C}_i, \tag{2.6}$$

which yields $(C_i - G)\dot{S}_i + S_i\dot{C}_i$ as the change in the Gini that is due to the change in the concentration coefficient and the income share of income source i. We see that an increase in the concentration coefficient of an income source always increases the Gini coefficient. More importantly, according to this decomposition a ceteris paribus increase in the share of an income source increases the Gini only if this income source has a disequalizing effect on total income inequality by the sign of $C_i - G$. Our approach is thus consistent with the Gini elasticity.[17]

2.3. Gini Decomposition by Population Subgroups

2.3.1. Explaining Income Inequality in Terms of Population Subgroups

Gini decompositions by population subgroups aim at explaining income inequality in terms of the income of different population subgroups. In this section, we draw the attention to the decomposition proposed by Podder (1993a), recently reasserted by Chatterjee and Podder (2007). Building on Rao (1969), the method is in a similar spirit as the decomposition by income sources presented in the previous section. Its focus lies on the assessment of whether the presence of income of a particular subgroup increases or decreases total income inequality. We will briefly introduce the proposed method before showing that such an assessment cannot be drawn from the decomposition.

Imagine an economy of N individuals (or households). We can collect their income in ascending order in a vector y, such that $y_1 \leq y_2 \leq \cdots \leq y_N$. Imagine further

[16] Note that $\dot{C}_i = \dot{R}_i G_i + R_i \dot{G}_i$ if C_i would have been decomposed into the "Gini correlation", R_i, and the Gini coefficient, G_i, of income source i, where $C_i = R_i G_i$.

[17] A discrete time formulation of equation (2.6) would be used for an empirical application.

that each individual can be assigned to one and only one of $\mathcal{G} \in \mathbb{N}$ groups. We can then construct $\mathcal{G}$ vectors x_g, $g = 1, \ldots, \mathcal{G}$, with elements

$$x_{gn} = \begin{cases} y_n & \text{if and only if individual } n \text{ is a member of group } g, \\ 0 & \text{otherwise,} \end{cases} \tag{2.7}$$

such that $y = \sum_g x_g$. Let us denote Y as the total income of the population and X_g as the total income of group g. Equivalent to equation (2.1) we can write the Gini coefficient of total income as

$$G = \sum_{g}^{\mathcal{G}} \frac{X_g}{Y}\, C_g, \tag{2.8}$$

where C_g is again the concentration coefficient, but here of the gth population subgroup vector x_g.[18] That is, here the concentration curve plots the cumulative proportions of vector x_g against the cumulative proportions of the total population ordered ascendingly according to their income. Again, it should be clear that $C_g \in [-1, 1]$, as the concentration curve may very well lie above the diagonal of the unit-square.

Equivalent to the decomposition by income sources, Podder (1993a) and Chatterjee and Podder (2007) infer from the sign of $C_g - G$ whether the presence of the income of group g increases or decreases total inequality: $C_g - G > 0$ (< 0) would imply that the presence of the income of group g increases (decreases) total income inequality. For the same argument as above, however, such a conclusion cannot be deduced from the sign of $C_g - G$. For example, eliminating the income of the richest group, for which $C_g - G > 0$, may very well increase the Gini by the shift of the subgroup to the bottom of the income distribution.

Again, we want to stress that, analogously to the decomposition by income sources, a straightforward assessment of the (dis)equalizing effect of the income of a specific subgroup on total income inequality is given by the Gini elasticity with respect to the mean of the population subgroup income vector.[19] Here, the elastic-

[18] Note that a further decomposition of the concentration coefficient into a "Gini correlation" and a Gini of subgroup income vector x_g—as is often done in the case of a decomposition by income sources (see e.g. Lerman and Yitzhaki, 1985)—is not meaningful here. The Gini of a subgroup income vector should not be misinterpreted as the *within* Gini, i.e. the Gini of a subgroup. Recall that $x_{gm} = 0$ if $m \notin G$, where G is the set of individuals belonging to subgroup g. Therefore, the Gini of income vector x_g, $G(x_g)$, will be different from zero if $\exists n \in G : x_{gn} > 0$ and $\exists m \notin G$. Consequently, even when income within subgroup g is equally distributed, $G(x_g)$ can be different from 0. Put differently, the Gini of the subgroup income vector x_g depends not only on the distribution of the income of subgroup g, but also on the population share of that subgroup and is thus difficult to interpret.

[19] Note that the decomposition in (2.8) can be viewed as a relabeling of the decomposition in

ity is defined as the percentage change in the Gini due to a marginal, percentage increase in the mean of income vector x_g. For the decomposition of Podder (1993a) this elasticity can be derived equivalently to the Gini elasticity with respect to the mean of an income source and is given by $\eta_g = X_g(C_g - G)/YG$ (see Podder, 1993a; Chatterjee and Podder, 2007).[20]

We would also like to stress that—in this respect—the approach of Podder (1993a) may provide a particular advantage over decompositions of alternative inequality indices. For the decomposition offered by Podder (1993a) the elasticity is readily computed and does not depend on derivatives of, e.g., "between-group" terms or "transvariation" terms, as they would arise if one would want to derive the elasticity for indices belonging to the Generalized Entropy family[21] or for Dagum's (1997) Gini decomposition.[22]

2.3.2. Explaining Income Inequality Trends in Terms of Population Subgroups

Next, we want to turn to the decomposition of inequality *trends* in the context of the Gini decomposition by population subgroups of Podder (1993a). The trend decomposition attributes *changes* in the Gini coefficient to *changes* in the population subgroups.

More precisely, using equation (2.8), Chatterjee and Podder (2007) decompose the change in the Gini into changes in the concentration coefficients, as well as changes in population and income shares of the different subgroups. In what follows, we show that this trend decomposition by population subgroups, contrary to its counterpart decomposition by income sources from section 2.2.2, however, is limited in its ability to provide insightful results. In particular, we argue that this limitation

(2.1). It follows that by rephrasing the interpretations of a contribution offered in (a)-(d) in terms of the income of a subgroup, the contributions derived from the decomposition in (2.8) lack the same interpretive content as their counterpart contributions from the income source decomposition.

[20]Note that by transforming equation (2.8), analogously to the transformation in the case of the decomposition by income sources, into

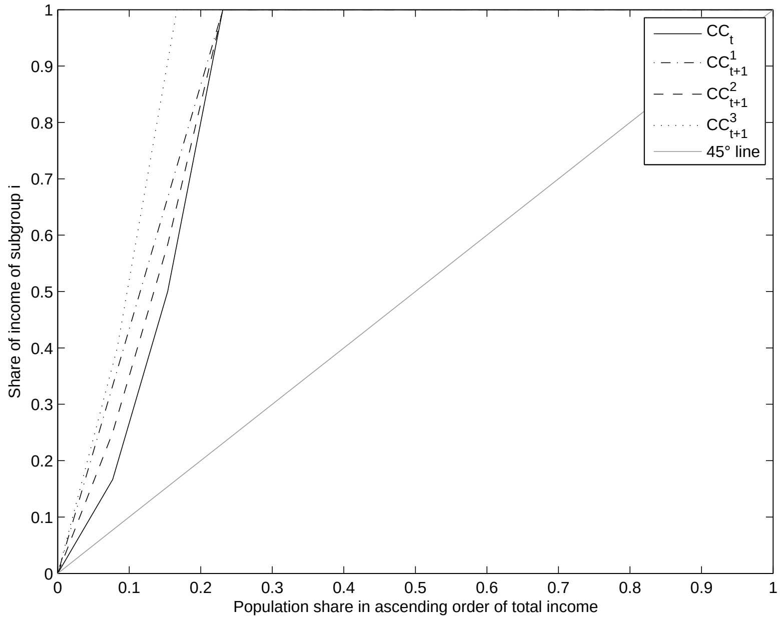
$$0 = \sum_g \frac{X_g}{Y} (C_g - G) = \sum_g \hat{s}_g \tag{2.9}$$

one obtains $\hat{s}_g$ as the semi-elasticity of the Gini coefficient with respect to the mean of the income of subgroup g.

[21]For a decomposition of these indices by population subgroups see Shorrocks (1984).

[22]Of course, these derivatives do not pose a disadvantage if an analysis of the interplay between different subgroups following a marginal change in the income of a particular subgroup is of interest. Yet, we are not aware of a subgroup income elasticity derived for inequality indices other than the Gini coefficient.

Figure 2.1.: Changes in the Concentration Curve



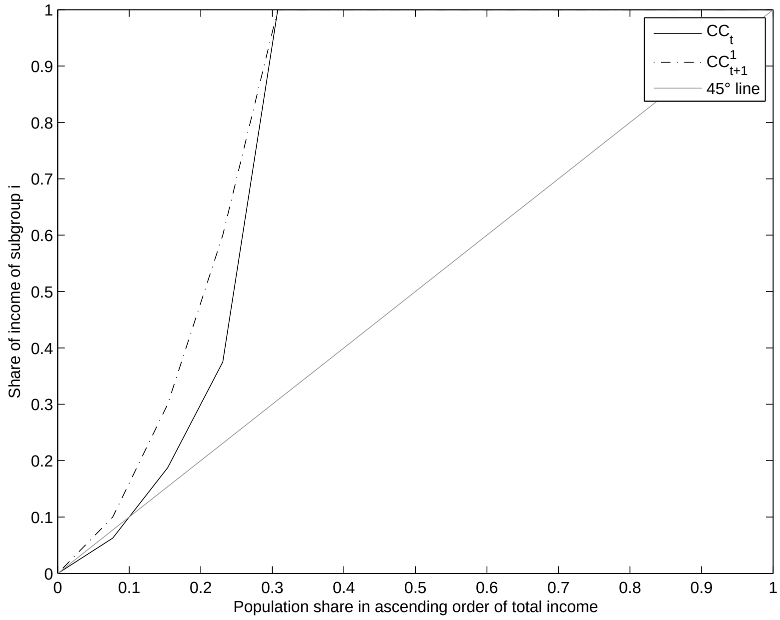
Notes: This figure depicts Examples 1 to 3. In period t the economy's income vector is $y = (1\ 2\ 3\ 10\ \cdots\ 10)'$ with number of individuals without loss of generality set equal to $\dim(y) = 13$. The poorest three individuals belong to subgroup g, the remaining 10 individuals belong to another subgroup. CC_t plots the concentration curve of subgroup income vector x_g in period t. CC^1_{t+1} plots the concentration curve in period $t+1$ as described in Example 1, CC^2_{t+1} as described in Example 2, and CC^3_{t+1} as described in Example 3. The shift of the concentration curve to the left indicates a fall in the concentration coefficient.

is due to the inability to derive precise conclusions from changes in the concentration coefficients of the population subgroups. We will show this by means of three illustrative examples.

In the following analysis, let us focus on a negative concentration coefficient of an arbitrary subgroup g, which decreases from one period to the next, i.e. $C_{g,t+1} - C_{gt} < 0$ where t is a time index. At first sight it might be appealing to follow Chatterjee and Podder (2007), who interpret such a change as "indicating that the within-group distribution shifted towards the lower-income population" (p. 282), suggesting "that the incomes of more [of group g] ... were concentrated in the lower half of the income distribution for the sample as a whole" (p. 282), or simply that "the distribution worsened" (p. 282) for subgroup g. Yet, the examples show that these interpretations of a negative change in the concentration coefficient may be misguided.

Consider an economy where the poorest three individuals belong to subgroup g receiving income of 1, 2 and 3 units, respectively. The rest of the population belongs to a different subgroup $j \neq g$ and receives income of, say, 10 units each. Clearly, $C_g < 0$.

Figure 2.2.: Change in the Concentration Curve due to a Fall in Income



Notes: In period t the economy's income vector is $y = (1\ 2\ 3\ 10\ \cdots\ 10)'$ with number of individuals without loss of generality set equal to $\dim(y) = 13$. The poorest four individuals belong to subgroup g, the remaining 9 individuals belong to another subgroup. CC_t plots the concentration curve of subgroup income vector x_g in period t. CC_{t+1} plots the concentration curve in period $t+1$ where the income of the 4th individual falls from 10 to 4 units. The shift of the concentration curve to the left indicates a fall in the concentration coefficient.

Example 1. Imagine that from period t to $t+1$ income within subgroup g is redistributed such that each of the three individuals now receives income of 2 units. It is apparent from Figure 2.1 that such a redistribution induces a fall in C_g. However, one can hardly interpret such a redistribution as a worsening in the distribution of the income of subgroup g.

Example 2. Now imagine instead that each of the individuals of subgroup g receives 2 additional units of income. Figure 2.1 illustrates that such a change leads to a decrease in the concentration coefficient. Yet again, this decrease in the concentration coefficient does not admit any of the interpretations offered by Chatterjee and Podder (2007).

Example 3. Imagine that the poorest individual dies between t and $t+1$. Subgroup g, thus, reduces in size to two individuals. Figure 2.1 shows that such a change in demography again leads to a decrease in the concentration coefficient of subgroup g. However, it would be mistaken to state that the incomes of more of subgroup g were concentrated in the lower half of the income distribution.

It is, of course, correct that a change that leads to more individuals of a subgroup being concentrated in the lower half of the income distribution, as described by

Chatterjee and Podder (2007), implies a decrease in the concentration coefficient. To see this, consider again the economy described above, but imagine that a fourth individual receiving an income of 10 units belongs to subgroup g. Since the rest of the population is larger than subgroup g and since each of the individuals not belonging to group g receives an income of 10 units, the median income is 10. Figure 2.2 shows that reducing the income of the fourth member of group g from 10 to 4 units—which implies that more of the individuals in group g receive an income left of the median—reduces the concentration coefficient.

However, our illustrative examples made it abundantly clear that there are several other possible changes within the subgroup that can account for the same effect, which, however, are incompatible with the interpretation of Chatterjee and Podder (2007). It is easy to think of many other, more complex, changes within a subgroup g, and even of changes in other subgroups $j \neq g$, that can account for the same change in the concentration coefficient C_g. It is thus difficult to relate changes in the Gini coefficient to underlying changes in the population subgroups and, therefore, to derive policy relevant conclusions from the Gini *trend* decomposition of Chatterjee and Podder (2007). We want to stress, however, that the usefulness of the Gini elasticity referred to above is not affected by this result as it is obtained by increasing the income of the respective population subgroup proportionally such that the concentration coefficients do not change.

2.4. Multi-Dimensional Gini Elasticity

Recent contributions in the inequality literature focus on a combination of decompositions by income sources and population subgroups, called multi-decomposition (Mussard, 2004; Mussard and Richard, 2012; Mussard and Savard, 2012; Mussini, 2013). By merging a decomposition by population subgroups with a decomposition by income sources, however, any such approach is inevitably subject to Shorrocks' (1988) non-interpretability critique.[23]

Considering the clear interpretation of the Gini elasticity with respect to income sources or population subgroups presented in the previous sections, the purpose of this section is to extend the single-dimension Gini elasticities to the framework of multi-decompositions. Such an extension provides a tool for assessing the effect of a marginal, proportional change in an income source of a specific population subgroup on the Gini coefficient, e.g., for analyzing the distributional effect of a tax reform in

[23]For example, Mussini (2013) merges Dagum's (1997) Gini decomposition by population subgroups with Rao's (1969) decomposition by income sources.

different regions of a country.

We start from Rao's (1969) decomposition by population subgroups which we restate here,[24]

$$G = \sum_{g}^{\mathcal{G}} \frac{X_g}{Y} \, C_g.$$

The same way total income can be expressed as a sum of income sources, each subgroup income vector x_g can be rewritten as $x_g = \sum_i x_g^{(i)}$, where $x_g^{(i)}$ denotes subgroup g's income vector of income source i. Using the covariance definition of the concentration coefficient, we can rewrite equation (2.8) as

$$G = \sum_{g}^{\mathcal{G}} \frac{X_g}{Y} \, \frac{2\,\mathrm{cov}(\sum_i^I x_g^{(i)}, F(y))}{X_g/N}, \tag{2.10}$$

where $F(\cdot)$ denotes the cumulative density function over total income y. Rearranging terms, we obtain

$$G = \sum_{g,i} \frac{N_g}{N} \, \frac{\mu_g^{(i)}}{\mu} \, C_g^{(i)}, \tag{2.11}$$

where $\sum_{g,i}$ denotes summation over all ordered pairs $\langle g, i\rangle \in \{1, \ldots, \mathcal{G}\} \times \{1, \ldots, I\}$, N_g denotes the number units (e.g. households) belonging to subgroup g, $\mu_g^{(i)}$ denotes the mean of income source i in subgroup g, and $C_g^{(i)}$ denotes the concentration coefficient of income source i in subgroup g.[25]

From the multi-dimensional decomposition in (2.11) we can easily derive the Gini elasticity with respect to the mean of income source i in subgroup g defined as

$$\eta_g^{(i)} := \frac{\partial G}{\partial \mu_g^{(i)}} \frac{\mu_g^{(i)}}{G}, \tag{2.12}$$

which gives the percentage change in the Gini due to a marginal, percentage increase in $\mu_g^{(i)}$.

We first derive the partial derivative of G with respect to $\mu_g^{(i)}$. It is important to note that the change in $\mu_g^{(i)}$ is a proportional change in the income vector $x_g^{(i)}$ such that the concentration coefficient $C_g^{(i)}$ is unaltered $\forall\, g$. The derivative is then given

[24] All variables follow their definitions from the previous sections.

[25] Note that for (2.11) to be defined we require that $\forall\, g, i \;\; \exists\, n : x_{gn}^{(i)} > 0$.

by

$$\frac{\partial G}{\partial \mu_g^{(i)}} = -\sum_{-g,-i} \frac{N_g}{N} \frac{\mu_{-g}^{(-i)}}{\mu^2} \frac{\partial \mu}{\partial \mu_g^{(i)}} C_{-g}^{(-i)} + \frac{N_g}{N} \frac{\mu - \frac{\partial \mu}{\partial \mu_g^{(i)}} \mu_g^{(i)}}{\mu^2} C_g^{(i)}, \tag{2.13}$$

where $\sum_{-g,-i}$ denotes summation over all pairs in $(\{1,\ldots,\mathcal{G}\} \times \{1,\ldots,I\}) \setminus \{\langle g,i \rangle\}$. Rewriting μ as $\mu = \sum_{g,i} N_g \mu_g^{(i)}/N$, the derivative $\partial\mu/\partial\mu_g^{(i)}$ is given by

$$\frac{\partial \mu}{\partial \mu_g^{(i)}} = \frac{N_g}{N}. \tag{2.14}$$

Inserting (2.14) into (2.13) and rearranging terms, we get

$$\frac{\partial G}{\partial \mu_g^{(i)}} = \frac{N_g}{N} \frac{1}{\mu} (C_g^{(i)} - G). \tag{2.15}$$

Multiplying this expression by $\mu_g^{(i)}/G$, yields the Gini elasticity (2.12)

$$\eta_g^{(i)} = \frac{N_g}{N} \frac{\mu_g^{(i)}}{\mu} \frac{(C_g^{(i)} - G)}{G}. \tag{2.16}$$

We see that combining Rao's (1969) Gini decomposition by income sources and population subgroups provides a straightforward approach to analyze the effect of a marginal, percentage change in the income of a particular source in a specific subgroup on total income inequality.[26] Similar to the single-dimensional elasticities, a marginal increase in the mean of income source i in subgroup g decreases the Gini if this income source is more favorably distributed for that subgroup than total income.

[26]Integrating the multi-elasticity over either subgroups or income sources will bring us back to the single dimension Gini elasticities from the previous sections,

$$\sum_g \eta_g^{(i)} = \eta_i$$
$$\sum_i \eta_g^{(i)} = \eta_g.$$

Equivalent to the single-dimension Gini decompositions, manipulating the multi-decomposition in equation (2.11) in the same manner as equation (2.3) yields a summation over $\eta_g^{(i)} G$, i.e. over multi-dimensional semi-elasticities.

2.5. Conclusion

This paper closely examined Gini decompositions by income sources and population subgroups within the well-known framework of Rao (1969). We showed that the methods put forth by Podder (1993b) and Podder (1993a) to analyze the role of income sources and (the income of) population subgroups, respectively, for total income inequality do not admit the interpretation intended by the authors. Furthermore, we showed that the method of Podder and Chatterjee (2002) to decompose the change in the Gini by income sources is at odds with the Gini elasticity, thus leading to erroneous conclusions. We were able to provide a trend decomposition consistent with the Gini elasticity. With respect to the contribution by Chatterjee and Podder (2007), we showed that the ambiguous interpretation of changes in the concentration coefficients does not allow for an insightful Gini trend decomposition by population subgroups within the framework of Rao (1969).

Throughout the paper, we highlighted the importance of Gini elasticities as a valuable tool for analyzing the (dis)equalizing character of income sources or (the income of) population subgroups, and in particular for evaluating the effectiveness of different tax and transfer policies to affect overall income inequality. We contributed to the recent trend of multi-decompositions by deriving the Gini elasticity with respect to an income source of a population subgroup from a simultaneous decomposition of the Gini coefficient by income sources and population subgroups. This facilitates the analysis of the distributional effect of changes in income sources in different population subgroups induced by, e.g., tax reforms aimed at different regions of a country.

3. The Macroeconomic Effects of Progressive Taxes and Welfare*

3.1. Introduction

Progressive taxes are one of the instruments by which fiscal policies aim at automatically stabilizing the business cycle (Auerbach and Feenberg, 2000). The traditional, demand-side argument for them rests upon their effect on disposable income (Brown, 1955): They reduce the volatility of the latter compared to the volatility of the market income and thereby stabilize aggregate demand and output. In modern DSGE models, in contrast, where households' intertemporal optimization renders disposable income irrelevant for aggregate demand, progressive taxes stabilize the economy through the supply-side (Mattesini and Rossi, 2012).

In this paper, we add to the debate on the macroeconomic properties of the progressive tax system by jointly analyzing its demand-side and supply-side business cycle effects, as well as the resulting welfare implications, using a non-linear DSGE model calibrated to the euro area.[1] We do so by introducing a fraction of so-called "rule-of-thumb" households and a progressive tax on wage income into an otherwise standard New Keynesian sticky-price model. By assumption, rule-of-thumb households consume their entire disposable income in each period. The progressive tax thus reduces their consumption volatility, in line with the traditional demand-side view (Brown, 1955). The remaining fraction of households are "Ricardian" in the sense that they seek to smooth their consumption intertemporally and are therefore immune to the disposable income channel. Their labor supply decision (as well as that of rule-of-thumb households), however, is affected by the design of the tax system. Progressive taxes reduce the elasticity of household labor supply, making firms' marginal cost curves become steeper and thereby resulting in a different price setting behavior by firms (Mattesini and Rossi, 2012).

*This paper was written in collaboration with Philipp Engler.

[1] We focus on the euro area because tax progression is more pronounced there than e.g. in the United States. See Mattesini and Rossi (2012) for a comparison of the degree of tax progression across countries.

Our first main finding is that in a baseline scenario without rule-of-thumb households, progressive taxes are desirable from a welfare perspective when only technology shocks drive the business cycle. Ricardian welfare rises when progressive taxes are introduced (instead of flat taxes) because the supply-side effects cause the volatility of inflation to fall. As the central bank follows a Taylor-type interest rate rule in our model, the volatility of the real rate also falls and with it the volatility of Ricardian households' consumption. This latter effect increases Ricardian welfare. The reduction in inflation volatility is caused by the steeper marginal cost curve which mitigates the price reaction of firms in the presence of technology shocks.

Once rule-of-thumb households are also considered, however, we observe that the interaction between the two household types crucially affects the welfare implications of the tax system. Rule-of-thumb households' welfare indeed rises when progressive taxes are introduced because their consumption volatility is significantly reduced. Ricardian households' welfare, in contrast, declines. The reason is that the decreased consumption volatility of rule-of-thumb households now increases the volatility of inflation in the presence of technology shocks. This, in turn, increases the volatility of the real rate, leading to more volatile Ricardian consumption. As aggregate welfare falls for our model calibration, our second main finding is that progressive taxes can no longer be justified on utilitarian grounds once both their supply-side and their demand-side effects are taken into account.

Our third main finding is that when only demand shocks drive the business cycle, economy-wide welfare falls after the introduction of progressive taxes. This holds for both the baseline model and the model with rule-of-thumb households. Specifically, Ricardian households are worse off in both scenarios because in the presence of demand shocks, a steeper marginal cost curve in fact increases the volatility of inflation, the latter destabilizing Ricardian consumption. In addition, and somewhat surprisingly, we find that the welfare of rule-of-thumb households declines as well. This is despite a reduced consumption volatility, which is also achieved in this setting. But another effect—related to the non-linearity of our model—dominates here: Progressive taxes not only increase the slope of the marginal cost curve; they also increase its convexity. With a convex marginal cost curve, firms' price increases tend to be larger than their price decreases, and, since this effect is more pronounced under progressive taxes, higher inflation rates, higher real interest rates, and lower Ricardian consumption demand are thus observed in this case. Average output is consequently smaller than under flat taxes, the latter also reducing rule-of-thumb households' consumption. This level effect holds for both technology and demand shocks and is, all other things equal, welfare-reducing. In the former case, however, the effect is dominated by a much lower consumption volatility for rule-of-thumb households whereas in the latter case, the level effect dominates. This last result shows, first, the importance of taking non-linearities into account, and second, the crucial role of the interaction between the two household types.

Beyond these core findings, we present three additional results. First, we compute the optimal degree of tax progression for the baseline economy without rule-of-thumb households. Second, since our model is calibrated to the euro area, we show that the above results also apply in a two-country model of a monetary union, the sole difference being that all effects are quantitatively smaller. Key for this quantitative difference is the link between tax progression and the volatility of the terms of trade. Third, we find that when only technology shocks drive the business cycle, the welfare gains from tax progression disappear in our baseline economy once monetary policy is conducted optimally. Overall, our findings suggest that it is difficult to make the case for progressive taxes based on their business cycle effects only, especially as demand shocks rather than technology shocks presumably are the driving force behind cyclical fluctuations.

There is a large and growing literature on automatic fiscal stabilizers.[2] However, to the best of our knowledge, there are only a few contributions that explicitly focus on the role of progressive taxes in a DSGE context. The paper closest to ours is Mattesini and Rossi (2012). The authors introduce a progressive tax on wages into an otherwise standard New Keynesian DSGE model and analyze, in a linear setting, how the tax affects both business cycle dynamics and the optimal conduct of monetary policy.[3] Our main contribution relative to their paper is threefold: First, we explicitly study the welfare effects of progressive taxes whereas Mattesini and Rossi (2012) only conduct a positive analysis. Second, we take the existence of rule-of-thumb households into account and thereby add the traditional Keynesian demand-side stabilization channel of progressive taxes to the analysis. Third, we employ a non-linear model, which allows us to also analyze how the progressive tax system affects the levels of the macroeconomic variables of interest (in addition to their volatilities).[4]

McKay and Reis (2016b) is another related contribution that needs to be men-

[2] Academic interest notably increased in the wake of the financial crisis of 2007-2008. See McKay and Reis (2016b) for a recent review of the literature.

[3] Collard and Dellas (2005) also analyze the consequences of progressive taxes for the conduct of monetary policy.

[4] Two other papers that use the same specification for the progressive tax as Mattesini and Rossi (2012) and this paper are Chen and Guo (2013, 2014). However, they employ an RBC model and solely focus on the theoretical relationship between tax progression and equilibrium (in)determinacy.

tioned. The authors combine a New Keynesian model in the spirit of Christiano et al. (2005) with a version of the standard incomplete markets model of Krusell and Smith (1998) and analyze the quantitative significance of automatic stabilizers in the U.S. business cycle. The progressive tax system is one of many automatic stabilizers they consider. Our paper differs from theirs in one crucial way: We employ a much simpler model and focus on only one automatic stabilizer, the progressive tax system. This simplification allows us to be more specific about the underlying economic mechanisms. In particular, we stress the important link between tax progression and inflation dynamics. Furthermore, we emphasize the role of the household type (and household interactions) in affecting key results. At last, we study the business cycle effects of progressive taxes for each shock type separately.[5]

Our paper is structured as follows. In Section 3.2, we introduce the model framework, followed by a description of the model calibration and the employed welfare measure in Section 3.3. In Section 3.4, we analyze how progressive taxes affect the model dynamics and economic welfare. We consider two model extensions in Section 3.5. Section 3.6 concludes.

3.2. The Model

Our baseline model is the one laid out in Mattesini and Rossi (2012): a standard New Keynesian model (see e.g. Galí, 2008), augmented by government expenditure and a progressive tax on wage income as in Guo and Lansing (1998). In an extension to this baseline model, we follow Galí et al. (2007) and allow for the presence of "rule-of-thumb" households.[6] In contrast to the conventional, intertemporally optimizing Ricardian households, rule-of-thumb households have no access to financial markets and thus base their consumption decision on current income only. Both household types supply (homogenous) labor elastically. The firm sector is monopolistically competitive, uses labor as the sole production input, and sets prices in a staggered manner as in Calvo (1983). Monetary policy follows a standard interest rate feedback rule (Taylor, 1993), government expenditure an exogenous process. In the following, letters without a time index t always denote the (non-stochastic) steady state value of the respective variable.

[5] McKay and Reis (2016a) is another recent paper. They study the optimal degree of automatic stabilization, amongst others tax progression, in a model framework similar to McKay and Reis (2016b).

[6] In contrast to Galí et al. (2007), we do not consider capital accumulation, however. See e.g. Bilbiie (2008) for a New Keynesian model including rule-of-thumb households but also abstracting from capital accumulation.

3.2.1. The Household Sector

The economy is populated by a continuum of households. A fraction of households λ consists of rule-of-thumb households while the rest $(1-\lambda)$ consists of Ricardian households. In what follows, variables related to Ricardian households are denoted with a superscript A (asset-holders), those related to rule-of-thumb households with a superscript N (non-asset holders).

Ricardian Households

The representative Ricardian household seeks to maximize lifetime utility given by

$$E_t \sum_{k=0}^{\infty} \beta^k \left\{ \frac{(C_{t+k}^A)^{1-\sigma}}{1-\sigma} - \frac{(N_{t+k}^A)^{1+\varphi}}{1+\varphi} \right\} \tag{3.1}$$

subject to a sequence of flow budget constraints

$$P_t C_t^A + B_t = R_{t-1} B_{t-1} + (1-\tau_t^A) W_t N_t^A + (1-\lambda)^{-1}(\Pi_t - \Pi) - T_t \tag{3.2}$$

where E_t is the rational expectation operator, $C_t^A \equiv \left(\int_0^1 C_t(i)^{1-\frac{1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}}$ the Dixit-Stiglitz consumption index (with $C_t(i)$ denoting consumption of differentiated good i sold by firm i (see below) and ϵ the elasticity of substitution between goods), and $P_t \equiv \left(\int_0^1 P_t(i)^{1-\epsilon} \, di \right)^{\frac{1}{1-\epsilon}}$ the corresponding price index (with $P_t(i)$ denoting the price of good i). N_t^A represents hours worked, W_t is the economy-wide (nominal) wage rate. Prices and wages are taken as given by the household. B_t is the amount of a bond purchased at the beginning of period t, R_t the corresponding (gross nominal) interest rate. Π_t are profits or dividends stemming from firm ownership.[7] The coefficients σ and φ determine the household's degree of relative risk aversion and labor disutility, respectively, β is the subjective discount factor. Finally, the household faces the tax rate τ_t^A on wage income as well as lump-sum taxes T_t (which are zero on average).

Following Guo and Lansing (1998), and, more recently, Mattesini and Rossi (2012), we assume that the wage tax schedule τ_t^A is given by

$$\tau_t^A = 1 - \eta \left(\frac{Y_n}{Y_{n,t}^A} \right)^{\phi_n} \tag{3.3}$$

[7] To simplify the analysis, we follow Galí et al. (2007) and use a technical device to equalize the steady state (income and) consumption levels of Ricardian and rule-of-thumb households. Galí et al. (2007) utilize lump-sum taxes and transfers, however, whereas we tax away the steady state value of firm profits Π (accruing to Ricardian households).

where $Y_{n,t}^A = \frac{W_t N_t^A}{P_t}$ is the Ricardian household's (current period) real wage income, and where $Y_n = \frac{WN}{P}$ is the respective steady state value (also serving as the reference value for taxation).[8] The coefficient $\eta \in (0, 1]$ determines the level of the tax schedule, the coefficient $\phi_n \in [0, 1)$ determines its slope. It is easy to show (see Mattesini and Rossi, 2012) that the following relationship between the marginal tax rate $\tau_t^{A,m} = \frac{\partial(\tau_t^A Y_{n,t}^A)}{\partial Y_{n,t}^A}$ and the average tax rate τ_t^A holds:

$$\tau_t^{A,m} = \tau_t^A + \eta\phi_n \left(\frac{Y_n}{Y_{n,t}^A}\right)^{\phi_n}. \tag{3.4}$$

Accordingly, the marginal tax rate is higher than the average tax rate whenever $\phi_n > 0$. In this case the tax schedule will be referred to as "progressive" since the average tax rate increases in income. When $\phi_n = 0$, instead, the marginal tax rate coincides with the average tax rate and the tax schedule will be referred to as "flat".

Against this background, the Ricardian household's first-order conditions are given by

$$(N_t^A)^{\varphi+\phi_n} = (C_t^A)^{-\sigma} \left(\frac{W_t}{P_t}\right)^{1-\phi_n} \eta(1-\phi_n) \left(\frac{WN}{P}\right)^{\phi_n} \tag{3.5}$$

$$1 = \beta E_t \left\{ \left(\frac{C_{t+1}^A}{C_t^A}\right)^{-\sigma} \frac{P_t}{P_{t+1}} R_t \right\} \tag{3.6}$$

where the first condition determines the household's labor supply and where the second condition is a standard Euler equation governing intertemporal consumption.[9] We can see from equation (3.5) that the progressive labor tax mitigates the response of hours worked to a change in the real wage (holding consumption constant). Put differently, the labor supply schedule becomes steeper as an increase in hours worked necessitates a stronger increase in the real wage because a growing fraction of the latter is taxed away. We will see below that through this mechanism, progressive taxes can potentially act as an automatic stabilizer on the supply-side of our model economy.[10]

Further notice that progressive taxation also affects the steady state labor supply

[8] Note that under our model calibration, steady state real wage income does not differ between Ricardian and rule-of-thumb households. Also note that we assume flexible wages. The Calvo device that is typically used to model wage stickiness (and that we use below to model price stickiness) would imply a continuum of wages and thus by equation (3.3) a continuum of household tax rates. This would complicate the analysis enormously.

[9] See Appendix A.1 for the derivation of the first-order conditions.

[10] This point has been first raised by Mattesini and Rossi (2012) in a New Keynesian context. In a non-DSGE context, the automatic stabilization properties of a steeper labor supply curve have been previously stressed by e.g. Auerbach and Feenberg (2000).

(and thus aggregate output) according to equation (3.5): A higher degree of progression ϕ_n implies a lower supply. Since in this paper, we seek to exclusively focus on the business cycle properties of the progressive tax system, we eliminate this steady state effect through the (implicit) use of an appropriately scaled employment subsidy (paid to firms).[11] This policy-invariant steady state considerably facilitates the analysis of our subsequent simulation results.

Rule-of-thumb Households

In an extension to the baseline model, we allow for a fraction of households who do not optimize their utility intertemporally. We refer to them as "rule-of-thumb" households, and they consume their entire (after-tax) income in each period. Different reasons for their consumption behavior have been proposed by the literature, one of them being lack of access to financial markets.[12] More importantly, we motivate the inclusion of this household type by the extensive empirical evidence, summarized in e.g. Galí et al. (2007), suggesting that a significant number of real-world households does not consume according to the permanent income hypothesis (in contrast to Ricardian households).

For convenience, we assume that rule-of-thumb households have the same period utility function as Ricardian households. The representative rule-of-thumb household's labor supply is thus governed by an equation equivalent to (3.5), while its consumption expenditures are, by definition, fully pinned down by current disposable income:[13]

$$P_t C_t^N = (1 - \tau_t^N) W_t N_t^N. \tag{3.7}$$

Apparently, through dampening disposable income fluctuations, the progressive tax τ_t^N has an immediate stabilizing effect on the rule-of-thumb household's consumption expenditures. All other things equal, due to the inclusion of rule-of-thumb households, the progressive tax system thus also acts as an automatic stabilizer on the demand-side of our model economy.[14]

[11]The subsidy (per unit of labor employed) would correspond to the value of the coefficient ϕ_n (and would have to be financed through lump-sum taxes). To see this, note that firm optimization (illustrated in Section 3.2.3) implies $\frac{W}{P} = \frac{MPL}{M_p}$ where MPL denotes the marginal product of labor and $M_p \equiv \frac{\epsilon}{\epsilon - 1}$ is the firm's price markup. With an employment subsidy τ^s, the optimality condition would read $\frac{W}{P}(1 - \tau^s) = \frac{MPL}{M_p}$ instead. Setting $\tau^s = \phi_n$, it follows that $\frac{W}{P} = \frac{MPL}{M_p}(1 - \phi_n)^{-1}$, implying, according to (3.5), that household labor supply is independent of the size of ϕ_n.

[12]Galí et al. (2007) also mention myopia, fear of saving, and ignorance of intertemporal trading opportunities.

[13]The functional form of the tax schedule is identical to that of Ricardian households.

[14]As already noted, Mattesini and Rossi (2012) do not capture this demand-side effect.

3.2.2. The Government

Fiscal Policy

The fiscal authority finances an exogenous stream of government consumption expenditure G_t by way of taxing household wage income, by taxing (away) the steady state profits of firms (accruing to Ricardian households), and by imposing a lump-sum tax on Ricardian households.[15] As in Mattesini and Rossi (2012), the lump-sum tax balances the budget in each period and is zero on average.[16] Accordingly, the period budget constraint of the government is given by

$$P_t G_t = (1-\lambda) W_t N_t^A \tau_t^A + \lambda W_t N_t^N \tau_t^N + (1-\lambda) T_t + \Pi. \tag{3.8}$$

Monetary Policy

We assume that the monetary authority follows a Taylor-type interest rate rule (Taylor, 1993). The rule targets price inflation only and is given by

$$R_t = \beta^{-1} \left(\frac{P_t}{P_{t-1}} \right)^{\phi_\pi} \tag{3.9}$$

where β^{-1} is the steady state interest rate and where $\phi_\pi > 1$.

In Section 3.5.2, we also consider Ramsey-optimal monetary policy as an alternative to this standard feedback rule.

3.2.3. The Firm Sector

Production

There is a continuum of monopolistically competitive firms, indexed by $i \in [0,1]$. Firm i produces the differentiated good i according to

$$Y_t(i) = A_t N_t(i) \tag{3.10}$$

where $Y_t(i)$ is the output of firm i, $N_t(i)$ the amount of labor employed by firm i, and A_t the (stochastic) level of technology common to all firms. The production

[15] G_t is defined analogously to the private consumption aggregate C_t. Further recall that the tax on steady state profits serves to equalize the steady state consumption levels of both household types.

[16] We could instead use government debt to balance the budget. However, this alternative modelling strategy would not affect our results because Ricardian equivalence holds in our setting (since, by assumption, only Ricardian households would be able to hold this government debt).

function implies that (real) marginal costs RMC_t are equalized across firms, i.e.

$$RMC_t(i) = RMC_t = \frac{W_t}{P_t} A_t^{-1}. \tag{3.11}$$

As already discussed above, progressive taxes imply a larger real wage increase for any given increase in employment (relative to flat taxes). This, in turn, raises marginal costs more. Hence, the marginal cost curve, just like the labor supply curve, becomes steeper when taxes are progressive. In addition, we will see below that the marginal cost curve also becomes more convex. Both of these effects crucially affect the price setting behavior of firms.

Price Setting

Firms set prices in a staggered fashion as in Calvo (1983), taking the household demand functions for their good (not shown for the sake of brevity) as given. Each period, a randomly drawn fraction of firms θ_p is not able to reset prices, while the remaining fraction $(1-\theta_p)$ is able to do so. The first-order condition for readjusting firms with respect to the newly set price P_t^o is standard and given by

$$\sum_{k=0}^{\infty} \theta_p^k E_t \left\{ Q_{t,t+k} \left(\frac{P_t^o}{P_{t+k}} \right)^{-\epsilon-1} Y_{t+k} \left[\frac{P_t^o}{P_{t+k}} - \frac{\epsilon}{\epsilon-1} RMC_{t+k} \right] \right\} = 0 \tag{3.12}$$

where $Q_{t,t+k} = \beta E_t \left\{ \left(\frac{C_{t+k}^A}{C_t^A} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \right\}$ is the (Ricardian) household's stochastic discount factor and $Y_t = \left[(Y_t(i))^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}}$ is aggregate output or real GDP.[17]

3.2.4. Equilibrium and Aggregation

The bond market is in equilibrium when $B_t = 0$ holds for all periods t.

Equilibrium in the labor market implies

$$N_t = \int_0^1 N_t(i)\, di \tag{3.13}$$

where $N_t = (1-\lambda)N_t^A + \lambda N_t^N$ is aggregate labor supply (the weighted average of Ricardian and rule-of-thumb labor supply) and where the right-hand side gives aggregate demand for labor.

The goods market is in equilibrium when supply equals demand for all goods

[17] Because firms are owned by Ricardian households they also use the same discount factor.

$i \in [0, 1]$, i.e.

$$Y_t(i) = C_t(i) + G_t(i). \tag{3.14}$$

Real GDP is obtained by adding private consumption demand and government consumption expenditure:

$$Y_t = C_t + G_t \tag{3.15}$$

where $C_t = (1 - \lambda)C_t^A + \lambda C_t^N$.

The aggregate production function is given by

$$Y_t = s_t^{-1} A_t N_t \tag{3.16}$$

where $s_t \geq 1$ is given by the difference equation

$$s_t = (1 - \theta_p)(\widetilde{p}_t)^{-\epsilon} + \theta_p(1 + \pi_t)^{\epsilon} s_{t-1} \tag{3.17}$$

with $\widetilde{p}_t \equiv \frac{P_t^o}{P_t}$ and where π_t denotes price inflation (see Schmitt-Grohé and Uribe, 2006). The variable s_t represents a real resource cost, induced by inefficient price dispersion across firms, if the value exceeds one.

Under the Calvo mechanism, the evolution of aggregate prices is lastly given by

$$1 = \theta_p(1 + \pi_t)^{-1+\epsilon} + (1 - \theta_p)\widetilde{p}_t^{\,1-\epsilon}. \tag{3.18}$$

Equation (3.18) could be combined with the price-setting first order condition (3.12) to obtain the economy's Phillips curve. As has been shown by Mattesini and Rossi (2012) in a linear world, progressive taxes, due to the steeper labor supply and thus marginal cost curve, give rise to a steeper Phillips curve.[18] That is, a given positive (negative) deviation of output from its flexible price equivalent leads to a larger inflationary (deflationary) response.

Finally, to further our understanding of aggregate price dynamics in a non-linear world, we combine real marginal cost function (3.11) with equations (3.5), (3.15), and (3.16) to obtain the following "equilibrium" real marginal cost function (for our

[18]As is common in the literature, Mattesini and Rossi (2012) thus linearize equations (3.18) and (3.12) to derive the Phillips curve. We do not illustrate their Phillips curve here since the subsequent analysis will be conducted in a non-linear setting (i.e. we employ a second-order approximation to all equilibrium conditions).

baseline model):

$$RMC_t = (s_t Y_t)^{\frac{\varphi+\phi_n}{1-\phi_n}} (Y_t - G_t)^{\frac{\sigma}{1-\phi_n}} A_t^{-\frac{1+\varphi}{1-\phi_n}} const. \tag{3.19}$$

Apparently, and as has already been suggested before, the progressive tax system increases the degree of convexity of the marginal cost function (in output and technology). This will turn out to have important implications for both the volatility and average level of prices in our economy (see Section 3.4).

3.3. Calibration, Simulation, and Welfare Measure

The model is solved using Dynare++ (Kameník, 2011). To capture the non-linearities of our model, we employ a second-order approximation of the equilibrium conditions.[19] The exogenous processes considered in our simulations are technology and government spending shocks. As a convenient welfare measure, we use a consumption loss equivalent à la Lucas (1987).

3.3.1. Calibration

Our model calibration is based on the assumption that the relevant time period is one quarter. The parametrization employed looks as follows: the household's subjective discount factor β is set to 0.99, consistent with a steady state value of the real interest rate of approximately 4 percent. The values $\sigma = 1$ (log utility of consumption) and $\varphi = 1$ (unitary Frisch elasticity of labor supply) for the household's utility function are standard. In our baseline model, we set $\lambda = 0$ (no rule-of-thumb households). When also considering rule-of-thumb households, we set their share in the population to 50 percent ($\lambda = 0.5$) as in Galí et al. (2007). This value is within the range of estimated values found in the literature (see e.g. Mankiw, 2000).[20] The elasticity of

[19] The model equations used for our simulations are shown in Appendix A.2. As briefly mentioned above, we also consider optimal monetary policy as an alternative to the conventional Taylor rule. The current version of Dynare (4.4.3) only allows a first order approximation of the equilibrium conditions when using the optimal policy command. We therefore use Dynare++ for all simulations. However, the impulse responses shown below for the specifications with Taylor rules were generated by Dynare 4.4.3. We checked and verified that this is inconsequential for our results.

[20] As is well-known in the literature, the existence of rule-of-thumb households shrinks the determinacy region of the model (see e.g. Galí et al., 2004). Mattesini and Rossi (2012) show that progressive taxes also have this property. For our baseline calibration, indeterminacy occurs under flat taxes when $\lambda > 0.61$ and under progressive taxes when $\lambda > 0.56$.

substitution between goods ϵ takes a value of 9, implying a steady state gross price markup of size 1.125. The degree of price rigidity is given by $\theta_p = 2/3$, i.e. the average duration of prices is assumed to be 3 quarters.

Turning to the fiscal and monetary policy parameters, we assume that $\eta = 0.84375$ which amounts to an average tax rate on wage income of roughly 16 percent. In our model economy, this value is consistent with a government spending share in GDP of 25 percent when steady state profit income is entirely taxed away by the government (and lump-sum taxes are zero on average). The tax progressivity parameter ϕ_n either takes the value 0 (flat tax) or 0.34 (the GDP-weighted average observed for the EA-12, based on the computations of Mattesini and Rossi, 2012). For the Taylor inflation coefficient, we choose the standard value $\phi_\pi = 1.5$.[21]

3.3.2. Exogenous Processes

The exogenous processes considered in the following are technology (supply) and government spending (demand) shocks. The shocks are specified as AR(1) processes, i.e. $a_t = \rho_a a_{t-1} + \epsilon_{a,t}$ where $a_t = ln(A_t)$ and $g_t = \rho_g g_{t-1} + \epsilon_{g,t}$ where $g_t = ln\left(\frac{G_t}{G}\right)$. The autocorrelation coefficient ρ_a takes the value 0.95, ρ_g takes the value 0.66. The standard deviations of the innovations ϵ are chosen so as to match the observed volatility of GDP and government purchases in the euro area. The values are 0.00365 for technology shocks and 0.0062 for government spending shocks. For each model specification, we ran 5 simulations with 200000 periods each.

3.3.3. Welfare Measure

Our welfare measure is expected household lifetime utility, which we convert into a convenient consumption loss equivalent in the spirit of Lucas (1987). More precisely, for each government policy regime, we solve for the variable ξ^{reg} of the following equation:

$$E_t \sum_{k=0}^{\infty} \beta^k U\left(C(1-\xi^{reg}), N\right) = E_t \sum_{k=0}^{\infty} \beta^k U\left(C_{t+k}, N_{t+k}\right). \tag{3.20}$$

$\xi^{reg} > 0$ represents the percentage reduction in average consumption in the (policy invariant) non-stochastic steady state that makes households indifferent between living in this deterministic state of the world (with reduced average consumption) and the stochastic state of the world under the policy regime in question.

[21]Estimating a reaction function for the ECB, Hayo and Hofmann (2006) find e.g. a Taylor inflation coefficient of roughly 1.5 for expected inflation.

For our model parametrization, this consumption equivalent is given by

$$\xi^{reg} = 100\left[1 - exp\left((W^{reg} - W)(1-\beta)\right)\right] \tag{3.21}$$

where W^{reg} is unconditional welfare in the stochastic environment (again under the policy regime in question) and W is welfare in the non-stochastic steady state.[22] When observing our household utility function, it should be obvious that the realization of ξ^{reg} depends on both the levels of consumption and employment as well as their volatilities.

3.4. Progressive Taxation and Welfare

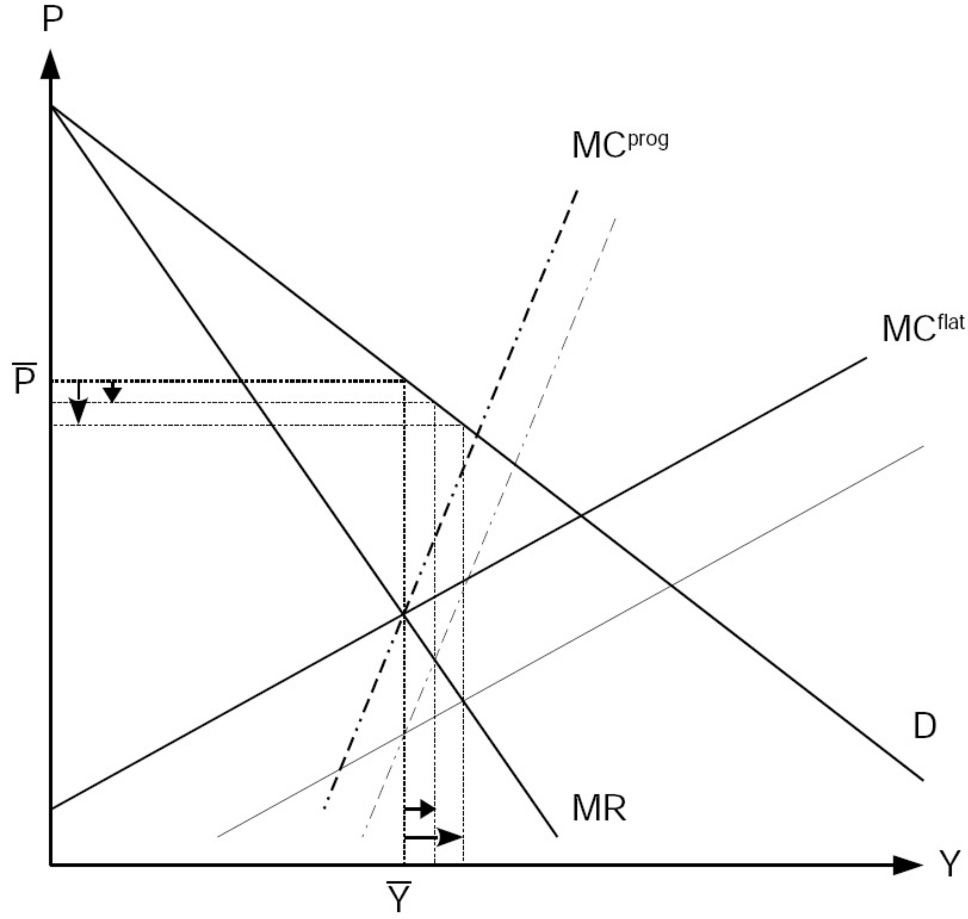
In this chapter, we analyze the business cycle and welfare effects of the progressive tax on labor income introduced in Section 3.2. To build intuition, we sketch the macroeconomic effects of the tax in a static setup first—taking the perspective of a representative monopolistic firm—before considering our fully-fledged dynamic model economy.

3.4.1. Intuition: Macroeconomic Effects of Progressive Taxation

How does the progressive tax system affect the cyclical behavior of the most closely observed macroeconomic variables inflation, real GDP, and employment? To answer this question, let us consider the pricing and production decision of an arbitrary, monopolistically competitive firm that has the possibility to adjust its price in the current period. Figure 3.1 sketches, in a static and linear setup, the (optimal) response of the firm to a technology shock and the resulting fluctuations of prices and real activity for a flat and a progressive tax system. Figure 3.2 repeats the exercise for a government spending shock. Two types of effects need to be differentiated: first, the effect of the progressive tax system on the volatility of the relevant variables (illustrated graphically in Figures 3.1 and 3.2), and, second, its effect on the price level (not illustrated for the sake of clarity).

[22] See also Benes and Kumhof (2011) for a recent application. When considering both household types, we compute the consumption loss equivalents $\xi^{A,reg} = 100\left[1 - exp\left((W^{A,reg} - W)(1-\beta)\right)\right]$, $\xi^{N,reg} = 100\left[1 - exp\left((W^{N,reg} - W)(1-\beta)\right)\right]$, and $\xi^{reg} = 100\left[1 - exp\left(((1-\lambda)W^{A,reg} + \lambda W^{N,reg}) - W)(1-\beta)\right)\right]$. Evidently, $\xi^{reg} \neq (1-\lambda)\xi^{A,reg} + \lambda\xi^{N,reg}$. In this case, ξ^{reg} is to be interpreted as the reduction in steady state consumption that makes a hypothetical household that does not have any prior knowledge of his type (A or N) indifferent between the stochastic and the non-stochastic world.

Figure 3.1.: Technology Shocks and Volatility of Output and Prices



As can be seen in Figure 3.1, and as already discussed above, progressive taxes imply, relative to flat taxes, a steeper marginal cost curve. Holding demand D constant[23], given fluctuations in technology therefore imply smaller movements of the (nominal) marginal cost schedule MC along the marginal revenue schedule MR (the bold MC schedules in the figure apply when technology is at its steady state value).[24] Correspondingly, the firm's output fluctuates less around the steady state output $\overline{Y}$ when the tax system is progressive, or, viewed differently, the firm's price fluctuates less around the steady state price $\overline{P}$. Aggregating over all firms, we can conclude that in the presence of technology shocks, progressive taxes dampen

[23]This assumption seems quite plausible when rule-of-thumb households are absent (and when we abstract from changes in the monetary policy stance). Note that in any given period, Ricardian households consume a fraction of their total expected lifetime resources. A temporary technology shock that changes their lifetime resources should thus only have a small effect on their current period consumption demand. In contrast, rule-of-thumb households base their consumption on current period resources. Technology shocks should therefore have a more pronounced effect on their consumption demand.

[24]To simplify matters, Figure 3.1 only shows the realization of a positive technology shock.

fluctuations of the overall price level (i.e. the volatility of inflation is reduced) and of real GDP. Yet, due to the stabilizing effect on output, progressive taxes increase the volatility of employment (not shown).[25]

At the same time, and not shown for ease of illustration in Figure 3.1, progressive taxes not only increase the slope of the marginal cost curve; they also increase its convexity. With a convex marginal cost curve, firms' price increases tend to be larger than their price decreases. When the level of technology fluctuates, for example, the price decreases in response to positive shocks are smaller than the increases in response to negative shocks. And since this effect is more pronounced under progressive taxes, we expect, relative to flat taxes, a higher price level (in the stochastic environment). This last point will be of importance in the dynamic setting discussed below where the interaction of inflation dynamics and monetary policy matters for equilibrium determination.

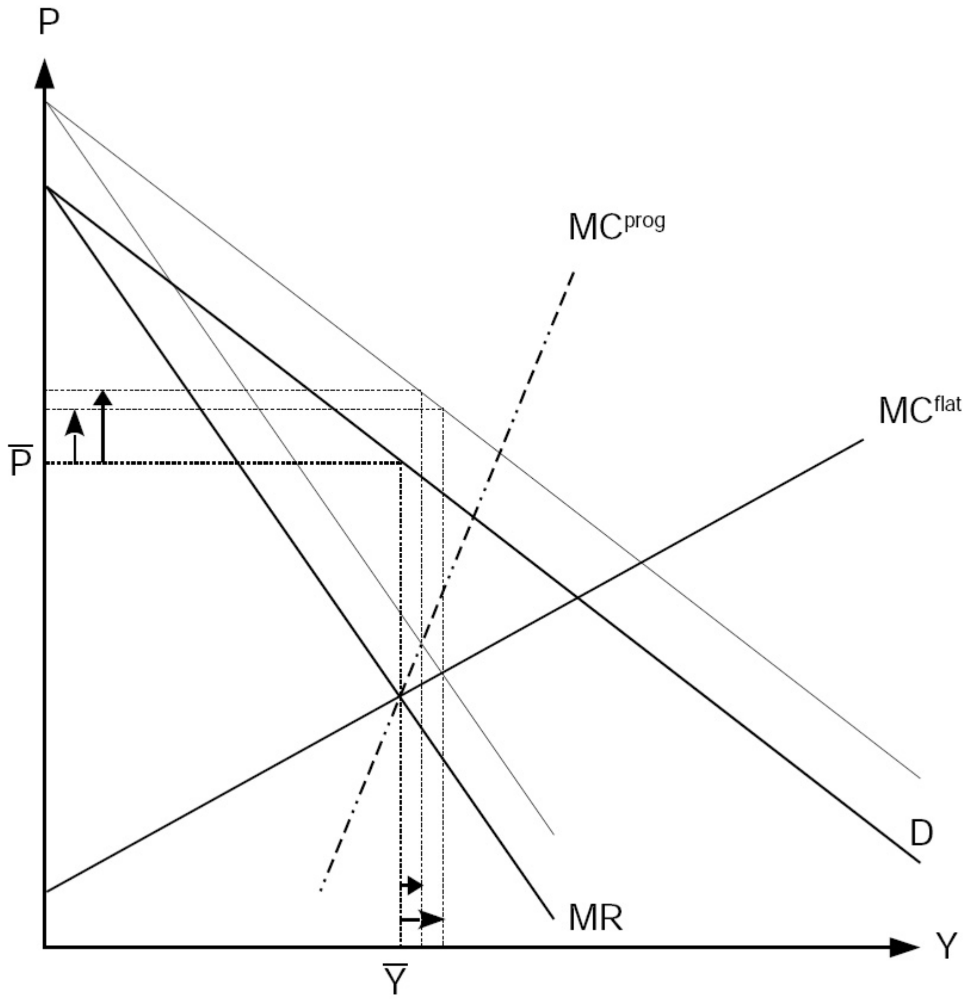
Figure 3.2, in comparison, illustrates the firm's (optimal) response to government spending shocks, or demand shocks more generally.[26] We see that for given marginal cost schedules, fluctuations in demand imply smaller deviations of the firm's output from its steady state value $\overline{Y}$ when the marginal cost curve is steeper, i.e. when taxes are progressive. The figure also shows, however, that the corresponding fluctuations of the firm's price are larger. Aggregating over all firms, we conclude that in the presence of demand shocks, progressive taxes reduce the volatility of real GDP while increasing the volatility of inflation (relative to flat taxes). Furthermore, because employment and output move in the same direction under demand shocks, progressive taxes reduce employment fluctuations (not shown).

In addition, we expect that progressive taxes also imply a higher price level in the presence of demand fluctuations. Due to the convexity of the marginal cost curve (again not illustrated for simplicity in Figure 3.2), shifts of the marginal revenue curve along the latter imply that the price increases in response to positive shocks are larger than the price decreases in response to negative shocks. Crucially, this level effect is again magnified with a more convex marginal cost curve (when taxes are progressive).

[25] This is due to the well-known fact that under technology shocks, output and employment move inversely when prices are sticky. See e.g. Galí (2008) for a textbook treatment or Galí and Rabanal (2004) for a review of the empirical literature. Progressive taxes imply a smaller increase (decrease) in output after a positive (negative) technology shock and thus a larger decline (increase) in employment.

[26] Again, for convenience, Figure 3.2 only shows the realization of a positive government spending shock.

Figure 3.2.: Spending Shocks and Volatility of Output and Prices



3.4.2. Progressive Taxation and Technology Shocks

Let us now turn to our fully-fledged dynamic model and analyze the general equilibrium effects of the progressive tax system. In what follows, we again study each shock type separately. The case of technological disturbances is considered first, and Table 3.1 below summarizes the respective model simulations. The first column shows results for the baseline model with only Ricardian households, the second results for the model extension with rule-of-thumb households. The table depicts the percentage change, when moving from a flat to a progressive tax system, of the consumption loss equivalent ξ, of the standard deviations $\sigma(\cdot)$ of inflation, real GDP, consumption, and employment, and of the average levels of consumption and employment, respectively.

Table 3.1.: Moments and Welfare Losses with Technology Shocks

	without RoT	**with RoT**
ξ	-14.3	$+15.7$
ξ^A		$+32.0$
ξ^N		-29.0
$\sigma(\pi)$	-12.1	$+4.4$
$\sigma(Y)$	-12.1	-12.1
$\sigma(C)$	-12.1	-12.1
$\sigma(N)$	$+64.0$	$+63.5$
$\sigma(C^A)$		$+4.3$
$\sigma(N^A)$		$+63.5$
$\sigma(C^N)$		-34.1
$\sigma(N^N)$		0
C	-0.0004	-0.001
N	$+0.0002$	$+0.001$
C^A		-0.00001
N^A		$+0.0021$
C^N		-0.0021
N^N		0

Notes: Results are changes compared to the flat-tax benchmark in percent.

Baseline Model

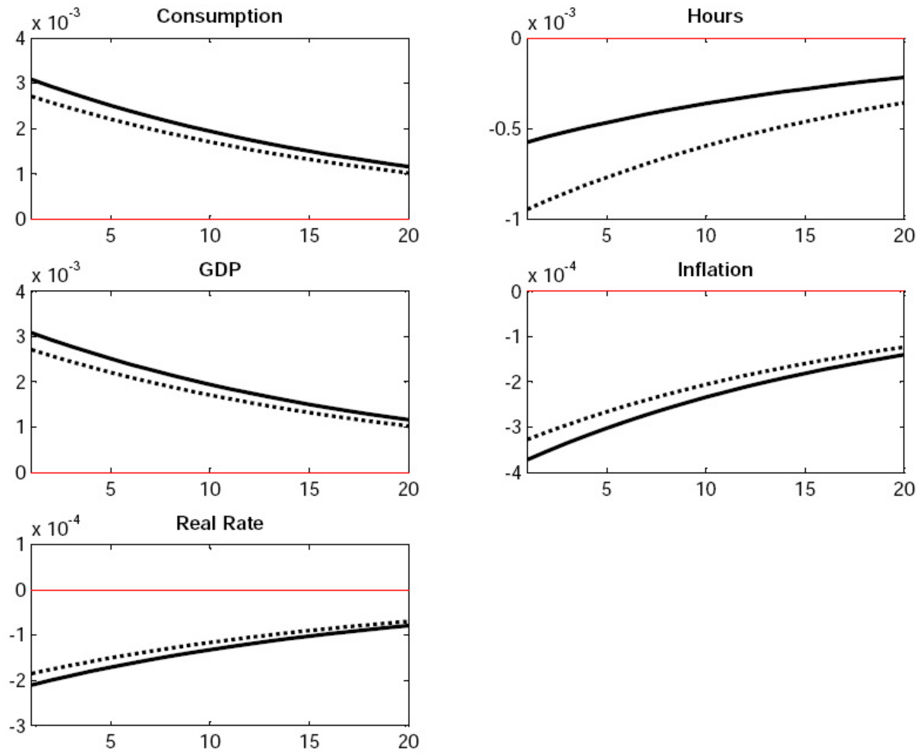
Table 3.1 shows that welfare rises when the progressive tax is introduced in the baseline model: The consumption loss equivalent falls by 14.3 percent. To understand this result, we first look at the impulse responses (to a positive technology shock) depicted in Figure 3.3.

Evidently, under both tax regimes, an improvement in technology reduces marginal costs and puts downward pressure on prices. This induces the central bank to boost aggregate demand by lowering the nominal interest rate (not shown, but see the Taylor rule (3.9)), and, at the same time, the real interest rate. But this response is, as a rule, not aggressive enough to raise Ricardian consumption demand and therefore output up to the point where marginal costs are perfectly stabilized. Hence, those firms that have the ability to adjust their prices will reduce them in general equilibrium.[27] Furthermore, since aggregate demand does not rise as fast as aggregate supply, employment falls, another typical feature of New Keynesian models.

When comparing the two tax systems in Figure 3.3, it becomes apparent that the results of the static and partial analysis conducted above carry over to the dynamic general equilibrium setting. As stressed previously, the representative firm's marginal cost curve becomes steeper when the tax system is progressive. A positive

[27] In our model, a rather high inflation coefficient $\phi_\pi = 5$ leads to an almost perfect stabilization of prices.

Figure 3.3.: Impulse Responses to a Positive Technology Shock



Notes: Solid (dotted) lines indicate flat (progressive) taxes. For each depicted model variable, the graph shows the absolute deviation from the steady state after a positive realization of ϵ_a of one standard deviation.

technology shock therefore leads to a smaller decrease in marginal costs and consequently to smaller price reductions by resetting firms (i.e. the supply response to the shock is feebler). The central bank's policy rate decline, and with it, the real rate decline, is thus weaker, attenuating the increase in consumption and output while leading to a more pronounced drop in hours worked. More generally, i.e. taking account of an entire history of positive and negative shocks to technology, we expect that the volatility of employment is higher whereas the volatilities of inflation, output, and consumption are lower when the tax system is progressive. This is confirmed in Table 3.1: The standard deviation of inflation, output, and consumption falls by about 12 percent each while the standard deviation of hours rises by 64 percent when moving from a flat to a progressive tax system.

Turning to the level effects at last, Table 3.1 shows that average consumption is slightly lower and average employment slightly higher when the tax system is progressive. As described in the previous section 3.4.1, the more convex marginal cost curve (3.19) implicates that prices will be set higher on average (relative to the flat tax system). The implied higher average inflation rate in turn results in a higher average real interest rate.[28] Consequently, when taxes are progressive, the average consumption level is lower.[29] The latter increases the incentive to supply labor and average hours are thus higher.

When evaluating the macroeconomic stabilization performance of the progressive tax system, it is useful to recall that the net welfare effect of any policy regime in our model is determined by its effect on the volatilities as well as the levels of consumption and employment. In our baseline economy, the two level effects and the increased volatility of employment reduce welfare (relative to the flat tax). These effects, however, are dominated by a reduced consumption volatility. The net effect is a 14.3 percent reduction of our consumption loss equivalent. In other words, the progressive tax system causes, relative to a flat tax, a roughly 14 percent decline in the welfare loss that is related to the stochastic environment.[30]

To put our results in perspective, note that the traditional Keynesian macroeconomic motivation for progressive taxes is that they stabilize aggregate demand through stabilizing disposable income (Brown, 1955). It is evident that macroeconomic stabilization is achieved differently in our baseline New Keynesian model economy. It is not the stabilization of disposable income that causes consumption and aggregate demand to be stabilized; rather, a supply-side effect is decisive: the changed slope of the marginal cost curve stabilizes inflation and thereby dampens real interest rate fluctuations, the latter having a smoothing effect on Ricardian household consumption demand.[31]

Model with Rule-of-Thumb Households

We next take the presence of rule-of-thumb households into account and thereby add the traditional Keynesian channel of disposable income stabilization to our analysis (Brown, 1955). As can be seen in Table 3.1, once rule-of-thumb households are also considered, the welfare gains from progressive taxation no longer exist at the aggregate level: The consumption loss equivalent ξ is 15.7 percent larger than under a flat tax, and a progressive tax therefore cannot be recommended from a strictly utilitarian point of view. In particular, notice that Ricardian households experi-

[28] This is the case because the nominal interest rate rises more than proportionally with the rate of price inflation when $\phi_\pi > 1$ holds.

[29] The level of consumption in any period of time can be computed by solving the consumption Euler equation (3.6) forward. This results in an equation that relates current consumption to the entire history of expected future real interest rates which, taken together, can be interpreted as a long-term real interest rate. When this long-term real interest rate rises, consumption falls.

[30] Recall that our baseline corresponds to the model of Mattesini and Rossi (2012). They, however, do not conduct a welfare analysis of the progressive tax system.

[31] Mattesini and Rossi (2012) do not discuss this interest rate effect and its implication for consumption demand.

ence a 32 percent increase in their consumption loss equivalent ξ^A when moving to this system. Rule-of-thumb households, however, benefit: their consumption loss equivalent ξ^N is reduced by 29 percent.[32]

To understand this second important (and at first sight somewhat counterintuitive) result, note that the deviation from the baseline model is driven by the influence of the progressive tax on the rule-of-thumb household's consumption demand and thereby aggregate demand:[33] The tax significantly reduces the volatility of disposable income and thus, by definition, consumption of this household type (see Table 3.1) and in this way dampens fluctuations in aggregate demand. More precisely, relative to the flat tax system, aggregate demand rises (falls) less in the face of a positive (negative) technology shock, the latter resulting in larger price reductions (increases) by firms.[34] Over the business cycle, the volatility of the inflation rate and hence the real rate of interest is thus larger, elevating, in turn, the volatility of Ricardian household consumption (see Table 3.1). Apparently, as measured by its effect on consumption demand, the traditional Keynesian disposable income stabilization mechanism of the progressive tax system turns out to be a stabilizing force for rule-of-thumb households but a destabilizing force for Ricardian households.

To complete the welfare discussion, we need to highlight three additional results. Firstly, irrespective of the tax system, employment is constant for rule-of-thumb households because income and substitution effects cancel each other out for the common case of log consumption utility ($\sigma = 1$). Secondly, and as in the baseline model, Ricardian households experience a higher volatility of employment when the tax system is progressive. The reason is once more found in the dampening effect of this system on aggregate output. Thirdly, and again equivalent to the baseline model, the "level effects" work (slightly) against the desirability of the progressive tax system (reduced consumption, increased hours). Taken together, these results allow us to conclude that when moving from the flat to the progressive tax system, the corresponding welfare improvement for rule-of-thumb households is due

[32]To not be confused by these numbers, note that aggregate welfare is given by $W = (1-\lambda)W^A + \lambda W^N$. As already suggested in Section 3.3.3, in terms of the corresponding consumption loss equivalent, we generally have $\xi \neq (1-\lambda)\xi^A + \lambda\xi^N$ instead. However, the conversion of W into ξ also does not affect our policy conclusions in the two-household case.

[33]Note that since we kept demand constant, this effect was not captured in the static analysis conducted above.

[34]In contrast to the baseline model, the reduced supply response to a technology shock is therefore overcompensated for by an even less pronounced demand response. The gap between supply and demand consequently increases and price movements are larger (relative to the flat tax). This overcompensation is not too surprising since the presence of rule-of-thumb households generally increases the significance of aggregate demand in determining the model's equilibrium.

Table 3.2.: Moments and Welfare Losses with Spending Shocks

	without RoT	**with RoT**
ξ	+20.2	+40.7
ξ^A		+53.0
ξ^N		+10.0
$\sigma(\pi)$	+35.3	+31.0
$\sigma(Y)$	−14.5	−17.3
$\sigma(C)$	+35.3	+239.3
$\sigma(N)$	−14.5	−17.3
$\sigma(C^A)$		+31.0
$\sigma(N^A)$		−17.3
$\sigma(C^N)$		−13.5
$\sigma(N^N)$		0
C	−0.00026	−0.001
N	+0.00004	+0.001
C^A		−0.003
N^A		+0.001
C^N		−0.0003
N^N		0

Notes: Results are changes compared to the flat-tax benchmark in percent.

to the reduced volatility of their consumption demand. Furthermore, the deterioration of Ricardian households' welfare can be attributed, at least in comparison to the baseline model, to the increasing volatility of their consumption. The traditional Keynesian demand stabilization channel thus has vastly different welfare implications for our two household types.[35]

3.4.3. Progressive Taxation and Government Spending Shocks

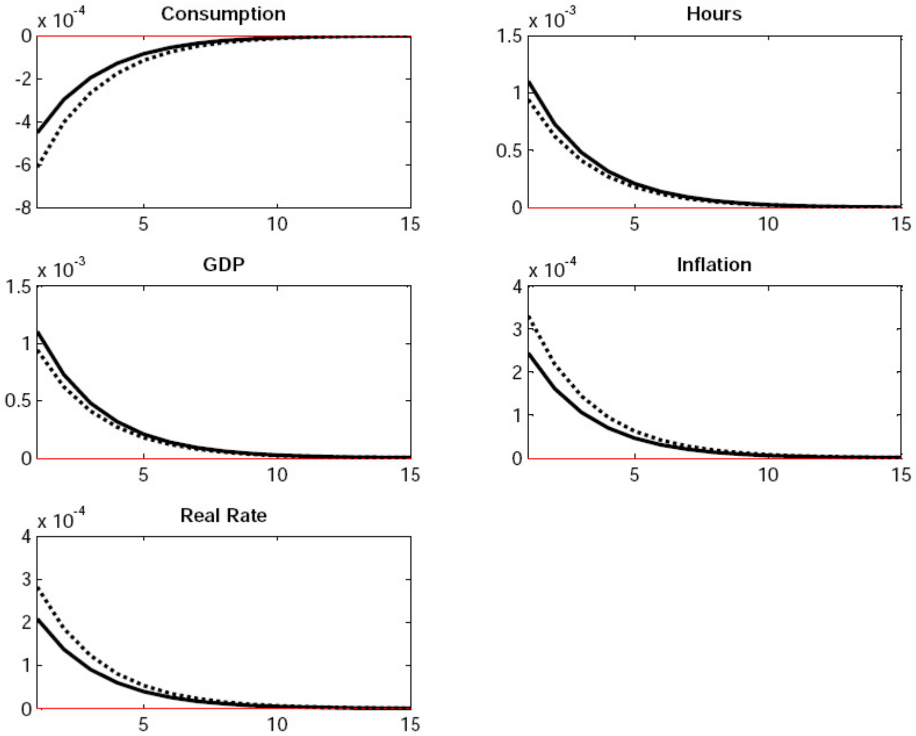
Table 3.2 next presents the business cycle and welfare effects of the progressive tax system when government spending shocks are the only type of disturbance. As before, the first column shows our simulation results for the baseline model with only Ricardian households, the second our results for the model extension with rule-of-thumb households.

Baseline Model

Table 3.2 shows that welfare falls when the progressive tax is introduced in the baseline model: The consumption loss equivalent rises by 20.2 percent. To understand

[35]Note that assuming $\sigma \neq 1$ instead does not change the results. In this case, rule-of-thumb household employment is volatile, but progressive taxation leads to a reduced volatility. The opposite still holds for Ricardian households.

Figure 3.4.: Impulse Responses to a Positive Spending Shock



Notes: Solid (dotted) lines indicate flat (progressive) taxes. For each depicted model variable, the graph shows the absolute deviation from the steady state after a positive realization of ϵ_g of one standard deviation.

this finding, it is useful to first look at the impulse response functions (to a positive government spending shock) depicted in Figure 3.4.

Under both tax systems, as can be seen, the increase in aggregate demand raises output and employment in the economy. The additional demand for labor causes an increase in real wages and marginal costs (not shown) and is thus inflationary. The central bank's policy rate rises more than proportionally with inflation (not shown), increasing the real interest rate in the economy and reducing or crowding out Ricardian consumption.

When comparing the two tax systems, we see that the results of our static and partial analysis again carry over to the general equilibrium setting. With a progressive tax system, the steeper marginal cost curve implies, for a given increase in government demand, an even larger increase in marginal costs and consequently more inflationary pressure. We observe a higher real interest rate as well as a larger decline in private consumption. The increase in aggregate demand and output is therefore dampened, and with it, the increase in employment. Over the business cycle, i.e. taking account of an entire history of positive and negative shocks to government spending, a lower volatility of output and employment but a higher volatility of inflation and consumption is thus observed (see Table 3.2). Furthermore, Table 3.2 shows that average consumption is slightly lower and average employment slightly higher when the tax system is progressive. As before, this is again due to the increased convexity of the marginal cost curve and ceteris paribus decreases the desirability of this system.

It might be insightful at this point to briefly draw a comparison to the previous case with technology shocks (still referring to the baseline model). In both cases, the progressive tax system's (supply-side) effect mitigates output fluctuations and in this sense acts as an automatic stabilizer. Crucial for welfare, however, seems to be the tax's effect on the volatility of Ricardian consumption. With technology shocks, the steeper marginal cost curve decreases this volatility through its dampening effect on inflation and thus raises welfare relative to the flat tax. The opposite happens with spending shocks. The steeper curve increases the volatility of inflation, thereby destabilizing Ricardian consumption and reducing welfare.

Model with Rule-of-Thumb Households

Table 3.2 shows that in the model extension with rule-of-thumb households, there are also no aggregate welfare gains when moving to the progressive tax system. On the contrary, the increase in the consumption loss equivalent ξ is even larger than in the baseline model (40.7 percent). Furthermore, and in contrast to the previous case with technology shocks, also rule-of-thumb households experience a welfare loss (their consumption loss equivalent rises by 10 percent).

To illustrate the role of the tax system in this case, consider, for example, the economy's response to a positive government spending shock. The increase in the rule-of-thumb household's consumption expenditure, resulting from of a higher real wage and thus disposable income, is dampened when the tax system is progressive.[36] All other things equal, this reduces the inflationary pressure relative to the flat tax. The results in Table 3.2 show, however, that this effect is more than offset by the impact of the steeper marginal cost curve on the rate of inflation. To be exact, in general equilibrium, the more pronounced effect of the government's (direct) demand increase on the rate of inflation outweighs the less pronounced effect of the rule-of-thumb household's (subsequent) demand increase.[37] As a consequence of the higher inflation rate, the central bank raises the real interest rate more and

[36]Note that the rule-of-thumb household's hours worked are again constant for $\sigma = 1$.

[37]We indeed observe (see the inflation volatilities in Table 3.2) that relative to the baseline model, the existence of rule-of-thumb households somewhat dampens the inflationary impact of the progressive tax system.

thereby induces a larger reduction in the Ricardian household's consumption. Over the business cycle, the volatility of Ricardian consumption thus rises and Ricardian welfare falls (the consumption loss equivalent increases by 53 percent). As mentioned, and in contrast to technology shocks, the rule-of-thumb household's welfare falls too: the higher average rate of inflation caused by the convexity of the marginal cost curve again reduces the average level of consumption which, in this case, dominates the effect of a lower consumption volatility. The stabilization of income and consumption is thus not enough to improve the rule-of-thumb household's welfare. This remarkable result implies that even for rule-of-thumb households, the non-linear supply-side effects can turn around the conventional case for progressive taxes based on disposable income stabilization.

At last, Table 3.2 confirms that, just as in the former cases, progressive taxes indeed mitigate output fluctuations and in this sense act as an automatic stabilizer for the economy. Our findings reveal, however, that from a welfare perspective, the stabilization of output is not in itself desirable in our New Keynesian model.

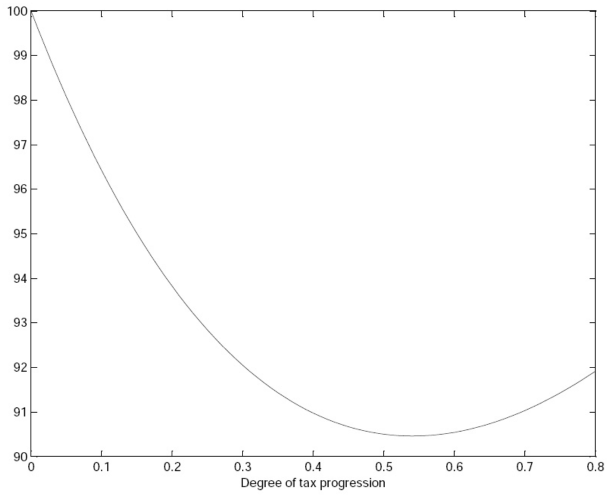
3.4.4. Optimal Tax Progression

Our previous simulations have shown that in the baseline economy, progressive taxes increase (reduce) welfare when technology shocks (government spending shocks) drive the business cycle; in the model extension with rule-of-thumb households, they decrease welfare for both shock types. When running our simulations we took the degree of tax progressivity as a given, i.e. we fixed ϕ_n at the value 0.34, the empirically observed average of the EA-12 countries. In this section, instead, we briefly illustrate what the optimal degree of tax progression in our model economy is. For this purpose, we let the coefficient of tax progression vary between the values 0 and 0.8 and compute household welfare in the presence of technology shocks, government spending shocks, and both shock types, respectively.[38]

Considering the baseline economy first, our calculations reveal that welfare uniformly increases in ϕ_n when only technology shocks are considered (not shown). In contrast, welfare uniformly decreases when only government spending shocks are considered (not shown), i.e., the optimal degree of tax progression is zero in this case. Consequently, when allowing for both shock types, the optimal degree of progression depends on the relative importance of the shocks in driving the business cycle. As can be seen in Figure 3.5, for our (shock) calibration, the optimum of the progressivity parameter ϕ_n is found at roughly the value 0.55. From a macroeco-

[38]Note that the highest observed value for ϕ_n by Mattesini and Rossi (2012) in a sample of 24 OECD countries is 0.66 for the Netherlands.

Figure 3.5.: Welfare and Tax Progression - Baseline Model



Notes: The welfare loss under the flat tax is normalized to 100.

nomic stabilization perspective, at least through the lens of our baseline model, it seems that the average EA-12 country could increase household welfare by increasing the degree of tax progression.

Unsurprisingly, for the model with rule-of-thumb households, however, we find that the optimal degree of tax progression is zero (not shown).

3.5. Model Extensions

We briefly consider two model extensions in this section. Since we calibrated the model to the Eurozone economy, we first check whether our results also hold up in the more realistic, yet somewhat less tractable setting of a currency union. Secondly, we check how an optimal conduct of monetary policy affects our previous results. For reasons explained below, in both cases we solely present results for the baseline economy without rule-of-thumb households.

3.5.1. Currency Union

To simplify matters, we assume that the currency union consists of only two countries, Home H and Foreign F, with relative sizes $(1-n)$ and n, respectively. In the following, for the sake of brevity, we only depict the model elements that differ from the previous closed economy setup.

Households consume both domestic and foreign goods.[39] More precisely, the Home

[39]Note that in the model version with rule-of-thumb households (not presented here), the con-

consumption aggregate C_t combines Home and Foreign consumption baskets according to

$$C_t = \left[(1-\omega^H)^{\frac{1}{\theta}}(C_t^H)^{\frac{\theta-1}{\theta}} + (\omega^H)^{\frac{1}{\theta}}(C_t^F)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{1-\theta}} \tag{3.22}$$

where ω^H determines the import share of household consumption and θ the elasticity of substitution between Home (C_t^H) and Foreign (C_t^F) baskets. These baskets are aggregators given by

$$C_t^H = \left[(1-n)^{-\frac{1}{\epsilon}}\int_n^1 (C_t^H(i))^{\frac{\epsilon-1}{\epsilon}}\, di\right]^{\frac{\epsilon}{\epsilon-1}} \tag{3.23}$$

$$C_t^F = \left[n^{-\frac{1}{\epsilon}}\int_0^n (C_t^F(i))^{\frac{\epsilon-1}{\epsilon}}\, di\right]^{\frac{\epsilon}{\epsilon-1}} \tag{3.24}$$

where $C_t^H(i)$ denotes the good produced by firm $i \in [n,1]$ located in country H and $C_t^F(i)$ the good produced by firm $i \in [0,n]$ located in country F.[40]

Home and Foreign (Ricardian) households can trade an international, risk-free bond. The corresponding interest rate is equal to the central bank policy rate (see below). Contrary to the closed economy case considered above, holdings of this bond are not necessarily equal to zero in the stochastic equilibrium. In other words, the current account is allowed to move into deficit or surplus in response to shocks.

Fiscal policy is set, as before, at the national level. Monetary policy is set at the union-level. The common central bank follows a Taylor-type interest rate rule that targets a weighted average of Home and Foreign price inflation and is given by

$$R_t = \beta^{-1}\left(\left(\frac{P_t^H}{P_{t-1}^H}\right)^{1-n}\left(\frac{P_t^F}{P_{t-1}^F}\right)^{n}\right)^{\phi_\pi} \tag{3.25}$$

where $P_t^H = \left((1-n)^{-1}\int_n^1 P_t^H(i)^{1-\epsilon}\, di\right)^{\frac{1}{1-\epsilon}}$ and $P_t^F = \left(n^{-1}\int_0^n P_t^F(i)^{1-\epsilon}\, di\right)^{\frac{1}{1-\epsilon}}$ denote the Home and Foreign price level, respectively.

Our model calibration looks as follows.[41] We assume that Home and Foreign are of equal size, i.e. $n = 0.5$. Both countries exhibit, for simplicity, the same degree of tax progression ($\phi_n = 0.34$). The elasticity of substitution between Home and Foreign consumption baskets is assumed to be $\theta = 2$ as in Obstfeld and Rogoff (2005) and Nakamura and Steinsson (2014). For the home bias, we set $\omega^H = \omega^F =$

sumption baskets illustrated next are the same for both household types.

[40]The Foreign household's consumption baskets are not shown because they have an identical form.

[41]Parameters not mentioned take on the same value as in the closed economy case.

Table 3.3.: Moments and Welfare Losses: Currency Union vs. Closed Economy

	Currency U.	**Closed E.**	**Currency U.**	**Closed E.**
	- Technology Shocks -		**- Spending Shocks -**	
ξ	-6.0	-14.3	$+14.4$	$+20.2$
$\sigma(\pi)$	-8.2	-12.1	$+37.6$	$+35.3$
$\sigma(Y)$	-10.9	-12.1	-14.4	-14.5
$\sigma(C)$	-11.3	-12.1	$+28.4$	$+35.3$
$\sigma(N)$	$+42.7$	$+64.0$	-14.4	-14.5
C	-0.0002	-0.0004	-0.0002	-0.00026
N	$+0.0006$	$+0.0002$	$+0.00001$	$+0.00004$

Notes: Results are changes compared to the flat-tax benchmark in percent.

0.2. The standard deviations of the innovations ϵ are assumed to be the same for both countries and again chosen so as to match the observed volatility of GDP and government purchases in the Eurozone. The values are 0.00343 for the technology shock and 0.0062 for the government spending shock. For simplicity, the shocks are assumed to be uncorrelated across countries. Finally, we set international bond holdings in the steady state equal to zero.

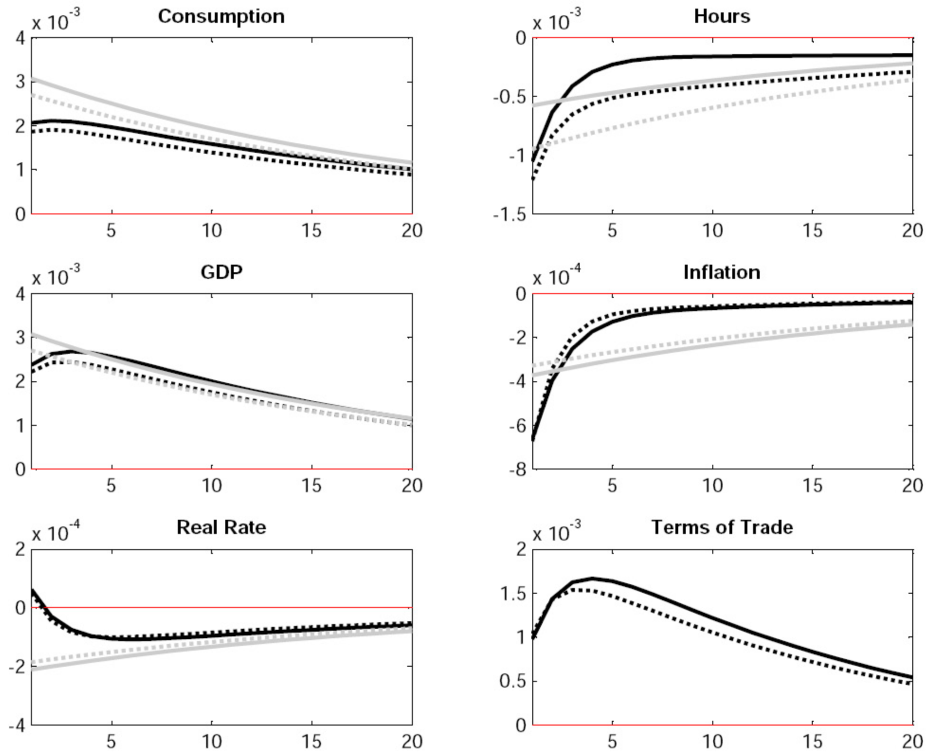
Table 3.3 confirms (for the baseline model) that the results previously obtained in the closed economy setting carry over, at any rate in qualitative terms, to the currency union setting.[42] Progressive taxes shift the volatilities and the averages of the model variables in the same direction as before; they increase (decrease) welfare in the presence of technology (government spending) shocks. Yet, when comparing the consumption loss equivalents, we find that under technology (government spending) shocks, the relative welfare gains (losses) when moving from flat to progressive taxes are somewhat smaller than in the closed economy case.

The main quantitative differences compared to the closed economy stem from the movement of the terms of trade and hence the trade balance. Consider the Home economy's impulse responses to a positive (Home) technology shock first (Figure 3.6). The Home terms of trade depreciate, allowing exports (not shown) and output to increase initially and thereby smooth consumption better than in the closed economy.[43] As prices adjust only in a staggered fashion, the terms of trade depreciation lasts for several quarters, causing output to increase in a hump shaped manner (in contrast to the closed economy). This prompts employment to rapidly return to the steady state level after a sharp initial drop. The initial employment drop is larger

[42]For the sake of brevity, we do not discuss the model with rule-of-thumb households because the results also do not change qualitatively.

[43]Note that the terms of trade are defined by $\frac{P_t^F}{P_t^H}$ here. The increase in the terms of trade in Figure 3.6 thus represents a depreciation for Home.

Figure 3.6.: Impulse Responses to a Positive Technology Shock



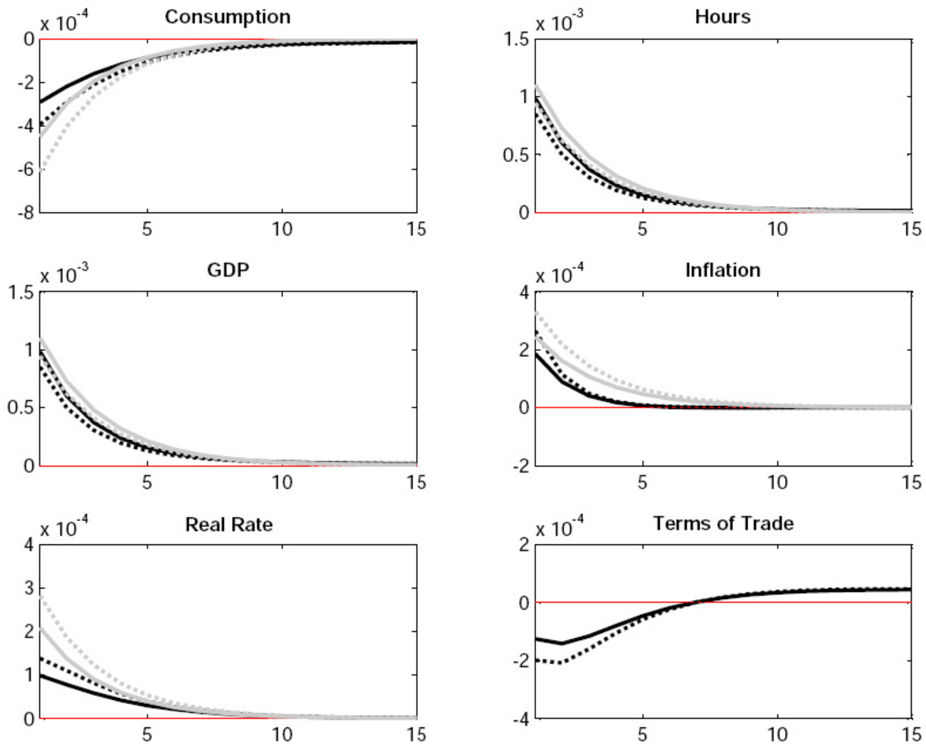
Notes: Solid (dotted) lines indicate flat (progressive) taxes. Grey lines depict the closed economy case. For each depicted model variable, the graph shows the absolute deviation from the steady state after a positive realization of ϵ_a of one standard deviation.

than in the closed economy because the central bank reacts less vigorously to the country specific shock than the national central bank in a closed economy.

The key to understanding the role of progressive taxes in the currency union setting is to realize that they lower the volatility of inflation (just as in the closed economy setting) and thus also the volatility of the terms of trade. Expenditure switching between Home and Foreign is therefore mitigated (not shown) and with it the key mechanism for consumption smoothing in an open economy. All other things equal, the relative reduction in the volatility of consumption (due to tax progression) should therefore be smaller than in the closed economy setting. And so should be, accordingly, the relative reduction in the consumption loss equivalent. Both of these points are confirmed in Table 3.3.

Figure 3.7 next displays the Home economy's impulse responses to a positive (Home) government spending shock. The responses look fairly similar to those of the closed economy case, the main difference, of course, being that the shock affects the terms of trade. Specifically, the Home terms of trade first rise above the steady state (before reversing after a couple of quarters), causing a deterioration

Figure 3.7.: Impulse Responses to a Positive Spending Shock



Notes: Solid (dotted) lines indicate flat (progressive) taxes. Grey lines depict the closed economy case. For each depicted model variable, the graph shows the absolute deviation from the steady state after a positive realization of ϵ_g of one standard deviation.

of the balance of trade (not shown). Through drawing on relatively cheap Foreign resources, Home households thus maintain a higher consumption level than in the closed economy case.

When comparing the two tax systems, notice that progressive taxes increase the volatility of inflation (just as in the closed economy setting). This, in turn, increases the volatility of the terms of trade and thereby induces more expenditure switching between Home and Foreign (not shown). As a result, the relative increase in the volatility of consumption (due to tax progression) and hence the consumption loss equivalent should be somewhat reduced in the currency union setting. Both points are confirmed in Table 3.3.

3.5.2. Optimal Monetary Policy

Most advanced economies achieve macroeconomic stabilization primarily through changes in the monetary policy stance. In this section, we briefly analyze whether a progressive tax system is a reasonable addition to the macroeconomic stabilization

Table 3.4.: Moments and Welfare Losses: Optimal Monetary Policy vs. Taylor Rule

	Optimal Policy	**Taylor Rule**
ξ	$+7.1$	-14.3
$\sigma(\pi)$	$+256.7$	-12.1
$\sigma(Y)$	-12.7	-12.1
$\sigma(C)$	-12.7	-12.1
$\sigma(N)$	$+76.2$	$+64.0$
C	-0.0019	-0.0004
N	$+0.00001$	$+0.0002$

Notes: Results are changes compared to the flat-tax benchmark in percent.

toolkit, i.e. whether it improves welfare, once the principal stabilization tool, monetary policy, is conducted optimally.[44] In what follows, we only present results for the baseline model and the case of technology shocks. The reason is that even under the non-optimal Taylor interest rate rule, the progressive tax did not improve welfare for the other model and shock specifications (quite the contrary). It should therefore be clear that the tax cannot improve welfare when monetary policy is conducted optimally.[45]

We will find it easier to grasp the subsequent results by first remembering that in the standard New Keynesian model without tax progression, the optimal monetary policy is characterized by a complete elimination of inflation and thereby (inefficient) price dispersion between firms.[46] Zero inflation is achieved by e.g. a much more aggressive reduction in the real interest rate in response to a positive technology shock (relative to the Taylor rule considered in section 3.4). Over the business cycle, the more volatile real interest rate increases the volatility of consumption but decreases the volatility of employment. Moreover, the elimination of price dispersion raises aggregate productivity according to equation (3.16) and hence increases average consumption. The latter in turn induces the household to work less hours.

To understand how the progressive tax affects welfare once monetary policy is conducted optimally, recall that the increase in welfare under the Taylor rule was accompanied by a *lower* consumption volatility and a *higher* volatility of hours whereas the level of consumption *fell* and hours *increased*. Under the optimal monetary policy, as can be seen in Table 3.4, the progressive tax still has these effects. All four moments are thus shifted in the "wrong" direction. The net effect on wel-

[44]Naturally, the central bank's objective function is household welfare. This objective function is maximized taking the optimality conditions of households and firms as well as the economy's resource constraint as given.

[45]We nonetheless checked that this claim holds indeed.

[46]See e.g. Woodford (2003, Chapter 6) or Galí (2008, Chapter 4).

fare is a 7.1 percent increase in the consumption loss equivalent (relative to the flat tax). The conclusion is that even in the presence of technology shocks (and referring to the baseline model), progressive taxes are only welfare improving as long as monetary policy is not conducted optimally.

3.6. Conclusion

Using a non-linear New Keynesian DSGE model, we find that a progressive tax on wage income stabilizes output and in this sense acts as an automatic fiscal stabilizer for the economy. We also find, however, that the progressive tax improves welfare only under a rather narrow set of circumstances. The tax improves aggregate welfare in the presence of technology shocks, but only when rule-of-thumb households are absent and monetary policy is not conducted optimally. When rule-of-thumb households are added and/or demand shocks are considered, no welfare gains exist in the aggregate. Yet, in the presence of technology shocks, the progressive tax is welfare-improving for rule-of-thumb households. Overall, our findings suggest that it is difficult to make the case for progressive taxes on their business cycle effects only, at least through the lens of our simple New Keynesian model. Especially the traditional demand-side stabilization mechanism of progressive taxes, incorporated into our model through the introduction of rule-of-thumb households, did not turn out to be a welfare-improving force at the aggregate level.

4. Revisiting the Progressive Consumption Tax: a Business Cycle Perspective

4.1. Introduction

"... the Equality of Imposition consisteth rather in the Equality of that which is consumed, than of the riches of the persons that consume the same. For what reason is there, that he which laboureth much, and sparing the fruits of his labour, consumeth little, should be more charged, than he that living idlely getteth little, and spendeth all he gets: seeing the one hath no more protection from the Common-wealth than the other? But when the Impositions are layd upon those things which men consume, every man payeth Equally for what he useth: Nor is the Common-wealth defrauded by the luxurious waste of private men."

- Hobbes (1651, p.181)

"Such a tax policy would discourage mansions and encourage factories. When rich men are an offense in the eyes of the relatively poor, it is because of their big domestic establishments and their big spendings, not because of their big savings and big industrial plants. Snobbery goes with the idle and extravagant way of living—with diamonds and retinues of servants; but snobbery is seldom seen in a big factory where the owner himself works. In fact, few workers in democratic America object to the rich man who lives and works like a poor man—who puts his gains into instruments of production, not into instruments of consumption."

- Fisher and Fisher (1942, p.94)

> *"It is only by spending, not by earning or saving, that an individual imposes a burden on the rest of the community in attaining his own ends."*
>
> \- Kaldor (1955, p.53)

The personal expenditure tax (PET) has a long intellectual tradition in economics. Famous proponents of this, largely untested[1], alternative to the personal income tax have been, amongst others, John Stuart Mill, Alfred Marshall, Arthur Pigou, Irving Fisher, Nicholas Kaldor, and James Meade.[2] The main idea behind the PET, put forward most prominently in Fisher and Fisher (1942) and Kaldor (1955), is quite simple: individuals (or households) report, in a first step, their income to the tax authority, and deduct, in a second step, all (net) savings. The resulting tax base equals personal consumption expenditure, to which, as under most conventional systems of personal income taxation, a set of graduated tax rates is finally applied.[3] The PET, or at least its common formulation with graduated tax rates, is thus a *progressive* consumption tax.[4] Other less familiar versions of a progressive consumption tax (not covered here for the sake of brevity), e.g. David Bradford's more recent "X-Tax" (see e.g. Bradford, 1986; Viard and Carroll, 2012), may differ in terms of the details of implementation, but have two key features with the PET in common: firstly, savings (or investments) are, one way or another, exempted from the tax base; and secondly, the tax is imposed (at least in part) on individuals, thus implying that the tax structure can easily be made progressive.[5] The first point

[1] According to Goode (1980), the only countries that briefly experimented with a PET are India and Sri Lanka (in the 1970s). More recent experiments are unknown to the author of this article.

[2] See e.g. Mill (1884, Book V, Chapter 1), Marshall (1925), Pigou (1928, Part II, Chapter 10), Fisher (1939, 1942), Fisher and Fisher (1942), Kaldor (1955), and Institute for Fiscal Studies (1978). Before Irving Fisher showed that a PET could be implemented via a relatively simple set of accounting rules, the practicality of such a tax was generally questioned, however. Accordingly, Mill, Marshall, and Pigou were convinced of the theoretical merits of a PET but had doubts about its practical implementation. John Maynard Keynes, in a similar vein, declared before the Committee on National Debt and Taxation (Colwyn Committee) that whereas the tax is "perhaps theoretically sound, it is practically impossible" (quoted in Kaldor, 1955, p.12).

[3] The PET could be implemented in practice through, e.g., the use of so-called "qualified accounts". For the sake of brevity, we cannot deal with this important issue here. We refer the reader to U.S. Treasury (1977), Institute for Fiscal Studies (1978), or Graetz (1979) for an extensive discussion of the implementation issues regarding the PET.

[4] To be more exact, a consumption tax is according to definition progressive when the average tax rate increases in the amount of consumption. A flat tax rate with only an allowance (e.g. the "Flat Tax" proposed by Hall and Rabushka, 1985) also satisfies this condition. Most formulations of a progressive consumption tax resort to a set of graduated tax rates (in addition to an allowance), however (see e.g. Fisher and Fisher, 1942; Kaldor, 1955; U.S. Treasury, 1977; Institute for Fiscal Studies, 1978).

[5] An incomplete list of other contemporary economists that have endorsed some version of a

clearly differentiates a PET-type system from the existing income tax[6], the second from existing sales or value-added taxes.[7]

The case for the PET has been made on several grounds. Proponents argue that the PET would allow to retain the basic progressivity of the personal income tax (in contrast to a VAT or sales tax) but be superior to the latter—by virtue of having a consumption tax base—on grounds of equity, economic efficiency, and administrative simplicity.[8]

The equity argument in favor of taxing consumption is straightforward and can be traced back to at least Thomas Hobbes' *Leviathan*. Individuals (or households), it is claimed, should not be taxed according to what they contribute to a society's common pool of goods and services (through supplying labor or capital); instead, they should be taxed according to what they take out of the common pool (through their consumption).[9] In other words, actual spending, and not spending power (i.e. income, or wealth), should be the basis for taxation (Kaldor, 1955, Chapter 1).

On grounds of economic efficiency, Irving Fisher has made a number of early contributions in favor of a consumption tax (Fisher, 1937, 1939, 1942). According to Fisher, taxing the income saved as well as the income from saving under an income tax amounts to "double taxation", discriminating against saving and discouraging capital accumulation (and therefore also reducing consumption in the long-run).[10] Expressed somewhat differently, income taxes are not neutral with respect to spending and saving, or, what amounts to the same thing, current and future consumption

progressive consumption tax includes Kenneth Arrow (2015), Samuel Bowles (Bowles and Park, 2005), The Economist (2010), Martin Feldstein (1978), Robert Frank (2010, 2011a, 2008), Kenneth Rogoff (2014, 2016), Laurence Seidman (1997), and John Whalley (Fullerton et al., 1983; Shoven and Whalley, 2005).

[6]It should be noted that the (income) tax system of many countries has some overlap with the PET. Pension plans (e.g. individual retirement accounts in the U.S.) often allow tax-deductible contributions and earnings to accumulate tax-free. Taxation only occurs at withdrawal. Tax-free contributions to pensions plans are usually limited in size, however, and early withdrawal is impractical or penalized.

[7]The PET and a VAT or sales tax further differ with respect to the incidence of taxation. See e.g. Kaldor (1955, Chapter 1) for an early reference on this point.

[8]It is not possible to give a comprehensive review of the literature on the PET, or consumption versus income taxation more generally, in this article. The reader may refer to U.S. Treasury (1977), Institute for Fiscal Studies (1978), or Pechman (1980) for a very thorough comparison between the PET and the income tax.

[9]In the context of the debate on the PET, this point has been raised by e.g. Kaldor (1955, Chapter 1), Institute for Fiscal Studies (1978, Chapter 3), Seidman (1997, Chapter 3), and also the political philosopher John Rawls (1971, Chapter 5). For opposing views, see e.g. Goode (1980) or Pechman (1990).

[10]See e.g. also U.S. Treasury (1977, Chapter 2), Institute for Fiscal Studies (1978, Chapter 23), Fullerton et al. (1983), Seidman (1997), or Okamoto (2005) for more recent contributions on the relative superiority of a (progressive) consumption tax with respect to the incentives to accumulate capital.

(Kaldor, 1955, Chapter 2).[11] They change the slope of the intertemporal budget constraint by depressing the rate of return to the saver below the rate of return of the underlying investment, thus distorting the intertemporal consumption choice (U.S. Treasury, 1977, Chapter 2; Institute for Fiscal Studies, 1978, Chapter 3). A consumption tax, in contrast, does not give rise to this intertemporal distortion.[12][13]

Lastly, and even more briefly, income taxes have been criticized on administrative grounds for necessitating complex rules concerning the measurement or imputation of income. A transition to a pure consumption tax would, for instance, allow to abolish tax regulations regarding capital gains, depreciation, and corporate profits.[14]

Since the early contributions of Irving Fisher and Nicholas Kaldor, most scholarly work on the PET appeared in the 1970s and early 1980s (e.g. Andrews, 1974; U.S. Treasury, 1977; Kay and King, 1978; Institute for Fiscal Studies, 1978; Graetz, 1979; Pechman, 1980; Fullerton et al., 1983), with the most comprehensive accounts being the U.S. Treasury's *Blueprints for Basic Tax Reform* (1977) and the Institute for Fiscal Studies' *The Structure and Reform of Direct Taxation* (1978).[15] More recently, there has been renewed interest in the subject. Particularly in the context of the inequality debate, peaking with the publication of Thomas Piketty's *Capital in the Twenty-First Century* (Piketty and Goldhammer, 2014), some economists have argued (see e.g. The Economist, 2010; Frank, 2011b; Rogoff, 2014, 2016; Arrow, 2015) that a PET, or some other version of a progressive consumption tax, would allow to address the growing problem of economic inequality more efficiently, i.e. with less harmful effects on for instance savings or work incentives, and in a more

[11] Income taxes discriminate against "late consumption" and, by implication, "early work" (relative to "early consumption" and "late work"). See e.g. U.S. Treasury (1977, Chapter 2).

[12] This at least holds when the individual faces a time-invariant consumption tax rate. Note, however, that a consumption tax, like an income tax, still distorts the individual's labor-leisure choice. Furthermore, the tax exemption of savings lowers the tax base under a consumption tax and thus ceteris paribus requires higher effective tax rates, thereby exaggerating the intratemporal distortion. It is therefore not clear from a theoretical point of view whether consumption taxes are superior to income taxes on efficiency grounds (i.e. tax systems cannot be compared by simply counting the number of economic distortions; see e.g. Atkinson and Stiglitz, 1980).

[13] A remotely related argument in favor of a consumption tax is that in the presence of capital market imperfections, exempting saved income from the tax base would allow entrepreneurs without access to external finance to fully reinvest their profits and thus to expand their enterprise more rapidly than under an income tax. See e.g. Institute for Fiscal Studies (1978, Chapter 2).

[14] See e.g. Andrews (1974) or U.S. Treasury (1977, Chapter 2). For a comprehensive case against a PET-type system on administrative grounds, see e.g. Graetz (1979). Note that we cannot cover the related topic of corporate taxes in this article. It shall only be mentioned that most PET proponents either argue in favor of the abolishment of such taxes or suggest to implement corporate taxes on a pure cash flow basis.

[15] The reports of the U.S. Treasury and the UK-based Institute for Fiscal Studies were produced under the guidance of David Bradford and James Meade, respectively. The UK report recommends the adoption of a progressive consumption tax (given that transitional problems can be dealt with satisfactorily), the U.S. report sees the tax as a promising alternative to the income tax.

targeted way (since we should ultimately care most about consumption inequality) than measures based on the taxation of income (e.g. a significant increase in top income tax rates; see Piketty et al., 2011) or wealth (e.g. the introduction of a global wealth tax; see Piketty and Goldhammer, 2014).[16] With some countries rapidly moving towards a cashless economy, and others at least entertaining the idea of abolishing cash, this and other debates around the PET might grow in importance since one of the major obstacles to the PET's implementation—tax evasion through cash hoarding in the transitional period (see e.g. Graetz, 1980; Seidman, 1997)—would disappear in such an economy.

Against this backdrop and given the growing academic interest on the role of fiscal policy in the macroeconomy following the financial crisis of 2007-08, this paper seeks to add to the existing literature on the merits and demerits of the PET by shedding light on a so far rather neglected issue: the PET's effect on the business cycle. It is by now a well-established result in macroeconomics that the design of the tax and transfer system affects the cyclical properties of the economy; the literature on automatic fiscal stabilizers has explored how government policies like e.g. progressive income taxes or unemployment benefits—policies enacted to promote redistributive or social goals rather than macroeconomic goals—help mitigate the impact of shocks on the real economy. To name but two studies that rely on microsimulations, Auerbach and Feenberg (2000), for instance, find that the U.S. income and payroll tax alone offsets roughly 8 percent of a shock to GDP. More recently, Dolls et al. (2012) find that automatic stabilizers absorb 32% (38%) of a proportional shock to household income and 34% (47%) of an unemployment shock in the U.S. (EU).[17] There still remains uncertainty about the quantitative significance of the automatic stabilizers (see e.g. Veld et al., 2013) and the relative importance of the various stabilization channels (see e.g. McKay and Reis, 2016b), but a key take-away of the literature is that the design of the tax and transfer system matters for macroeconomic fluctuations.[18]

To the best of our knowledge, Kaldor (1955, Chapter 6) is the only scholar that explicitly discusses the role of the PET in a business cycle context. Kaldor argues that discretionary tax changes are a more efficient instrument of macroeconomic control under a PET than under an income tax because the PET allows the policymaker to

[16] Two contributions, Bowles and Park (2005) and Frank (2008), also need to be mentioned in this regard. Both make the case for a progressive consumption tax on grounds of positional externalities in the consumption sphere.

[17] Mattesini and Rossi (2012) and McKay and Reis (2016a,b) are other recent contributions on automatic stabilizers.

[18] McKay and Reis (2016b) also provide an excellent review of the literature.

operate directly on aggregate demand.[19] Kaldor, yet, does not discuss the built-in stabilization properties of the PET, i.e. its potential role as an automatic stabilizer. Seidman (1997, Chapter 4) solely addresses the possible short-term macroeconomic problems when transitioning to a PET. The two most exhaustive accounts of the PET, U.S. Treasury (1977) and Institute for Fiscal Studies (1978), do not touch on business cycle issues at all.[20]

In this paper, we contribute to the literature on the PET and the wider literature on automatic fiscal stabilizers by analyzing the PET's macroeconomic properties in a modern business cycle model. More specifically, we propose a simple way to model a PET and introduce the latter into an otherwise standard, closed-economy New Keynesian DSGE model. Mattesini and Rossi (2012) have shown, using the same baseline model, that a corresponding progressive tax on (wage) income considerably changes the economy's response to shocks (relative to a flat tax). We investigate, instead, how the PET affects this response. The main aim of the paper is thus to help understand how a move to a different tax system, one that relies on the progressive taxation of consumption expenditure as opposed to income, affects macroeconomic fluctuations, and consequently, economic welfare.

The key results of the paper are the following: Firstly, we find that the PET, just as the conventional progressive income tax, stabilizes output (relative to a flat tax) and thus acts as an automatic stabilizer for the economy. Yet, and secondly, the PET has a quantitatively different effect on the volatilities of most macroeconomic variables than the progressive income tax. Thirdly, we find that a transition from

[19] To quote Kaldor at length: "Thus from the point of view of the efficient conduct and control of the economy it seems pointless to have taxes of any other kind than taxes (or subsidies) on expenditure. Income taxes, or taxes on business savings, are blunt, cumbrous, and ineffective as instruments of control—they operate in a round-about manner with uncertain effect except in those cases (like the taxation of the working classes) where income and expenditure, for lack of a cushion, are closely and rigidly linked so that the tax on the one has much the same influence as the tax on the other. But in all other cases income taxes, whether personal or business taxes, are peculiarly inappropriate as instruments of short-term or 'anti-cyclical' fiscal policy simply because their short-run effect on conduct is both less significant and less predictable than their long-run effect. If a change in the tax is introduced which appears to be associated with economic motives (and it would be difficult for a Chancellor to hide his true motives in such eventualities) the taxpayers (whether individuals or businesses) will expect it to be a temporary charge—which is just what it is intended to be—and react to it in much the same way as if it were a capital tax; [...] a purely short term change in income tax may be entirely at the expense of savings." More recently, Frank (2011, Chapter 5) reasserts this point. He argues that temporary income tax cuts provide not much stimulus in a recession because they tend to be saved by consumers. In contrast, a temporary tax cut under a PET would provide a strong stimulus because consumers can only benefit from the cut by increasing their expenditures immediately.

[20] Institute for Fiscal Studies (1978, Chapter 1) explicitly states: "We have not examined the special problems of the taxation of oil revenues or of land and development values. We have not investigated the tax problems involved in short term demand management for the macroeconomic control of economic activity. We have no intention of denying the great importance of these topics."

the existing progressive income tax to the PET would improve economic welfare under government spending, monetary policy, time preference, and taste shocks. Welfare would decline, however, under a technology shock.

The paper is structured as follows. In Section 4.2, the DSGE model is presented and a PET is introduced (along with a conventional progressive income tax). For ease of illustration, a linearized model version is derived. The model is calibrated in Section 4.3 and the model dynamics are analyzed using impulse response functions. Section 4.4 conducts a comparative welfare analysis. Section 4.5 concludes.

4.2. The Model

The employed model is a textbook New Keynesian DSGE model of a closed economy (Galí, 2008), augmented by government expenditure and a progressive tax system.[21] The model features several types of shocks commonly considered in the DSGE literature. We compare the economy's response to these shocks under a progressive tax on consumption (of the PET-type) with that under a conventional progressive tax on (wage) income (Mattesini and Rossi, 2012). The economy is populated by a representative household that maximizes lifetime utility with respect to consumption and hours worked subject to a lifetime budget constraint. There are two types of firms. A perfectly competitive retail firm utilizes the output of intermediate goods firms to assemble a final good, the latter being used for private and government consumption. Intermediate goods firms are many in number, produce a differentiated good using labor only, and set prices in a staggered manner as in Calvo (1983). Monetary policy follows a standard Taylor-type interest rate rule (Taylor, 1993), government expenditure an exogenous process.[22]

4.2.1. The Household Sector

Expenditure Tax. We first consider the household problem under the PET. Our representative household seeks to maximize lifetime utility given by

$$E_t \sum_{k=0}^{\infty} \beta^k e^{\psi_{t+k}} \left\{ e^{\xi_{t+k}} \frac{(C_{t+k})^{1-\sigma}}{1-\sigma} - \frac{(N_{t+k})^{1+\varphi}}{1+\varphi} \right\} \tag{4.1}$$

[21]At the very outset, note that this model does not allow for savings in equilibrium. We will see that it still makes a difference in terms of economic stabilization whether the expenditure side or the revenue side of the household budget is "targeted" by the progressive tax system.

[22]In what follows, letters without a time index t always represent the (non-stochastic) steady state value of the respective variable.

subject to a sequence of flow budget constraints

$$(1+\tau_t^c)P_tC_t + B_t = R_{t-1}B_{t-1} + W_tN_t + \Pi_t - T_t \quad (4.2)$$

where E_t is the rational expectation operator, C_t a consumption bundle (defined below), P_t the price index for final goods (also defined below), N_t hours worked, and W_t the (nominal) wage. Prices and wages are taken as given by the household. B_t is the amount of a risk-free one-period bond purchased at the beginning of period t, R_t is the corresponding (gross nominal) interest rate. Π_t are the profits of the intermediate goods sector, transferred to the owner household in the form of dividends. The coefficients σ and φ determine the degree of relative risk aversion and labor disutility (inverse of the Frisch labor supply elasticity), respectively. β is the subjective discount factor, ψ_t a time preference shock, ξ_t a taste shock. Finally, the household faces the tax τ_t^c on personal consumption expenditure as well as lump-sum taxes T_t (which are zero on average; see below).

Our modeling strategy for the personal expenditure tax τ_t^c follows Guo and Lansing (1998) and Mattesini and Rossi (2012).[23] We assume that the tax schedule τ_t^c has the form

$$\tau_t^c = \eta_c \left(\frac{C_t}{C}\right)^{\phi_c} - 1 \quad (4.3)$$

where C is steady state consumption and the reference value for taxation, and where $\eta_c > 1$ pins down the level of the consumption tax schedule (the average tax rate), while $\phi_c \geq 0$ determines the progressivity of the consumption tax schedule.[24]

[23] Guo and Lansing (1998) and Mattesini and Rossi (2012) also use a representative agent model. The former consider a progressive tax on capital and labor income in a Real Business Cycle model, the latter a progressive tax on labor income in a standard New Keynesian model.

[24] Notice that an income tax usually applies the relevant tax rate to a tax base that includes the tax payment itself, whereas consumption taxes usually apply the tax rate to a base that excludes the tax payment. Income tax rates are thus stated in what is called a tax-inclusive form, consumption taxes in a tax-exclusive form. To not confuse the reader, we follow the convention and also quote the personal expenditure tax in tax-exclusive form. The drawback is that the average tax rate and the progression coefficient have to be chosen and interpreted with care in order to make a valid comparison with the progressive income tax (e.g. holding the tax burden constant, tax-exclusive rates τ^{ex} appear higher than tax-inclusive rates: $\tau^{in} < \tau^{ex} = \frac{\tau^{in}}{1-\tau^{in}}$). The results of this paper, however, are not affected by the modeling strategy. To be more concrete, we also checked a tax-inclusive schedule $\tau_t^c = 1 - \eta_c \left(\frac{C^{in}}{C_t^{in}}\right)^{\phi_c}$ with $\eta_c \in (0,1]$, $\phi_c \geq 0$, and where C^{in} corresponds to before-tax or tax-inclusive consumption. This is the schedule employed below for the progressive income tax and the one also used by Guo and Lansing (1998) and Mattesini and Rossi (2012). In this case, the households budget would read $(1-\tau_t^c)P_tC_t^{in} + B_t = R_{t-1}B_{t-1} + W_tN_t + \Pi_t - T_t$, or equivalently, $\left(\frac{1}{\eta_c (C^{in})^{\phi_c}} C_t^{ex}\right)^{\frac{1}{1-\phi_c}} P_t + B_t = R_{t-1}B_{t-1} + W_tN_t + \Pi_t - T_t$ where the first term in brackets on the left-hand side is equal to C_t^{in} and where C_t^{ex} is after-tax or tax-exclusive

To understand the tax schedule, first assume that $\phi_c = 0$ holds. In this case, the tax rate on personal consumption expenditure $\tau^c = \eta_c - 1$ is constant and we speak of a "flat" consumption tax.[25] In contrast, when $\phi_c > 0$ holds, the average tax rate τ_t^c varies with current period consumption C_t. More precisely, the average tax rate τ_t^c will be above (below) the steady state tax rate τ^c whenever the tax base C_t is above (below) the reference value C, with larger deviations leading to larger rate adjustments. In this case, it is appropriate to speak of a "progressive" consumption tax (this is the typical version of the PET).

To see this last point more formally, notice that the following relationship between the marginal tax rate $\tau_t^{c,m} = \frac{\partial(\tau_t^c C_t)}{\partial C_t}$ and the average tax rate τ_t^c holds:

$$\tau_t^{c,m} = \tau_t^c + \eta_c \phi_c \left(\frac{C_t}{C}\right)^{\phi_c}. \tag{4.4}$$

Accordingly, whenever $\phi_c > 0$, the marginal tax rate is higher than the average tax rate, or, what amounts to the same thing, the average tax rate increases in the tax base.

Under this setup, the representative household's first order conditions are then given by

$$1 = \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma-\phi_c} \frac{P_t}{P_{t+1}} R_t e^{\Delta\psi_{t+1}} e^{\Delta\xi_{t+1}} \right\} \tag{4.5}$$

$$e^{\xi_t} \frac{W_t}{P_t} C_t^{-\sigma-\phi_c} = N_t^{\varphi} \eta_c C^{-\phi_c}(1 + \phi_c) \tag{4.6}$$

where the first condition is a consumption Euler equation and where the second condition determines the household's labor supply. Apparently, the progressive consumption tax has a similar effect on the household's intertemporal consumption choice as an increase in the concavity of the household's consumption utility function (an increase in the coefficient σ). That is, all other things equal, the household seeks a smoother consumption path over time. The tax's effect on labor supply is

consumption (the consumption entering the utility function). This modeling strategy seems not very intuitive and requires to keep track of both C^{ex} and C^{in}. Most importantly, the exact same results can be replicated with the tax-exclusive schedule (4.3) when adjusting the coefficients η_c and ϕ_c properly. See also Section 4.3.1 for more details on this issue.

[25] As a side note, this case is identical to the conventional approach to model value-added taxes in the DSGE literature. That is, the literature assumes, unrealistically, that the VAT liability is transferred to the government by the consumer (i.e. a flat PET is actually assumed). In a business cycle context, this assumption seems innocuous as long as the (alleged) VAT rate remains unchanged. Voigts (2017) convincingly argues, however, that this modeling approach leads to erroneous conclusions about the macroeconomic effects of discretionary changes in the tax rate because instantaneous pass-through to consumers is implicitly assumed, contradicting a wealth of empirical evidence and being inconsistent with the sticky-price assumption in DSGE models.

less apparent but also resembles that of an increase in σ. This will become more obvious when we look at a linearized version of equation (4.6) later.

In summary, with the PET we have introduced a countercyclical device (at least insofar as consumption and output move together) on the expenditure side of the household's budget. Unsurprisingly, we will see below that this device reduces output fluctuations in general equilibrium, i.e., it acts as an automatic fiscal stabilizer for the economy.

Income Tax. We next consider the household problem under the income tax. The representative household maximizes lifetime utility (4.1) subject to a sequence of flow budget constraints

$$P_t C_t + B_t = \left(R_{t-1} - \tau^{int}(R_{t-1} - 1)\right) B_{t-1} + W_t N_t (1 - \tau_t^n) + \Pi_t (1 - \tau^{div}) - T_t \tag{4.7}$$

where τ^{int} and τ^{div} are "flat" tax rates on interest income and dividend income, respectively, and where τ_t^n is a wage tax schedule given by (see Mattesini and Rossi, 2012)

$$\tau_t^n = 1 - \eta_n \left(\frac{Y_n}{Y_{n,t}}\right)^{\phi_n}, \tag{4.8}$$

with $Y_{n,t} \equiv \frac{W_t N_t}{P_t}$ denoting current period real wage income, and with the corresponding steady state value $Y_n \equiv \frac{WN}{P}$ serving as the reference value for taxation.[26] The coefficient $\eta_n \in (0, 1]$ determines the level of the tax schedule (the average tax rate), the coefficient $\phi_n \in [0, 1)$ its progressivity.[27]

It is again straightforward to show that the following relationship between the marginal tax rate (on wage income) $\tau_t^{n,m} = \frac{\partial(\tau_t^n Y_{n,t})}{\partial Y_{n,t}}$ and the average tax rate τ_t^n holds:

$$\tau_t^{n,m} = \tau_t^n + \eta_n \phi_n \left(\frac{Y_n}{Y_{n,t}}\right)^{\phi_n}. \tag{4.9}$$

We thus speak of a "progressive" ("flat") wage tax schedule when $\phi_n > 0$ ($\phi_n = 0$)

[26]Note that in contrast to most of the DSGE literature, and to obtain a maximum distinction between a tax on consumption expenditure only and an income tax, we allow for a "comprehensive" version of the latter and thus also consider a tax on household interest income. The tax can of course (and will) be "switched off" later to draw a proper comparison between the PET introduced above and the relevant existing literature on the progressive income tax (Mattesini and Rossi, 2012).

[27]The mechanics underlying this tax schedule correspond to those of the consumption tax schedule introduced above. The wage tax is quoted in tax-inclusive form, however.

holds.

Under this tax regime, the household's consumption Euler equation and the optimality condition for its labor supply, in turn, are given by

$$1 = \beta E_t \left\{ \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+1}} \left(R_t - \tau^{int}(R_t - 1)\right) e^{\Delta\psi_{t+1}} e^{\Delta\xi_{t+1}} \right\} \tag{4.10}$$

$$e^{\xi_t} \left(\frac{W_t}{P_t}\right)^{1-\phi_n} C_t^{-\sigma} \eta_n (1-\phi_n) \left(\frac{WN}{P}\right)^{\phi_n} = N_t^{\varphi+\phi_n}. \tag{4.11}$$

The consumption Euler equation is standard, except for the fact that the tax on interest income τ^{int} depresses the household's rate of return on saving. Regarding labor supply, note that as the progressivity of the wage tax schedule increases, the quantity of hours worked becomes less responsive to a change in the real wage (holding consumption constant), or, to put it another way, the labor supply curve becomes steeper. That is, to induce a given increase in hours worked, a larger increase in the real wage is necessary (when the tax system is progressive) since a growing fraction of the latter is taxed away.

We will see below that through this supply-side effect, the progressive (wage) income tax reduces output fluctuations and thus acts as an automatic fiscal stabilizer (we refer to Mattesini and Rossi (2012) for a detailed account on this point).[28]

4.2.2. The Government

Fiscal Policy

Depending on the tax regime in place, the fiscal authority finances an exogenous stream of government consumption G_t through either a tax on household consumption expenditure or household income.[29] Across regimes, the government imposes a lump-sum tax T_t (which is zero on average) to balance the budget in each period.[30]

Expenditure Tax. Under the PET, the period budget constraint of the government is given by

$$P_t G_t = \tau_t^c P_t C_t + T_t. \tag{4.12}$$

[28] Auerbach and Feenberg (2000) also stress this supply-side stabilization effect of the progressive income tax system: In the presence of labor demand fluctuations, a steeper labor supply curve reduces fluctuations in employment and ceteris paribus also output.

[29] As will be clear below, G_t is defined analogously to the private consumption bundle C_t.

[30] Allowing for government debt would not change our results since Ricardian equivalence holds in the model economy.

Income Tax. Under the income tax, in contrast, the period budget constraint of the government is given by

$$P_tG_t = \tau_t^n W_t N_t + \tau^{div}\Pi_t + \tau^{int}(R_{t-1} - 1)B_{t-1} + T_t. \tag{4.13}$$

Monetary Policy

Monetary policy follows a standard Taylor-type interest rate rule (Taylor, 1993). The rule targets price inflation only and is given by

$$R_t = R\left(\frac{P_t}{P_{t-1}}\right)^{\phi_\pi} e^{v_t} \tag{4.14}$$

where R is the steady state interest rate, $\phi_\pi > 1$ the Taylor inflation coefficient, and where v_t is a monetary policy shock.[31]

4.2.3. The Firm Sector

Final Goods Producer

The representative, perfectly competitive final goods producer assembles the final good Y_t according to the following constant returns to scale technology

$$Y_t = \left(\int_0^1 X_t(i)^{1-\frac{1}{\epsilon_p}}\, di\right)^{\frac{\epsilon_p}{\epsilon_p-1}} \tag{4.15}$$

where $X_t(i)$ is the amount of intermediate good i, with $i \in [0,1]$, and where ϵ_p is the elasticity of substitution (between intermediate goods). The firm takes the prices of the intermediate goods $P_t(i)$ as well as the price of the final good P_t as given. Profit maximization results in standard demand functions for the intermediate goods i

$$X_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon_p} Y_t \tag{4.16}$$

with the price of the final good P_t given by

$$P_t = \left(\int_0^1 P_t(i)^{1-\epsilon_p}\, di\right)^{\frac{1}{1-\epsilon_p}}. \tag{4.17}$$

[31] In the common case of $\tau^{int} = 0$, the steady state interest rate is given by $R = \beta^{-1}$. Otherwise, we have $R = \frac{1-\beta\tau^{int}}{\beta(1-\tau^{int})}$. Note that these results follow from the Euler equations.

Intermediate Goods Producers

There is a continuum of monopolistically competitive intermediate goods firms, indexed by $i \in [0,1]$. Firm i produces differentiated good $Y_t(i)$ according to

$$Y_t(i) = A_t N_t(i) \tag{4.18}$$

where $N_t(i)$ is the amount of labor employed by firm i and A_t the (stochastic) level of technology common to all firms. The production function implies that real marginal costs MC_t are equalized across firms, i.e.

$$MC_t(i) = MC_t = \frac{W_t}{P_t} A_t^{-1}. \tag{4.19}$$

We assume that intermediate goods firms set prices in a staggered fashion as in Calvo (1983). Each period t, a randomly drawn fraction of firms $1-\theta_p$, for some $0 < \theta_p < 1$, is able to reset their prices, whereas the remaining fraction of firms θ_p is not able to do so. Resetting firms take the demand functions for their good (4.16) as given. Their first-order condition with respect to the newly set price P_t^o is standard and given by

$$\sum_{k=0}^{\infty} \theta_p^k E_t \left\{ Q_{t,t+k} \left(\frac{P_t^o}{P_{t+k}} \right)^{-\epsilon-1} Y_{t+k} \left[\frac{P_t^o}{P_{t+k}} - \frac{\epsilon}{\epsilon-1} MC_{t+k} \right] \right\} = 0 \tag{4.20}$$

where $Q_{t,t+k}$ is the household's stochastic discount factor.[32]

4.2.4. Exogenous Processes

We have five exogenous variables in our model: a productivity shock A_t, government spending G_t, a monetary policy shock v_t, a time preference shock ψ_t, and a taste shock ξ_t. Let us define $a_t = ln(A_t)$ and $\widehat{g}_t \equiv ln\left(\frac{G_t}{G}\right)$. As is standard in the literature,

[32] Because firms are owned by households they also use the same discount factor as households. Under the PET, the stochastic discount factor is given by $Q_{t,t+k} = \beta E_t \left\{ \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma-\phi_c} \frac{P_t}{P_{t+k}} e^{\Delta\psi_{t+1}} e^{\Delta\xi_{t+1}} \right\}$. Under the income tax, we have $Q_{t,t+k} = \beta E_t \left\{ \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} e^{\Delta\psi_{t+1}} e^{\Delta\xi_{t+1}} \right\}$ instead.

we assume stationary AR(1) processes for all shocks, i.e.

$$a_t = \rho_a a_{t-1} + \epsilon_{a,t} \tag{4.21}$$

$$\widehat{g}_t = \rho_g \widehat{g}_{t-1} + \epsilon_{g,t} \tag{4.22}$$

$$v_t = \rho_v v_{t-1} + \epsilon_{v,t} \tag{4.23}$$

$$\psi_t = \rho_\psi \psi_{t-1} + \epsilon_{\psi,t} \tag{4.24}$$

$$\xi_t = \rho_\xi \xi_{t-1} + \epsilon_{\xi,t} \tag{4.25}$$

with $0 < \rho < 1$ and innovation ϵ drawn from a standard normal distribution.

4.2.5. Market Clearing and Aggregation

In a representative agent model such as the one at hand, bond market clearing implies $B_t = 0$ for all periods t.

The labor market is in equilibrium when household labor supply equals aggregate labor demand by (intermediate goods) firms, i.e.

$$N_t = \int_0^1 N_t(i)\, di. \tag{4.26}$$

The intermediate goods market is in equilibrium when supply equals demand for all intermediate goods $i \in [0, 1]$, i.e.

$$Y_t(i) = X_t(i). \tag{4.27}$$

In turn, the final goods market is in equilibrium when aggregate supply or real GDP equals the sum of private and government consumption demand, i.e.

$$Y_t = C_t + G_t. \tag{4.28}$$

Following Schmitt-Grohé and Uribe (2006), the aggregate production function of our economy is given by

$$Y_t = s_t^{-1} A_t N_t \tag{4.29}$$

where $s_t \geq 1$ is determined by the difference equation

$$s_t = (1 - \theta_p)(\widetilde{p}_t)^{-\epsilon_p} + \theta_p (1 + \pi_t)^{\epsilon_p} s_{t-1} \tag{4.30}$$

with $\widetilde{p}_t \equiv \frac{P_t^o}{P_t}$ and where π_t denotes (final goods) price inflation. The variable

s_t represents the resource cost from inefficient price dispersion across intermediate goods firms when the value exceeds one.[33]

Finally, in the Calvo pricing model, the evolution of aggregate or final goods prices is given by the law of motion

$$1 = \theta_p(1+\pi_t)^{-1+\epsilon_p} + (1-\theta_p)\widetilde{p}_t^{\,1-\epsilon_p}. \tag{4.31}$$

4.2.6. Steady State

In the next section, we will employ a (log-)linear approximation of the model around the (non-stochastic) steady state. It will thus be useful to briefly characterize this steady state.

We first assume that aggregate price inflation is zero in the steady state. To find aggregate output or activity next, we combine the household's labor supply first order condition with the steady state relations $\frac{W}{P} = \frac{\epsilon_p - 1}{\epsilon_p}$ (from (4.19) and (4.20)) and $Y = N$ and make use of the household's budget constraint.

Expenditure Tax. Accordingly, under the consumption tax, steady state output is given by

$$Y = \left(\frac{\epsilon_p - 1}{\epsilon_p}\left(\frac{1}{\eta_c}\right)^{1-\sigma}\frac{1}{1+\phi_c}\right)^{\frac{1}{\varphi+\sigma}}. \tag{4.32}$$

Income Tax. In comparison, under the income tax, steady state output is given by[34]

$$Y = \left(\frac{\epsilon_p - 1}{\epsilon_p}\eta_n^{1-\sigma}(1-\phi_n)\right)^{\frac{1}{\varphi+\sigma}}. \tag{4.33}$$

We see that the steady state output depends on both the average level of taxation (η) and the degree of tax progressivity (ϕ). Our model calibration below will ensure that the steady state level of output is the same for both tax systems (i.e. the incentives to supply labor are equalized in the steady state).

[33] Since there is no price dispersion under flexible prices, $s_t = 1$ holds for all t in this case.

[34] To get this expression, we assumed a uniform tax rate for household labor and dividend income.

4.2.7. Linearization

To make the model more tractable, we now employ a (log-)linear approximation of the model equations around the (non-stochastic) steady state. This also allows us to condense the model into three familiar equations: a Phillips curve, an IS curve, and a monetary policy rule. In the following, a small variable with a hat denotes the log-deviation of the respective variable from its steady state value, i.e. $\widehat{z}_t \equiv \ln(Z_t) - \ln(Z) = ln\left(1 + \frac{Z_t - Z}{Z}\right) \approx \frac{Z_t - Z}{Z}$, where the last approximation holds for "small" percentage deviations of Z_t from Z. The subsequent account will be rather brief but we will summarize our main findings at the end of this section.

The Phillips Curve

Expenditure Tax. After linearizing the price setting first order condition (4.20) and the law of motion of the aggregate price index (4.31), we combine the resulting equations to obtain the following standard forward-looking inflation equation

$$\pi_t = \beta E_t \{\pi_{t+1}\} + \lambda \widehat{mc}_t \tag{4.34}$$

where $\lambda \equiv \frac{(1-\theta_p)(1-\beta\theta_p)}{\theta_p}$.[35]

We next derive linear expressions for the labor supply first-order condition (4.6), marginal cost (4.19), the aggregate production function (4.29), and the definition of real GDP (4.28), respectively:

$$\widehat{\omega}_t + \xi_t = (\sigma + \phi_c)\widehat{c}_t + \varphi \widehat{n}_t \tag{4.35}$$

$$\widehat{mc}_t = \widehat{\omega}_t - a_t \tag{4.36}$$

$$\widehat{y}_t = a_t + \widehat{n}_t \tag{4.37}$$

$$\widehat{y}_t = \gamma_c \widehat{c}_t + (1 - \gamma_c)\widehat{g}_t \tag{4.38}$$

with $\gamma_c \equiv \frac{C}{Y}$ and where $\widehat{\omega}_t \equiv \widehat{w}_t - \widehat{p}_t$. As indicated above, it becomes obvious from equation (4.35) that the PET has a similar effect on the labor supply decision as an increase in the coefficient σ. We will refer to the resulting general equilibrium effects below.

Combining the previous equations allows us to express marginal cost in terms of

[35] See e.g. Galí (2008, Chapter 3). Further note that the time preference shock ψ_t and the taste shock ξ_t have no first-order effect on the relationship between inflation and marginal cost.

aggregate output and the exogenous processes a_t, $\widehat{g}_t$, and ξ_t:

$$\widehat{mc}_t = \frac{\sigma + \varphi\gamma_c + \phi_c}{\gamma_c}\widehat{y}_t - (1+\varphi)a_t - \frac{(\sigma+\phi_c)(1-\gamma_c)}{\gamma_c}\widehat{g}_t - \xi_t. \tag{4.39}$$

Since $\widehat{mc}_t = 0$ holds under flexible prices (i.e. the price markup is constant), we also have

$$0 = \frac{\sigma + \varphi\gamma_c + \phi_c}{\gamma_c}\widehat{y}_t^f - (1+\varphi)a_t - \frac{(\sigma+\phi_c)(1-\gamma_c)}{\gamma_c}\widehat{g}_t - \xi_t \tag{4.40}$$

where $\widehat{y}_t^f$ denotes the flexible price or "natural" output. Subtracting (4.40) from (4.39) then yields

$$\widehat{mc}_t = \frac{\sigma + \varphi\gamma_c + \phi_c}{\gamma_c}(\widehat{y}_t - \widehat{y}_t^f) \tag{4.41}$$

where the flexible price output is given by

$$\widehat{y}_t^f = \frac{(1+\varphi)\gamma_c}{\sigma + \varphi\gamma_c + \phi_c}a_t + \frac{(\sigma+\phi_c)(1-\gamma_c)}{\sigma + \varphi\gamma_c + \phi_c}\widehat{g}_t + \frac{\gamma_c}{\sigma + \varphi\gamma_c + \phi_c}\xi_t. \tag{4.42}$$

Finally, by substituting (4.41) into (4.34), we obtain the New Keynesian Phillips curve under the PET

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa_c\widetilde{y}_t \tag{4.43}$$

where the slope of the Phillips curve is given by

$$\kappa_c \equiv \lambda\frac{\sigma + \varphi\gamma_c + \phi_c}{\gamma_c} \tag{4.44}$$

and where $\widetilde{y}_t \equiv \widehat{y}_t - \widehat{y}_t^f$ is the output gap.

Income Tax. The linearized version of the labor supply first-order condition (4.11) is given by

$$(1-\phi_n)\widehat{\omega}_t + \xi_t = \sigma\widehat{c}_t + (\varphi + \phi_n)\widehat{n}_t. \tag{4.45}$$

Using (4.45) instead of (4.35) and repeating the steps taken above, we obtain the following New Keynesian Phillips curve under the progressive income tax (see

Mattesini and Rossi, 2012)

$$\pi_t = \beta E_t \{\pi_{t+1}\} + \kappa_n \widetilde{y}_t \tag{4.46}$$

where the slope of the Phillips curve is given by

$$\kappa_n \equiv \lambda \frac{\sigma + \gamma_c(\varphi + \phi_n)}{\gamma_c(1 - \phi_n)}. \tag{4.47}$$

The variable $\widetilde{y}_t \equiv \widehat{y}_t - \widehat{y}_t^f$ represents the output gap under the income tax, and the corresponding natural output is given by

$$\widehat{y}_t^f = \frac{(1+\varphi)\gamma_c}{\sigma + (\varphi + \phi_n)\gamma_c} a_t + \frac{\sigma(1-\gamma_c)}{\sigma + (\varphi + \phi_n)\gamma_c} \widehat{g}_t + \frac{\gamma_c}{\sigma + (\varphi + \phi_n)\gamma_c} \xi_t. \tag{4.48}$$

The IS Curve

Expenditure Tax. Linearizing the consumption Euler equation (4.5) gives

$$\widehat{c}_t = E_t \{\widehat{c}_{t+1}\} - \frac{1}{\sigma + \phi_c} \left(\widehat{r}_t - E_t \{\pi_{t+1}\} + E_t \{\Delta\psi_{t+1} + \Delta\xi_{t+1}\}\right). \tag{4.49}$$

Combining the last equation with the linear expression for real GDP (4.38) yields the model's IS curve, expressed in terms of aggregate output, under the PET:

$$\begin{aligned} \widehat{y}_t = E_t \{\widehat{y}_{t+1}\} - (1-\gamma_c) E_t \{\Delta\widehat{g}_{t+1}\} - \frac{\gamma_c}{\sigma + \phi_c} \Big(\widehat{r}_t - E_t \{\pi_{t+1}\} \\ + E_t \{\Delta\psi_{t+1} + \Delta\xi_{t+1}\}\Big). \end{aligned} \tag{4.50}$$

Expressed in terms of the output gap, the IS curve reads

$$\widetilde{y}_t = E_t \{\widetilde{y}_{t+1}\} - \frac{\gamma_c}{\sigma + \phi_c} \left(\widehat{r}_t - E_t \{\pi_{t+1}\} - \widehat{rr}_t^f\right) \tag{4.51}$$

where $\widehat{rr}_t^f \equiv \widehat{r}_t^f - E_t \left\{\pi_{t+1}^f\right\}$ is the real interest rate under flexible prices, often denoted as the "natural" real rate, and given by[36]

$$\begin{aligned} \widehat{rr}_t^f = \frac{(1+\varphi)(\sigma + \phi_c)}{\sigma + \varphi\gamma_c + \phi_c} E_t \{\Delta a_{t+1}\} - \frac{(\sigma + \phi_c)(1-\gamma_c)\varphi}{\sigma + \varphi\gamma_c + \phi_c} E_t \{\Delta\widehat{g}_{t+1}\} \\ - \frac{\varphi\gamma_c}{\sigma + \varphi\gamma_c + \phi_c} E_t \{\Delta\xi_{t+1}\} - E_t \{\Delta\psi_{t+1}\}. \end{aligned} \tag{4.52}$$

[36]To obtain the natural real interest rate, insert the equation for natural output (4.42) into the IS curve (4.50) and solve for the real interest rate.

Income Tax. Linearizing the consumption Euler equation (4.10) yields

$$\widehat{c}_t = E_t\left\{\widehat{c}_{t+1}\right\} - \frac{1}{\sigma}\left((1-\beta\tau^{int})\widehat{r}_t - E_t\left\{\pi_{t+1}\right\} + E_t\left\{\Delta\psi_{t+1} + \Delta\xi_{t+1}\right\}\right). \tag{4.53}$$

The IS curve, expressed in terms of aggregate output, is then given by

$$\begin{aligned}\widehat{y}_t = {} & E_t\left\{\widehat{y}_{t+1}\right\} - (1-\gamma_c)E_t\left\{\Delta\widehat{g}_{t+1}\right\} - \frac{\gamma_c}{\sigma}\Big((1-\beta\tau^{int})\widehat{r}_t - E_t\left\{\pi_{t+1}\right\} \\ & + E_t\left\{\Delta\psi_{t+1} + \Delta\xi_{t+1}\right\}\Big).\end{aligned} \tag{4.54}$$

Expressed in terms of the output gap, the IS curve reads

$$\widetilde{y}_t = E_t\left\{\widetilde{y}_{t+1}\right\} - \frac{\gamma_c}{\sigma}\left((1-\beta\tau^{int})\widehat{r}_t - E_t\left\{\pi_{t+1}\right\} - \widehat{rr}_t^f\right) \tag{4.55}$$

where $\widehat{rr}_t^f \equiv (1-\beta\tau^{int})\widehat{r}_t^f - E_t\left\{\pi_{t+1}^f\right\}$ is the (after-tax) real interest rate under flexible prices and given by

$$\begin{aligned}\widehat{rr}_t^f = {} & \frac{(1+\varphi)\sigma}{\sigma+(\varphi+\phi_n)\gamma_c}E_t\left\{\Delta a_{t+1}\right\} - \frac{\sigma(1-\gamma_c)(\varphi+\phi_n)}{\sigma+(\varphi+\phi_n)\gamma_c}E_t\left\{\Delta\widehat{g}_{t+1}\right\} \\ & - \frac{(\varphi+\phi_n)\gamma_c}{\sigma+(\varphi+\phi_n)\gamma_c}E_t\left\{\Delta\xi_{t+1}\right\} - E_t\left\{\Delta\psi_{t+1}\right\}.\end{aligned} \tag{4.56}$$

Government Policy

Finally, to close the model, the linearized version of the interest rate rule (4.14) is given by

$$\widehat{r}_t = \phi_\pi\pi_t + v_t. \tag{4.57}$$

Expenditure Tax. For the sake of completeness, the linearized version of the consumption tax schedule (4.3) is

$$\widehat{\tau}_t^c = \left(\frac{\eta_c}{\eta_c - 1}\right)\phi_c\widehat{c}_t. \tag{4.58}$$

Income Tax. Similarly, the linearized version of the wage tax schedule (4.8) is

$$\widehat{\tau}_t^n = \left(\frac{\eta_n}{1-\eta_n}\right)\phi_n(\widehat{\omega}_t + \widehat{n}_t). \tag{4.59}$$

Table 4.1.: Summary: Linearized Model

Euler equation [ET]	$\widehat{c}_t = E_t\left\{\widehat{c}_{t+1}\right\} - \frac{1}{\sigma+\phi_c}\left(\widehat{r}_t - E_t\left\{\pi_{t+1}\right\} + E_t\left\{\Delta\psi_{t+1} + \Delta\xi_{t+1}\right\}\right)$
Euler equation [IT]	$\widehat{c}_t = E_t\left\{\widehat{c}_{t+1}\right\} - \frac{1}{\sigma}\left((1-\beta\tau^{int})\widehat{r}_t - E_t\left\{\pi_{t+1}\right\} + E_t\left\{\Delta\psi_{t+1} + \Delta\xi_{t+1}\right\}\right)$
IS curve [ET]	$\widehat{y}_t = E_t\left\{\widehat{y}_{t+1}\right\} - (1-\gamma_c)E_t\left\{\Delta\widehat{g}_{t+1}\right\} - \frac{\gamma_c}{\sigma+\phi_c}\left(\widehat{r}_t - E_t\left\{\pi_{t+1}\right\} + E_t\left\{\Delta\psi_{t+1} + \Delta\xi_{t+1}\right\}\right)$
IS curve [IT]	$\widehat{y}_t = E_t\left\{\widehat{y}_{t+1}\right\} - (1-\gamma_c)E_t\left\{\Delta\widehat{g}_{t+1}\right\} - \frac{\gamma_c}{\sigma}\left((1-\beta\tau^{int})\widehat{r}_t - E_t\left\{\pi_{t+1}\right\} + E_t\left\{\Delta\psi_{t+1} + \Delta\xi_{t+1}\right\}\right)$
Phillips curve [ET]	$\pi_t = \beta E_t\left\{\pi_{t+1}\right\} + \lambda\frac{\sigma+\gamma_c\varphi+\phi_c}{\gamma_c}(\widehat{y}_t - \widehat{y}^f_t)$
Phillips curve [IT]	$\pi_t = \beta E_t\left\{\pi_{t+1}\right\} + \lambda\frac{\sigma+\gamma_c(\varphi+\phi_n)}{\gamma_c(1-\phi_n)}(\widehat{y}_t - \widehat{y}^f_t)$
Natural output [ET]	$\widehat{y}^f_t = \frac{(1+\varphi)\gamma_c}{\sigma+\varphi\gamma_c+\phi_c}a_t + \frac{(\sigma+\phi_c)(1-\gamma_c)}{\sigma+\varphi\gamma_c+\phi_c}\widehat{g}_t + \frac{\gamma_c}{\sigma+\varphi\gamma_c+\phi_c}\xi_t$
Natural output [IT]	$\widehat{y}^f_t = \frac{(1+\varphi)\gamma_c}{\sigma+(\varphi+\phi_n)\gamma_c}a_t + \frac{\sigma(1-\gamma_c)}{\sigma+(\varphi+\phi_n)\gamma_c}\widehat{g}_t + \frac{\gamma_c}{\sigma+(\varphi+\phi_n)\gamma_c}\xi_t$
Natural rate [ET]	$\widehat{rr}^f_t = \frac{(1+\varphi)(\sigma+\phi_c)}{\sigma+\varphi\gamma_c+\phi_c}E_t\left\{\Delta a_{t+1}\right\} - \frac{(\sigma+\phi_c)(1-\gamma_c)\varphi}{\sigma+\varphi\gamma_c+\phi_c}E_t\left\{\Delta\widehat{g}_{t+1}\right\} - \frac{\varphi\gamma_c}{\sigma+\varphi\gamma_c+\phi_c}E_t\left\{\Delta\xi_{t+1}\right\} - E_t\left\{\Delta\psi_{t+1}\right\}$
Natural rate [IT]	$\widehat{rr}^f_t = \frac{(1+\varphi)\sigma}{\sigma+(\varphi+\phi_n)\gamma_c}E_t\left\{\Delta a_{t+1}\right\} - \frac{\sigma(1-\gamma_c)(\varphi+\phi_n)}{\sigma+(\varphi+\phi_n)\gamma_c}E_t\left\{\Delta\widehat{g}_{t+1}\right\} - \frac{(\varphi+\phi_n)\gamma_c}{\sigma+(\varphi+\phi_n)\gamma_c}E_t\left\{\Delta\xi_{t+1}\right\} - E_t\left\{\Delta\psi_{t+1}\right\}$
Labor supply [ET]	$(\sigma+\phi_c)\widehat{c}_t + \varphi\widehat{n}_t = \widehat{\omega}_t + \xi_t$
Labor supply [IT]	$\sigma\widehat{c}_t + (\varphi+\phi_n)\widehat{n}_t = (1-\phi_n)\widehat{\omega}_t + \xi_t$
Tax schedule [ET]	$\widehat{\tau}^c_t = \left(\frac{\eta_c}{\eta_c-1}\right)\phi_c\widehat{c}_t$
Tax schedule [IT]	$\widehat{\tau}^n_t = \left(\frac{\eta_n}{1-\eta_n}\right)\phi_n(\widehat{\omega}_t + \widehat{n}_t)$
Production function	$\widehat{y}_t = a_t + \widehat{n}_t$
Aggregate demand	$\widehat{y}_t = \gamma_c\widehat{c}_t + (1-\gamma_c)\widehat{g}_t$
Output gap	$\widetilde{y}_t = \widehat{y}_t - \widehat{y}^f_t$
Real marginal cost	$\widehat{mc}_t = \widehat{\omega}_t - a_t$
Monetary policy	$\widehat{r}_t = \phi_\pi\pi_t + v_t$

Notes: ET (IT) denotes the model with progressive consumption (income) taxation. Equations without specification apply to both model versions. Note that some of the equations are redundant but are shown nonetheless for comparative purposes.

Model Summary

In conclusion, Table 4.1 contrasts both tax regimes. The linearized equations depicted summarize the equilibrium dynamics of all the model variables. The model dynamics, however, can also be expressed more compactly in terms of the New Keynesian Phillips curve, the IS curve, and the interest rate rule only.

Expenditure Tax. Under the PET, the model's linearized equilibrium can be expressed compactly by the New Keynesian Phillips curve (4.43), the IS curve (4.51), and the interest rate rule (4.57). These three equations, together with the process for the natural rate of interest (4.52), fully describe the dynamics of inflation π_t, the output gap $\widetilde{y}_t$, and the interest rate $\widehat{r}_t$.

Income Tax. Equivalently, under the income tax, the New Keynesian Phillips curve (4.46), the IS curve (4.55), and the interest rate rule (4.57), together with the natural rate (4.56), completely determine the dynamics of inflation π_t, the output gap $\widetilde{y}_t$, and the interest rate $\widehat{r}_t$.

Before we simulate the model to illustrate the general equilibrium effects of the two tax systems, we need to discuss some of our previous findings.

Firstly, both model versions collapse into the same standard New Keynesian model when we set $\phi_c = \phi_n = 0$ (and set $\tau^{int} = 0$ under the income tax, as is common in the literature), i.e. when we assume a flat tax system. Income and consumption taxes are thus equivalent in this case.

Secondly, and as already suggested above, the equations for natural output show that both tax systems act as an automatic stabilizer for the flexible-price economy in the sense that the relevant shocks (technology a_t, government spending g_t, taste ξ_t) have a smaller impact on output (relative to the flat tax). The exception is the PET's amplifying effect on output under government spending shocks (the derivative of the appropriate coefficient with respect to ϕ_c is positive). These effects will hold in the sticky-price economy as well (see the next section).

Thirdly, unlike the progressive tax on wage income, the progressive tax on consumption affects the household's Euler equation and thus the economy's IS curve. Unsurprisingly, all other things equal, the progressive consumption tax creates a greater incentive to smooth consumption (and thus output) over time, i.e., it makes the economy less responsive to "intertemporal disturbances" (shocks to ψ_t and ξ_t) and interest rate fluctuations (see e.g. equation (4.50)).

Fourthly, due to their effect on the labor supply decision, both the progressive consumption tax and the progressive wage tax increase the slope of the Phillips curve (relative to the flat tax). The intuition for the wage tax is straightforward (see Mattesini and Rossi, 2012): a given increase in hours worked can only be induced by offering higher real wages than in the flat tax case since a growing fraction of wages is taxed away. Consequently, increasing output above its natural level (through hiring more labor, at least compared to the flexible price scenario) is more costly for firms and creates more inflationary pressure. The intuition for the consumption tax is not too dissimilar: households work to (eventually) consume. To induce a given increase in hours, higher real wages than in the flat tax case have to be offered because the accompanying consumption increase is taxed at increasing rates. We thus observe more inflationary pressure when raising output above its natural level.[37] However, notice that the Phillips curve is steeper under the progressive wage tax for all (plausible) parameter values:[38]

$$\kappa_n > \kappa_c \;\Leftrightarrow\; \sigma + \gamma_c(1+\varphi) > 1. \tag{4.60}$$

4.3. Equilibrium Dynamics

In this section, we examine whether the structural differences between the PET and the income tax identified above also lead to quantitatively significant differences in general equilibrium. To this effect, we compute impulse response functions; these will graphically illustrate how the tax system affects our (linearized) model economy's cyclical behavior.[39] We depict the dynamic responses for the progressive consumption tax, the progressive income tax, and, for comparative purposes, a flat tax. The program Dynare (Adjemian et al., 2011) is used for this exercise.[40] As

[37]As already referred to above, note that an increase in the concavity of the household's consumption utility function (a larger σ) would have the same effect as the progressive consumption tax in this regard. In this case, when increasing output above its natural level, higher real wages have to be offered (relative to the case of a smaller σ) due to a more rapidly diminishing marginal utility of consumption.

[38]To obtain this condition, simply rearrange the expressions for κ_n and κ_c and assume that $\phi_c = \frac{\phi_n}{1-\phi_n}$. The latter assumption equalizes steady state employment and output (for the same relative size of the government) and implies a comparable degree of tax progressivity across the two tax systems. See the subsequent section 4.3.1 on the model's calibration for details regarding this point.

[39]We also employed a second-order approximation to the original, non-linear model equations. The order of approximation does not affect the qualitative nature of the impulse responses.

[40]The linearized model is simple enough to be also solved by "pen and paper". We used e.g. the method of undetermined coefficients to derive closed-form solutions for inflation and the output gap for the PET and an income tax with $\tau^{int} = 0$ (Mattesini and Rossi, 2012). See Appendix B.1 for the results. This approach, however, becomes quite cumbersome if one is interested in the responses of the remaining model variables as well.

a complement, we also present business cycle statistics of the simulated model (for the progressive tax systems only).

4.3.1. Calibration

The calibration we employ for our model simulations is based on the assumption that the relevant time period is one quarter. Our parametrization looks as follows: the household's subjective discount factor β is set to 0.99, consistent with a steady state value of the real interest rate of approximately 4 percent. The values $\sigma = 1$ (log utility of consumption) and $\varphi = 1$ (unitary Frisch elasticity of labor supply) for the household's utility function are standard in the literature. The elasticity of substitution between goods ϵ_p takes a value of 6, implying a steady state gross price markup of size 1.2 (for intermediate goods producers). The degree of price rigidity is given by $\theta_p = 2/3$, i.e. the average duration of (intermediate goods) prices is assumed to be 3 quarters. These last two parametrizations are also commonly used in the business cycle literature (see e.g. Galí, 2008).

Turning to the fiscal and monetary policy parameters, we first have $\phi_\pi = 1.5$, a standard value for the Taylor inflation coefficient. For the (progressive) income tax, we set $\tau^{div} = 0.2$ and $\tau^n = 0.2$ (i.e. $\eta_n = 0.8$), consistent with a government spending share in GDP of 20% ($1 - \gamma_c = 0.2$). The wage income tax progressivity parameter is set equal to the observed, GDP-weighted average value for the EA-12 member countries: $\phi_n = 0.34$ (based on the computations of Mattesini and Rossi, 2012).[41] As a baseline, we set $\tau^{int} = 0$, thereby replicating the income tax system in Mattesini and Rossi (2012). To also implement a "comprehensive" income tax, we set $\tau^{int} = 0.2$. For the (progressive) consumption tax, we assume that $\eta_c = 1.25$ holds, amounting to an average tax rate on consumption of 25% ($\tau^c = 0.25$).[42] This again yields a government spending share in GDP of 20%. The value of the consumption tax progressivity parameter is set to $\phi_c = \frac{\phi_n}{1-\phi_n} = 0.\overline{51}$, a value that aligns the steady state work incentives (and therefore the employment and output levels) under the PET with those under the income tax (with $\phi_n = 0.34$). This last parametrization thus ensures that the two tax systems are equally "progressive".[43]

[41] The qualitative nature of our results does not depend on the size of this parameter. We choose the EA-12 value because it is somewhat higher than e.g. the respective U.S. value (0.18) and thus more convenient for illustrative purposes.

[42] Recall that we express the income tax in tax-inclusive form, the consumption tax in tax-exclusive form, however. The tax rate on income thus only appears to be lower.

[43] The formulas for steady state output (4.32) and (4.33) show that given our choice of η_n and η_c (our numbers imply the same relative size of the government), steady state output, and by definition employment, is equalized across the two tax regimes when $\phi_c = \frac{\phi_n}{1-\phi_n} = \frac{0.34}{1-0.34} = 0.\overline{51}$ holds, implying identical incentives to supply labor in the steady state. This last point can also be illustrated by evaluating the marginal tax rates, given by (4.4) and (4.9), at the steady state. For

As mentioned, we also consider a flat tax for comparative purposes below. Our model allows for two different versions of a flat tax: a flat income tax ($\phi_n = 0$) with interest rate taxation ($\tau^{int} = 0.2$); and a flat tax without interest rate taxation ($\tau^{int} = 0$). In the latter case, the income tax ($\phi_n = 0$) corresponds to the consumption tax ($\phi_c = 0$). See Section 4.2.7.

Finally, note that since we consider each shock type separately in the following and are only interested in the qualitative nature of the subsequent results (given the simplicity of our model economy), we will not make an effort to calibrate the shock processes so as to match observable business cycle statistics. A calibration exercise of this sort would also be quite cumbersome as we allow for five different shock types. The autocorrelation coefficients ρ of the shock processes are thus all set to the standard textbook value 0.9. The standard deviations of the innovations ϵ are all set to the standard value 0.01.[44]

Before we turn to the model simulations, notice that our parametrization implies $\kappa_c \approx 0.49$ and $\kappa_n \approx 0.67$ (the corresponding value for the flat tax is roughly 0.38). The progressive consumption tax thus indeed features a "flatter" Phillips curve than the progressive income tax.

4.3.2. Model Simulations

Figures B.1 to B.5 in Appendix B.2 show the impulse response functions (for the main model variables) to a technology, government spending, monetary policy, time preference, and taste shock, respectively.[45] The figures show the responses of five different tax systems: the progressive consumption tax (PET), a progressive income tax (IT) as in Mattesini and Rossi (2012) where $\tau^{int} = 0$ holds, a "comprehensive" or "full" progressive income tax (full IT) where $\tau^{int} > 0$ holds in addition to the previous system, a flat tax (FL) on either consumption or income (where $\tau^{int} = 0$ holds under the income tax), and a "comprehensive" or "full" flat income tax (full

our parametrization, this yields $\tau^{c,m} \approx 0.89$ and $\tau^{n,m} \approx 0.47$, respectively. Hence, under the PET, and starting in the steady state, 1.89 additional units of real income are required (obtainable by supplying more labor) to increase consumption by one unit. Likewise, under the income tax, one additional unit of real income allows to increase consumption by 0.53 units. In other words, 1.89 additional units of real income are required to increase consumption by one unit. We thus have the same "rate of conversion" between labor and consumption across tax regimes. Finally, and as mentioned earlier, notice that we could have expressed the consumption tax in tax-inclusive form instead. In this case, the tax progressivity coefficients ϕ would have been directly comparable across tax regimes (i.e. we would have chosen $\phi_c = 0.34$ to guarantee the same degree of progressivity). As explained above, our modeling strategy does not affect the results, i.e. the more intuitive tax-exclusive formulation with $\phi_c = \frac{\phi_n}{1-\phi_n} = 0.\overline{51}$ is equivalent to the tax-inclusive formulation with $\phi_c = 0.34$.

[44] We checked that our results are unaffected by these choices.

[45] The results are robust to changes in the model parameters.

FL) where $\tau^{int} > 0$ holds. In what follows, and for obvious reasons, we are mostly interested in how the PET performs relative to the progressive income tax. The flat tax, however, also serves as a useful benchmark. As already mentioned above, the assumption $\tau^{int} > 0$ is rather uncommon in the DSGE literature. We will therefore refer to the two "full" income tax systems only in passing in the following. Finally, notice that the main purpose of the subsequent account is to only give a brief, first impression of the simulation results; to show that there are—for a wide range of shocks—important quantitative (and sometimes also qualitative) differences between the PET and the other tax systems. Especially since we are dealing with five different shock types, a comprehensive analysis of the deeper economic mechanisms driving our results—in particular some of the more subtle differences between the PET and the progressive income tax (IT)—is not within the scope of this paper and will be therefore left for future research.

To illustrate the role of the PET in the business cycle, it will be best to first draw a comparison with the "naked" flat tax (FL). A quick glance at the impulse response functions reveals that there are noticeable quantitative differences between the two tax systems. Not unexpectedly, but crucially, the responses show that for all shock types considered, the PET leads, relative to the flat tax, to a significant stabilization of household consumption demand. The latter, in turn, brings about, with the exception of the government spending shock, a stabilization of aggregate output. A first important result of this simulation exercise is thus that the PET—just as the conventional progressive income tax (see the impulse responses for the tax system IT)—acts as an automatic fiscal stabilizer for the economy.

Consider, for example, the responses to a (positive) technology shock. Consumption and output increase, but the responses are significantly dampened under the PET (still compared to FL). The intuition is straightforward: as consumption rises above its steady state value, the average tax rate on household consumption expenditure (automatically) rises as well; this mitigates the increase in consumption demand and therefore output. Over the business cycle, there is thus a greater incentive for households to smooth their consumption, the latter also mitigating output fluctuations. For the time preference, taste, and monetary policy shocks, the economic intuition behind the PET's stabilizing effect on output is similar. Since consumption and output move inversely under government spending shocks (in contrast to the other shock types), however, the PET's stabilizing effect on consumption in fact increases output fluctuations in this case (as already indicated above).[46]

[46]The PET's effect on employment (relative to FL) also depends on whether consumption and employment move together or in opposite directions after a shock hits the economy. Thus the PET's stabilizing (destabilizing) effect on employment in the presence of monetary policy, time

Table 4.2.: Standard Deviations of Model Variables

	— a —		— $\widehat{g}$ —		— v —		— ψ —		— ξ —	
	IT	**Full IT**	**IT**	**Full IT**	**IT**	**Full IT**	**IT**	**Full IT**	**IT**	**Full IT**
$sd(\pi)$	+31.1	−31.7	−2.1	−49.0	−3.4	−37.2	−3.4	−49.6	−35.4	−66.3
$sd(c)$	−13.5	−10.7	−35.5	−33.4	+31.1	−14.8	+31.1	−31.6	−10.6	−13.3
$sd(n)$	+39.8	+28.0	+35.5	+31.4	+31.0	−14.8	+31.1	−31.6	−10.6	−13.3
$sd(y)$	−13.5	−10.7	+35.5	+31.4	+31.0	−14.8	+31.1	−31.6	−10.6	−13.3
$sd(\widetilde{y})$	+77.7	−7.4	+33.3	−30.7	+31.0	−14.8	+31.1	−31.6	−12.5	−54.3

Notes: Results denote the percentage change in the standard deviation of the model variable when moving from the respective tax regime to the PET.

Furthermore, our simulations show that the PET likewise reduces fluctuations in the output *gap* relative to the flat tax. As the PET also increases the slope of the Phillips curve (see Section 4.2.7), the latter, however, does not automatically translate into a more stable inflation rate. We indeed observe a higher volatility of inflation in the presence of technology and government spending shocks (see the amplitude of the impulse responses).

Lastly, note that the PET's performance relative to the flat tax *with* interest rate taxation (full FL) is qualitatively rather similar. Yet, it becomes quite apparent that the latter system is less successful in terms of macroeconomic stabilization than the "naked" flat tax, especially with regards to output gap and inflation stabilization. The reason is that a system of interest rate taxation reduces the effectiveness of monetary policy (see the relevant IS curve).

Before we compare the PET with the progressive income tax, recall that the PET exerts the just described general equilibrium effects in the sticky-price economy through, firstly, affecting the household's intratemporal choice (labor supply), and secondly, its intertemporal choice (Euler equation). As already referred to above, an increase in the concavity of the household's consumption utility function would have a similar effect in general equilibrium (just set $\phi_c = 0$ and imagine a higher σ in the equations depicted in Table 4.1). The PET reduces consumption (and output) volatility due to an automatic adjustment of tax rates over the business cycle; a higher σ due to a more rapidly declining marginal utility of consumption.

We next draw a brief comparison between the PET and the conventional progressive income tax (IT). The impulse response functions reveal that for all five shock types considered, there are significant quantitative differences between the

preference, and taste shocks (technology and government spending shocks).

two progressive tax systems. These differences are also summarized in Table 4.2, which depicts the change in the standard deviation of the main model variables when moving from the income tax to the PET (for each shock type in isolation). A second important result of this simulation exercise is thus that a progressive tax on consumption expenditure produces quite different macroeconomic dynamics than a progressive tax on wage income.

Compared to the flat tax, the macroeconomic differences between the PET and the income tax are less clear-cut and more difficult to pin down, however. This is not too surprising since the income tax also exerts, through affecting the household's intratemporal choice (labor supply), a stabilizing influence on the economy (Mattesini and Rossi, 2012). We will therefore only highlight the most salient results and leave a thorough interpretation of these results for future research.

The impulse response functions first reveal that for the shocks that affect the flexible-price allocation (technology a_t, government spending g_t, taste ξ_t), the (quite intuitive) results of the previous comparison with the flat tax largely carry over, at least in qualitative terms. For all three shock types, we observe that the PET stabilizes consumption relative to the income tax. As before, with again the exception of the government spending shock, this stabilizes output.[47]

One of the most noticeable and interesting differences between the two tax systems indeed occurs under the government spending shock. The reason is that this shock has an opposite effect on the tax bases of the two tax systems: consumption and real wage income. A positive government spending shock increases aggregate demand and thus real wages and employment but crowds out household consumption demand. Due to the automatic reduction in the tax rate on consumption expenditure, the latter effect is attenuated under the PET, however. Instead, under the progressive income tax, the negative effect on consumption demand is amplified by an automatic increase in the tax rate on wages. Since consumption and output move in opposite directions, we thus observe a bigger output response under the PET.

Interestingly, and now in contrast to the flat tax, for both shock types that do not affect the flexible-price allocation (monetary policy v_t, time preference ψ_t), the income tax outperforms the PET in terms of consumption and output or employment stabilization. This is somewhat surprising at first sight since all other things equal, the PET makes the economy less responsive to intertemporal disturbances or (exogenous) interest rate fluctuations (compare the IS curves in Table 4.1). The general equilibrium effect of these shocks, however, also depends on the endogenous monetary policy response to inflation and its interaction with the (slope of the)

[47] The PET's relative effect on employment then again follows from these results.

Phillips curve and is therefore difficult to work out beforehand.[48] The conclusion to be drawn from the impulse response functions is that the steeper slope of the Phillips curve under the income tax is the decisive factor that reduces consumption fluctuations, relative to the PET, in general equilibrium.[49]

At this point, it will also be useful to briefly highlight the differential effect of the two tax systems on the volatility of inflation. The impulse response functions show that the PET generates larger fluctuations in the inflation rate under the technology shock, but smaller fluctuations under the government spending, monetary policy, time preference, and taste shock (see also Table 4.2 for a numerical comparison). Even though the income tax generally speaking leads to smaller output *gap* fluctuations than the PET, this effect seems to be overcompensated for by the steeper slope of the Phillips curve under the income tax.

Finally, notice that equivalent to the flat tax case considered above, the progressive income tax *with* interest rate taxation (full IT) has inferior macroeconomic stabilization properties (relative to both the conventional progressive income tax and the PET; see also Table 4.2). Especially the output gap and thus inflation again display rather large fluctuations.

4.4. Welfare

The last section has shown that the PET and the progressive income tax lead to quite different macroeconomic dynamics. In this section, we will briefly consider the resulting welfare implications. To this effect, we return to the original, non-linearized model equations and employ a second-order approximation to the latter as well as the household's (expected) lifetime utility function.[50] The program Dynare (Adjemian et al., 2011) is again used for this exercise. Subsequently, we can compare household welfare across tax regimes. More precisely, for both regimes, we convert our welfare measure into a consumption loss equivalent à la Lucas (1987). That is,

[48]Consider, for instance, the "first round" under the (positive) monetary policy shock (not visible in the impulse responses). The larger initial impact of the shock on output, and by definition the output gap, under the income tax (see the IS curve) has an even more pronounced deflationary impact due to the steeper Phillips curve. The latter creates a stronger (endogenous) monetary policy reversal than under the PET. This reversal then has a bigger impact on output according to the IS curve and so forth. The net effect (not even taking expectations into account) seems unclear.

[49]This seems to be a robust outcome. We also checked this result using the closed-form solutions in Appendix B.1.

[50]It is in principle possible to conduct the welfare analysis using a linear-quadratic approach. This approach is very cumbersome and prone to error, however. See e.g. Kim and Kim (2003).

we compute the variable ζ^{tax} of the following equation:

$$E_t \sum_{k=0}^{\infty} \beta^k U\left(C(1-\zeta^{tax}), N\right) = E_t \sum_{k=0}^{\infty} \beta^k U\left(C_{t+k}, N_{t+k}\right). \tag{4.61}$$

ζ^{tax} is the percentage reduction in average steady state consumption that makes the household indifferent between living in the (policy invariant) steady state environment (with reduced average consumption) and the stochastic environment under a particular tax regime.

For our model parametrization, the consumption loss equivalent is given by

$$\zeta^{tax} = 100\left(1 - exp\left((W^{tax} - W)(1-\beta)\right)\right) \tag{4.62}$$

where W^{tax} (W) is welfare in the stochastic (steady state) environment.

We compute ζ^{tax} for each shock type separately. Since the absolute values of ζ^{tax} are of less concern here (recall that we have chosen arbitrary values for the autocorrelation coefficients and the standard deviations of the shock processes), we only report the percentage change in ζ^{tax} when moving from the progressive income tax to the PET.[51] For the conventional income tax (IT), the results are as follows and seem quantitatively significant: The consumption loss equivalent increases by roughly 55% under technology shocks, but decreases by roughly 13% under government spending shocks, 12% under monetary policy shocks, and 7% under time preference shocks. Under taste shocks, welfare is higher under the PET as well. Since our computations reveal that welfare in the stochastic environment under the PET (marginally) exceeds steady state welfare, we are not able to compute the corresponding change in ζ^{tax} in this case, however.[52]

In summary, moving to the PET increases welfare in the presence of all the demand shocks, but decreases welfare in the presence of the supply shock.[53] From a welfare perspective, at least through the lens of our simple New Keynesian model, the desirability of the PET thus crucially depends on whether shocks originate from the demand-side or the supply-side of the economy. Furthermore, notice that the PET's performance relative to the progressive income tax *with* interest rate taxation (full IT) is rather similar (no numbers shown). The welfare gains for the demand shocks are somewhat higher, however. Furthermore, there is now a welfare gain for the technology shock as well. Table 4.3 at last confirms that the previous results are

[51] We checked that the results below do not depend on our particular shock calibration.

[52] This is a rather rare but not necessarily illogical case. See e.g. Lester et al. (2014).

[53] Under supply (demand) shocks, output and prices move in the opposite (same) direction in our model economy.

Table 4.3.: Welfare and Model Parameters

	— a —		— $\widehat{g}$ —		— v —		— ψ —		— ξ —	
	IT	**Full IT**	**IT**	**Full IT**	**IT**	**Full IT**	**IT**	**Full IT**	**IT**	**Full IT**
baseline	−	+	+	+	+	+	+	+	+	+
$\varphi = 0.5$	−	+	+	+	+	+	+	+	+	+
$\varphi = 2$	−	+	+	+	+	+	+	+	+	+
$\sigma = 0.5$	−	+	+	+	+	+	+	+	+	+
$\sigma = 2$	−	+	+	+	+	+	+	+	+	+
$\theta_p = 1/3$	−	+	+	+	+	+	+	+	−	+
$\theta_p = 1/2$	−	+	+	+	+	+	+	+	0	+
$\theta_p = 3/4$	−	+	+	+	+	+	+	+	+	+
$\phi_\pi = 5$	−	−	+	+	+	+	+	+	−	−
$\epsilon_p = 5$	−	+	+	+	+	+	+	+	+	+
$\epsilon_p = 9$	−	+	+	+	+	+	+	+	+	+

Notes: Results show the change in welfare when moving from the respective tax regime to the PET. A + (−) sign thus implies a higher (lower) level of welfare under the PET. The first row shows the results for the baseline calibration. For the remaining rows, except for the parameter explicitly stated, all other parameters are at their baseline value.

also quite robust across a set of different parameter values.

It is not within the scope of this paper to thoroughly analyze the drivers behind these results. The model simulations suggest a common theme, however. When comparing the PET with the income tax (IT), it becomes apparent that the former increases (decreases) welfare whenever it decreases (increases) the volatility of inflation relative to the latter (this effect on inflation is also captured in the linear model above; see the respective numbers in Table 4.2). Furthermore, the simulations reveal that each welfare increase (decrease) is associated with a higher (lower) consumption *level* (not shown; note that this effect is not captured in the linear model). The link between the volatility of inflation and the consumption level seems obvious: a lower volatility reduces inefficient price dispersion between firms (see equation (4.30)); this increases the economy's productivity (see equation (4.29)) and ceteris paribus affords more output and thus consumption.[54] The previous results therefore seem to again confirm the importance of price stability in sticky price models. Lastly, and as already indicated above, note that one possible reason for the PET's relative superiority with respect to inflation stabilization (at least as far as demand shocks are

[54]The same line of reasoning also works for the progressive income tax with interest rate taxation.

concerned) might be the smaller slope of the Phillips curve under the PET (which, all other things equal, implies a lower inflation volatility). However, more research has to be conducted to understand this link as well as the other possible drivers of welfare.

4.5. Conclusion

This paper was a first attempt to examine the business cycle properties (and the resulting welfare implications) of the personal expenditure tax (PET), an age-old yet largely untested alternative to the personal income tax. The main contribution of the paper was to propose a simple way to model a PET, to introduce the latter into an otherwise standard New Keynesian DSGE model (augmented by government expenditure), to derive a log-linear version of the model, and to draw a comparison with the existing income tax (Mattesini and Rossi, 2012). The model simulations have shown three things: Firstly, the PET, just as the progressive income tax, acts as an automatic stabilizer for the economy. Yet, and secondly, the PET has a quantitatively quite different effect on the volatilities of the main macroeconomic variables than the income tax. Thirdly, the PET yields welfare gains, relative to the income tax, for all the demand shocks considered; there are welfare losses, however, under a technology shock. Overall, the simulation results suggest that there is ample room for future research on the role of the PET in the business cycle.

The most interesting and natural extensions of the model at hand would be to include an open economy dimension and/or real investment and capital accumulation.[55] Both extensions would e.g. allow for more situations where (wage) income and consumption move in opposite directions after shocks (in our model, this holds only for government spending shocks) and where the PET thus clearly differentiates itself from the income tax in terms of the direction of tax rate adjustments.

In a somewhat different and elaborate model framework, our analysis of the business cycle characteristics of the PET could be extended in a number of other promising ways. Firstly, the zero lower bound (ZLB) on nominal interest rates could be incorporated into the model. This would allow us to analyze the effectiveness of discretionary fiscal policy in a depressed economy (where the ZLB binds and conventional monetary policy is thus impotent). One obvious exercise would be to look at the size of the government spending multiplier in this setting. Another interesting question to ask would be whether a temporary cut in tax rates would provide

[55] We briefly experimented with a model including capital. The results of the previous analysis did not change much. However, we did not yet examine shocks that can only be considered in this kind of model (e.g. investment shocks).

a bigger stimulus under the PET than under the existing income tax (as suggested by e.g. Kaldor, 1955; Frank, 2011a). Secondly, to investigate how the PET affects the economy's response to financial shocks, a model with a realistic financial sector (similar to e.g. Jakab and Kumhof, 2015) could be employed. For instance, it seems plausible at first sight that a progressive tax on consumption might be more successful in curbing economic fluctuations originating from volatile mortgage or consumer credit markets than a progressive tax on income. It might be worthwhile to check this intuition using a formal model. Thirdly, agent heterogeneity as in McKay and Reis (2016b) could be included into the model. This would allow us to study how the redistributive side of the PET interplays with its business cycle characteristics.

A. Appendix to Chapter 3

A.1. Derivation of Household First-Order Conditions

The Lagrangian of the Ricardian household's problem is given by

$$L = E_t \sum_{k=0}^{\infty} \beta^k \Bigg\{ \frac{(C_{t+k}^A)^{1-\sigma}}{1-\sigma} - \frac{(N_{t+k}^A)^{1+\varphi}}{1+\varphi} + \lambda_{t+k} \Big(R_{t+k-1} B_{t+k-1} \\ + \eta \left(\frac{WNP_{t+k}}{W_{t+k} N_{t+k}^A P} \right)^{\phi_n} W_{t+k} N_{t+k}^A + (\Pi_t - \Pi) - T_t - P_{t+k} C_{t+k}^A - B_{t+k} \Big) \Bigg\}. \tag{A.1}$$

Differentiating with respect to N_t, C_t, and B_t, respectively, yields the following first-order conditions:

$$(N_t^A)^{\varphi} = \lambda_t \left((1-\phi_n)(W_t N_t^A)^{-\phi_n} W_t \eta \left(\frac{WN}{P} \right)^{\phi_n} P_t^{\phi_n} \right) \tag{A.2}$$

$$\lambda_t = \frac{(C_t^A)^{-\sigma}}{P_t} \tag{A.3}$$

$$\lambda_t = \beta R_t E_t \left\{ \lambda_{t+1} \right\}. \tag{A.4}$$

Combining and rearranging finally yields

$$(N_t^A)^{\varphi+\phi_n} = (C_t^A)^{-\sigma} \left(\frac{W_t}{P_t} \right)^{1-\phi_n} \eta(1-\phi_n) \left(\frac{WN}{P} \right)^{\phi_n} \tag{A.5}$$

$$1 = \beta E_t \left\{ \left(\frac{C_{t+1}^A}{C_t^A} \right)^{-\sigma} \frac{P_t}{P_{t+1}} R_t \right\}. \tag{A.6}$$

A.2. Full Model with Rule-of-Thumb Households

The following equations describe the equilibrium of the model with rule-of-thumb households presented in Section 3.2:[1]

$$C_t^A + \frac{B_t}{P_t} = R_{t-1}\frac{B_{t-1}}{P_{t-1}}\pi_t^{-1} + (1-\tau_t^A)\frac{W_t}{P_t}N_t^A + \left(\frac{1}{1-\lambda}\right)\frac{\Pi_t - \Pi}{P_t} - \frac{T_t}{P_t} \tag{A.7}$$

$$1 = \beta E_t\left\{\left(\frac{C_{t+1}^A}{C_t^A}\right)^{-\sigma}\pi_{t+1}^{-1}R_t\right\} \tag{A.8}$$

$$(N_t^A)^{\varphi+\phi_n} = (C_t^A)^{-\sigma}\left(\frac{W_t}{P_t}\right)^{1-\phi_n}\eta\left(\frac{WN}{P}\right)^{\phi_n} \tag{A.9}$$

$$C_t^N = (1-\tau_t^N)\frac{W_t}{P_t}N_t^N \tag{A.10}$$

$$(N_t^N)^{\varphi+\phi_n} = (C_t^N)^{-\sigma}\left(\frac{W_t}{P_t}\right)^{1-\phi_n}\eta\left(\frac{WN}{P}\right)^{\phi_n} \tag{A.11}$$

$$N_t = (1-\lambda)N_t^A + \lambda N_t^N \tag{A.12}$$

$$C_t = (1-\lambda)C_t^A + \lambda C_t^N \tag{A.13}$$

$$\tau_t^A = 1 - \eta\left(\frac{WN}{P}\frac{P_t}{W_tN_t^A}\right)^{\phi_n} \tag{A.14}$$

$$\tau_t^N = 1 - \eta\left(\frac{WN}{P}\frac{P_t}{W_tN_t^N}\right)^{\phi_n} \tag{A.15}$$

$$\tau_t = (1-\lambda)\tau_t^A + \lambda\tau_t^N \tag{A.16}$$

$$G_t = (1-\lambda)\frac{W_t}{P_t}N_t^A\tau_t^A + \lambda\frac{W_t}{P_t}N_t^N\tau_t^N + (1-\lambda)\frac{T_t}{P_t} + \frac{\Pi}{P_t} \tag{A.17}$$

$$R_t = \beta^{-1}\pi_t^{\phi_\pi} \tag{A.18}$$

$$\Pi_t = Y_t - \frac{W_t}{P_t}N_t \tag{A.19}$$

$$RMC_t = \frac{W_t}{P_t}A_t^{-1} \tag{A.20}$$

$$1 = \theta_p(1+\pi_t)^{-1+\epsilon} + (1-\theta_p)\widetilde{p}_t^{\,1-\epsilon} \tag{A.21}$$

$$s_t = (1-\theta_p)(\widetilde{p}_t)^{-\epsilon} + \theta_p(1+\pi_t)^{\epsilon}s_{t-1} \tag{A.22}$$

$$X_{1,t} = \frac{\epsilon-1}{\epsilon}X_{2,t} \tag{A.23}$$

$$X_{1,t} = \widetilde{p}_t^{\,-\epsilon-1}Y_tRMC_t + \theta_pE_t\left\{\beta\left(\frac{C_{t+1}^A}{C_t^A}\right)^{-\sigma}\pi_{t+1}^{\epsilon}\left(\frac{\widetilde{p}_t}{\widetilde{p_{t+1}}}\right)^{-\epsilon-1}X_{1,t+1}\right\} \tag{A.24}$$

[1] Recall that we introduced an employment subsidy to remove the effect of the progressive tax system on steady state labor supply. Labor supply conditions (A.9) and (A.11) thus differ slightly from equation (3.5).

$$X_{2,t} = \widetilde{p_t}^{-\epsilon} Y_t + \theta_p E_t \left\{ \beta \left(\frac{C^A_{t+1}}{C^A_t} \right)^{-\sigma} \pi^{\epsilon-1}_{t+1} \left(\frac{\widetilde{p_t}}{\widetilde{p_{t+1}}} \right)^{-\epsilon} X_{2,t+1} \right\} \tag{A.25}$$

$$Y_t = s_t^{-1} A_t N_t \tag{A.26}$$

$$Y_t = C_t + G_t \tag{A.27}$$

$$g_t = ln\left(\frac{G_t}{G} \right) \tag{A.28}$$

$$g_t = \rho_g g_{t-1} + \epsilon_{g,t} \tag{A.29}$$

$$a_t = ln(A_t) \tag{A.30}$$

$$a_t = \rho_a a_{t-1} + \epsilon_{a,t}. \tag{A.31}$$

Note that equations (A.23), (A.24), and (A.25) represent a recursive formulation of the readjusting firm's price setting first-order condition (3.12). To be more precise, we have

$$x_t^1 \equiv \sum_{k=0}^{\infty} \theta_p^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left(\frac{P_t^o}{P_{t+k}} \right)^{-\epsilon-1} RMC_{t+k} \right\} \tag{A.32}$$

$$x_t^2 \equiv \sum_{k=0}^{\infty} \theta_p^k E_t \left\{ Q_{t,t+k} Y_{t+k} \left(\frac{P_t}{P_{t+k}} \right)^{-\epsilon-1} \frac{P_t^o}{P_{t+k}} \right\}. \tag{A.33}$$

Following Schmitt-Grohé and Uribe (2006), the latter two equations can be expressed recursively by (A.24) and (A.25).

B. Appendix to Chapter 4

B.1. Closed-Form Solutions

For convenience, we only derived closed-form solutions for inflation π_t and the output gap $\widetilde{y}_t$. The closed-form solutions for the remaining model variables could be obtained in a straightforward way, e.g. $\widehat{y}_t = \widetilde{y}_t + \widehat{y}_t^f$, $\widehat{n}_t = \widehat{y}_t - a_t$, and so forth. Note that when we "switch off" the progressivity ($\phi_c = \phi_n = 0$), both systems of taxation turn into one and the same flat tax. Also note that as in Mattesini and Rossi (2012), the income tax featured here refrains from taxing interest income (i.e. $\tau^{int} = 0$ is assumed).

For inflation π_t, the closed-form solution is given by

$$\pi_t = o_{\pi a} a_t + o_{\pi g} g_t + o_{\pi \xi} \xi_t + o_{\pi v} v_t + o_{\pi \psi} \psi_t \tag{B.1}$$

where

$$[ET] \quad o_{\pi a} = -\frac{\gamma_c(1+\varphi)(1-\rho_a)(\sigma+\phi_c)\kappa_c}{(\sigma+\varphi\gamma_c+\phi_c)\left[(1-\beta\rho_a)(1-\rho_a)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_a)\kappa_c\right]} < 0$$

$$[IT] \quad o_{\pi a} = -\frac{\gamma_c(1+\varphi)(1-\rho_a)\sigma\kappa_n}{(\sigma+(\varphi+\phi_n)\gamma_c)\left[(1-\beta\rho_a)(1-\rho_a)\sigma+\gamma_c(\phi_\pi-\rho_a)\kappa_n\right]} < 0$$

$$[ET] \quad o_{\pi g} = \frac{\gamma_c(1-\gamma_c)\varphi(1-\rho_g)(\sigma+\phi_c)\kappa_c}{(\sigma+\varphi\gamma_c+\phi_c)\left[(1-\beta\rho_g)(1-\rho_g)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_g)\kappa_c\right]} > 0$$

$$[IT] \quad o_{\pi g} = \frac{\gamma_c(1-\gamma_c)(\varphi+\phi_n)(1-\rho_g)\sigma\kappa_n}{(\sigma+(\varphi+\phi_n)\gamma_c)\left[(1-\beta\rho_g)(1-\rho_g)\sigma+\gamma_c(\phi_\pi-\rho_g)\kappa_n\right]} > 0$$

$$[ET] \quad o_{\pi \xi} = \frac{\gamma_c^2\varphi(1-\rho_\xi)\kappa_c}{(\sigma+\varphi\gamma_c+\phi_c)\left[(1-\beta\rho_\xi)(1-\rho_\xi)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_\xi)\kappa_c\right]} > 0$$

$$[IT] \quad o_{\pi \xi} = \frac{\gamma_c^2(\varphi+\phi_n)(1-\rho_\xi)\kappa_n}{(\sigma+(\varphi+\phi_n)\gamma_c)\left[(1-\beta\rho_\xi)(1-\rho_\xi)\sigma+\gamma_c(\phi_\pi-\rho_\xi)\kappa_n\right]} > 0$$

$$[ET] \quad o_{\pi v} = -\frac{\gamma_c \kappa_c}{(1-\beta\rho_v)(1-\rho_v)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_v)\kappa_c} < 0$$
$$[IT] \quad o_{\pi v} = -\frac{\gamma_c \kappa_n}{(1-\beta\rho_v)(1-\rho_v)\sigma+\gamma_c(\phi_\pi-\rho_v)\kappa_n} < 0$$

$$[ET] \quad o_{\pi\psi} = \frac{\gamma_c(1-\rho_\psi)\kappa_c}{(1-\beta\rho_\psi)(1-\rho_\psi)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_\psi)\kappa_c} > 0$$
$$[IT] \quad o_{\pi\psi} = \frac{\gamma_c(1-\rho_\psi)\kappa_n}{(1-\beta\rho_\psi)(1-\rho_\psi)\sigma+\gamma_c(\phi_\pi-\rho_\psi)\kappa_n} > 0.$$

For the output gap $\widetilde{y}_t$, the closed form solution is given by

$$\widetilde{y}_t = o_{ya}a_t + o_{yg}g_t + o_{y\xi}\xi_t + o_{yv}v_t + o_{y\psi}\psi_t \tag{B.2}$$

where

$$[ET] \quad o_{ya} = -\frac{\gamma_c(1+\varphi)(1-\rho_a)(\sigma+\phi_c)(1-\beta\rho_a)}{(\sigma+\varphi\gamma_c+\phi_c)\left[(1-\beta\rho_a)(1-\rho_a)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_a)\kappa_c\right]} < 0$$
$$[IT] \quad o_{ya} = -\frac{\gamma_c(1+\varphi)(1-\rho_a)\sigma(1-\beta\rho_a)}{(\sigma+(\varphi+\phi_n)\gamma_c)\left[(1-\beta\rho_a)(1-\rho_a)\sigma+\gamma_c(\phi_\pi-\rho_a)\kappa_n\right]} < 0$$

$$[ET] \quad o_{yg} = \frac{\gamma_c(1-\gamma_c)\varphi(1-\rho_g)(\sigma+\phi_c)(1-\beta\rho_g)}{(\sigma+\varphi\gamma_c+\phi_c)\left[(1-\beta\rho_g)(1-\rho_g)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_g)\kappa_c\right]} > 0$$
$$[IT] \quad o_{yg} = \frac{\gamma_c(1-\gamma_c)(\varphi+\phi_n)(1-\rho_g)\sigma(1-\beta\rho_g)}{(\sigma+(\varphi+\phi_n)\gamma_c)\left[(1-\beta\rho_g)(1-\rho_g)\sigma+\gamma_c(\phi_\pi-\rho_g)\kappa_n\right]} > 0$$

$$[ET] \quad o_{y\xi} = \frac{\gamma_c^2\varphi(1-\rho_\xi)(1-\beta\rho_\xi)}{(\sigma+\varphi\gamma_c+\phi_c)\left[(1-\beta\rho_\xi)(1-\rho_\xi)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_\xi)\kappa_c\right]} > 0$$
$$[IT] \quad o_{y\xi} = \frac{\gamma_c^2(\varphi+\phi_n)(1-\rho_\xi)(1-\beta\rho_\xi)}{(\sigma+(\varphi+\phi_n)\gamma_c)\left[(1-\beta\rho_\xi)(1-\rho_\xi)\sigma+\gamma_c(\phi_\pi-\rho_\xi)\kappa_n\right]} > 0$$

$$[ET] \quad o_{yv} = -\frac{\gamma_c(1-\beta\rho_v)}{(1-\beta\rho_v)(1-\rho_v)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_v)\kappa_c} < 0$$
$$[IT] \quad o_{yv} = -\frac{\gamma_c(1-\beta\rho_v)}{(1-\beta\rho_v)(1-\rho_v)\sigma+\gamma_c(\phi_\pi-\rho_v)\kappa_n} < 0.$$

$$[ET] \quad o_{y\psi} = \frac{\gamma_c(1-\rho_\psi)(1-\beta\rho_\psi)}{(1-\beta\rho_\psi)(1-\rho_\psi)(\sigma+\phi_c)+\gamma_c(\phi_\pi-\rho_\psi)\kappa_c} > 0$$

$$[IT] \quad o_{y\psi} = \frac{\gamma_c(1-\rho_\psi)(1-\beta\rho_\psi)}{(1-\beta\rho_\psi)(1-\rho_\psi)\sigma+\gamma_c(\phi_\pi-\rho_\psi)\kappa_n} > 0.$$

B.2. Linearized Model: Impulse Response Functions

The figures on the next pages show the impulse response functions for the main model variables and five different tax systems.[1] "PET" denotes the progressive consumption tax, "IT" the conventional progressive income tax (where $\tau^{int} = 0$), "FL" the flat tax on either consumption or income (i.e. with $\tau^{int} = 0$ under the income tax), "full IT" the progressive income tax with $\tau^{int} = 0.2$, and "full FL" a flat tax on all income (i.e. $\tau^{int} = 0.2$). For each model variable depicted, the graph shows the log-deviation from the steady state after a positive realization of the relevant innovation ϵ of one standard deviation.

[1] "Nom. Rate" denotes the nominal interest rate, "Real Rate" the (after-tax) real interest rate.

Figure B.1.: Impulse Responses to a Positive Technology Shock

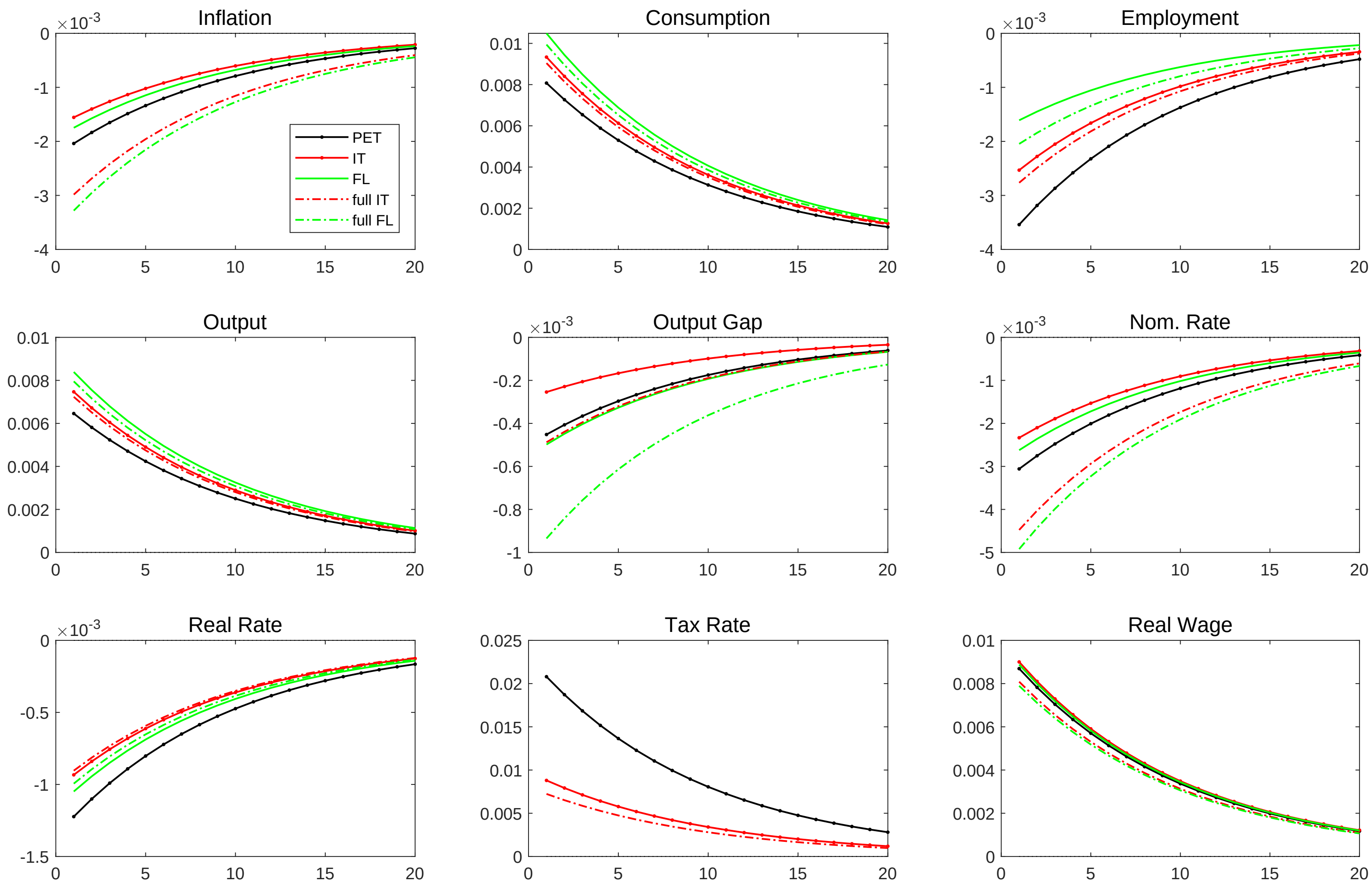


Figure B.2.: Impulse Responses to a Positive Government Spending Shock

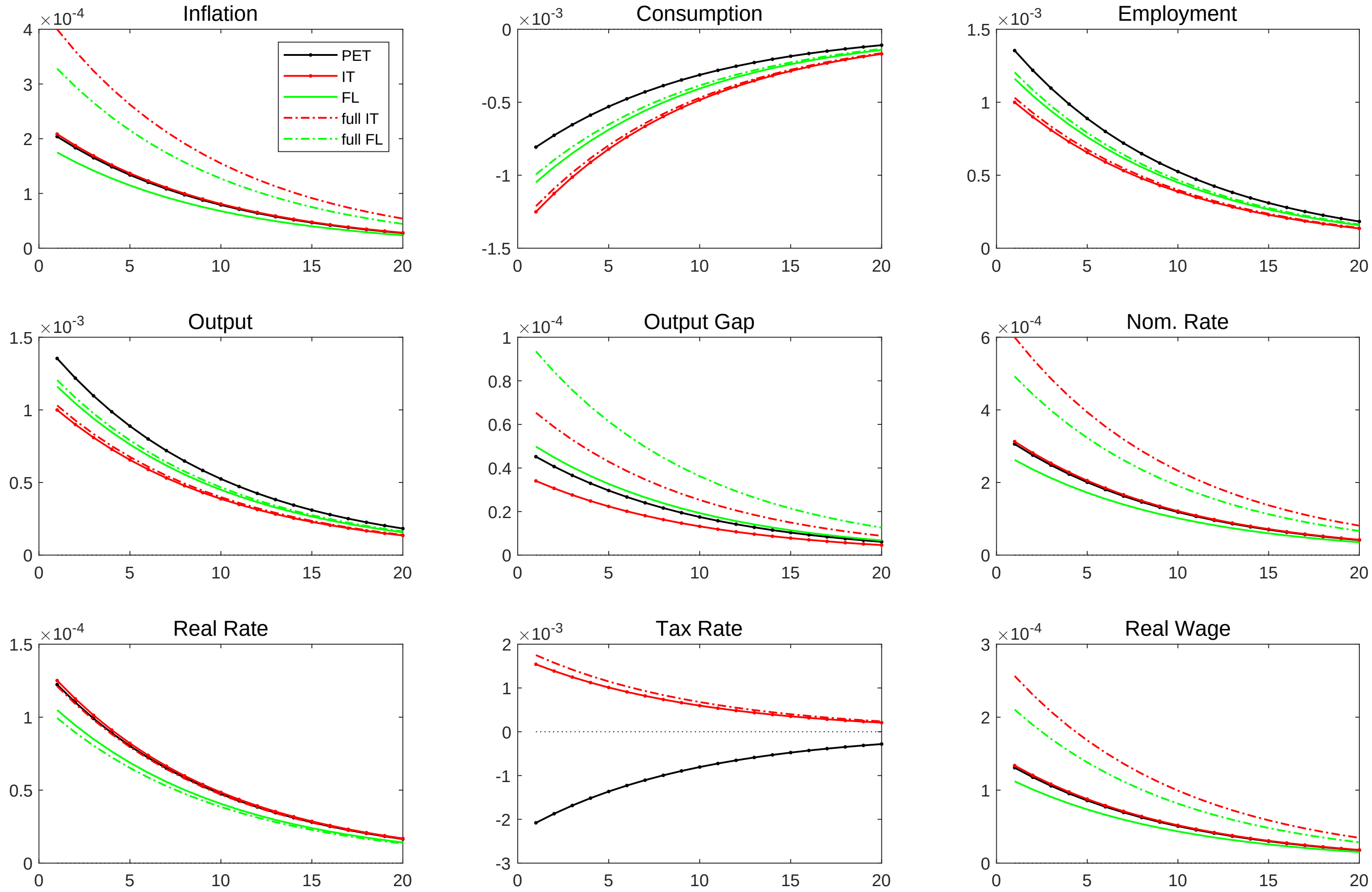


Figure B.3.: Impulse Responses to a Positive Monetary Policy Shock

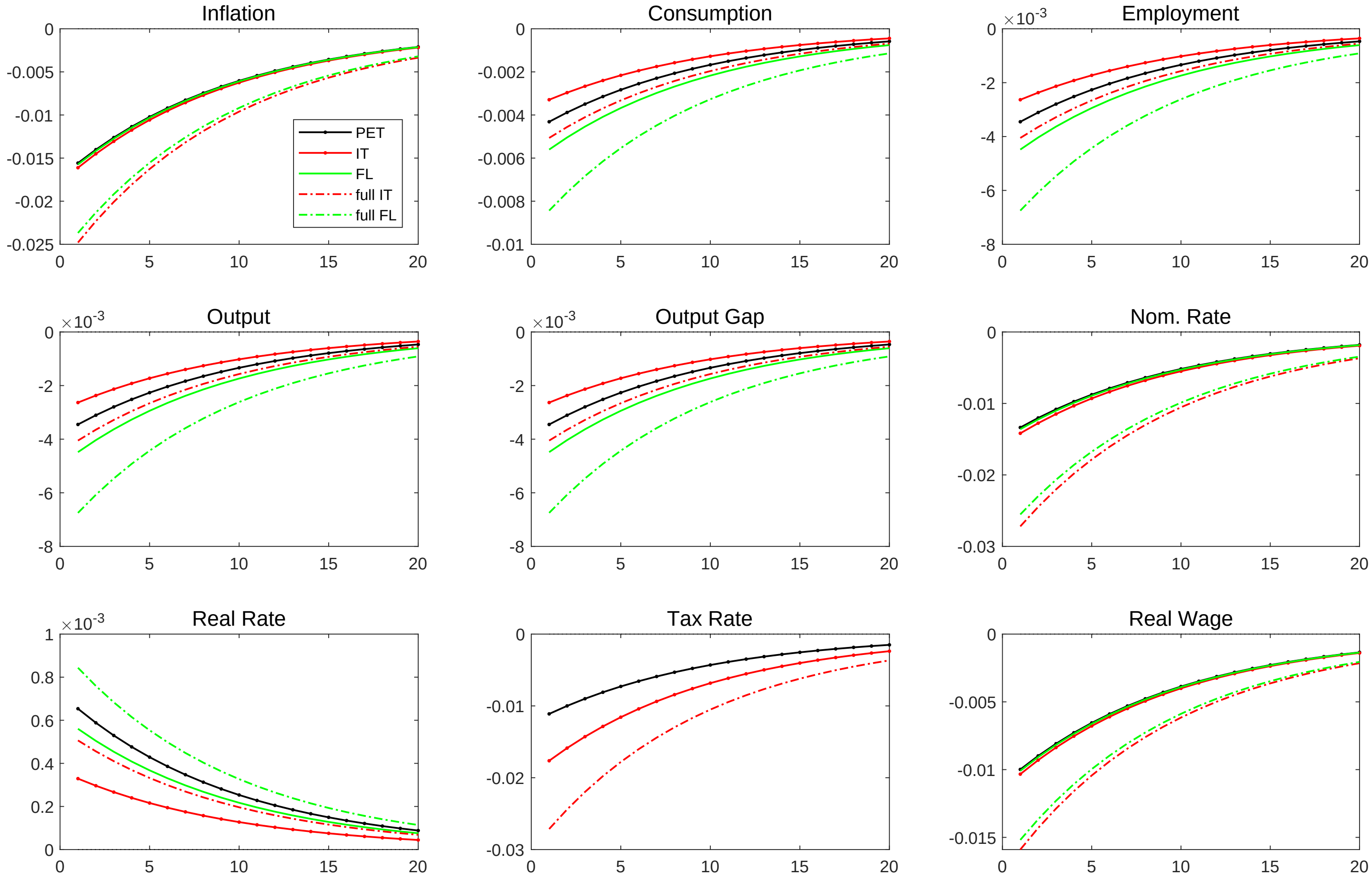


Figure B.4.: Impulse Responses to a Positive Time Preference Shock

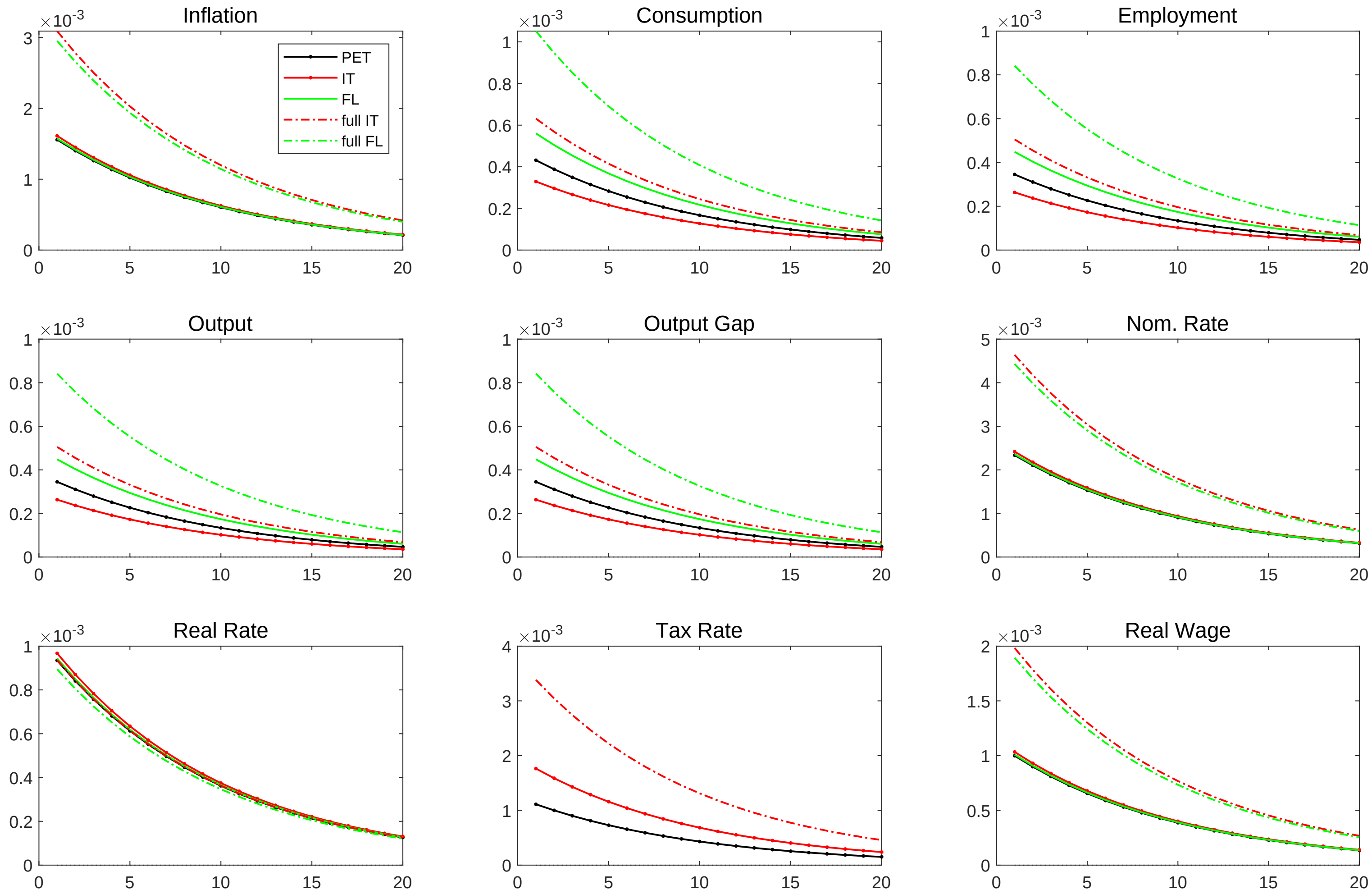
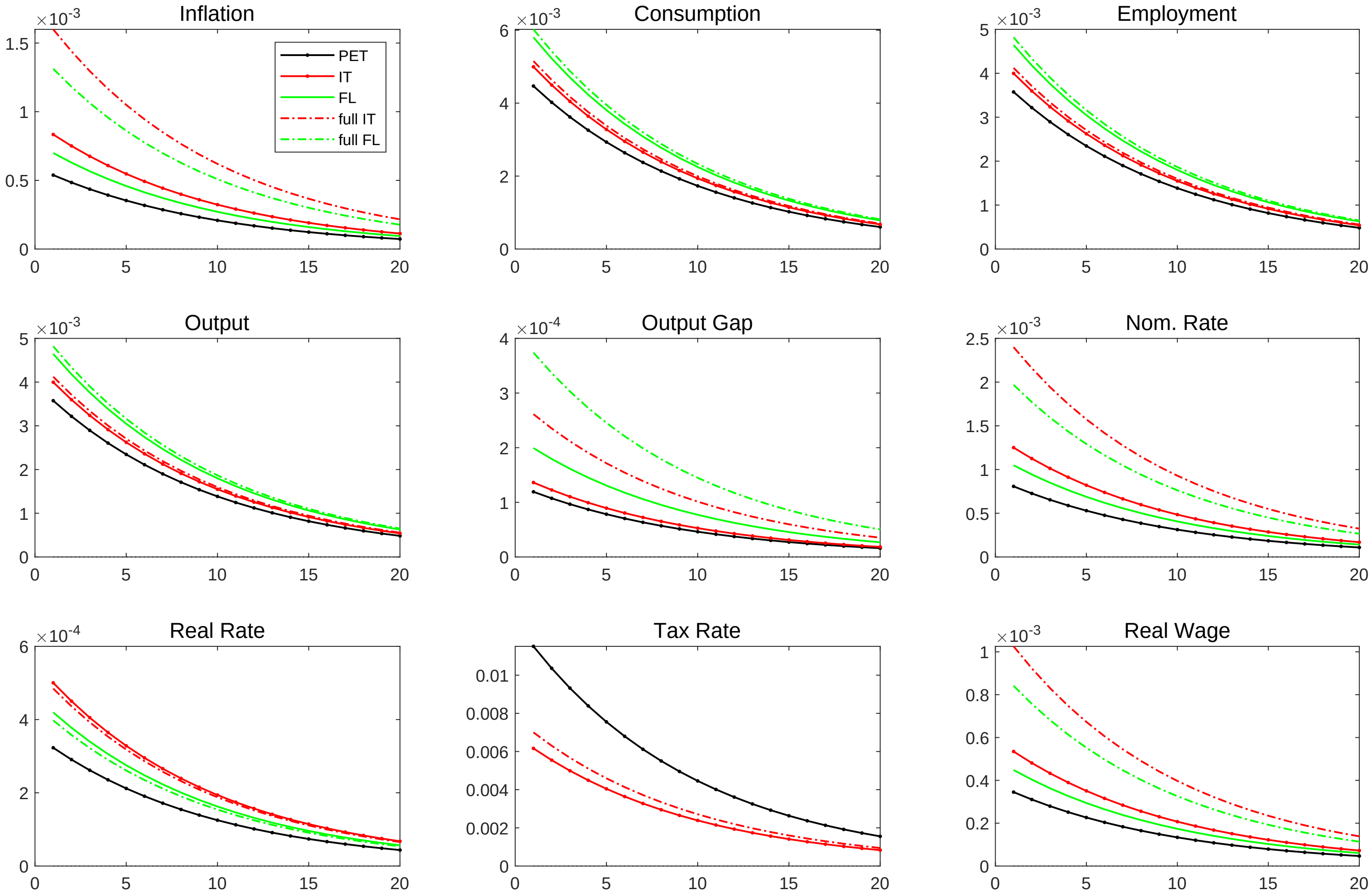


Figure B.5.: Impulse Responses to a Positive Taste Shock



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Abstract

This dissertation consists of three papers that deal with the measurement or decomposition of income inequality and the macroeconomic effects of the government's tax policies. The first paper addresses several shortcomings in the existing literature on the decomposition of the Gini coefficient. The second and the third paper explore theoretically the automatic stabilization and welfare properties of the progressive income tax and the progressive consumption or expenditure tax, respectively.

The first paper — **Chapter 2: Gini Decompositions and Gini Elasticities: on Measuring the Importance of Income Sources and Population Subgroups for Income Inequality** — is about the decomposition of the Gini coefficient. The essay confines itself to decomposition methods that are based on the framework of Rao (1969), a framework that decomposes the Gini into so-called "concentration coefficients". The economic inequality literature utilizes these techniques to understand the importance of specific income sources (e.g. capital or labor income) or population subgroups (e.g. ethnic or linguistic groups) for total income inequality; the techniques also lend themselves to the analysis of the distributional effects of government tax and transfer policies. The main contribution of the paper is to help clarify the literature on this widely used Gini decomposition framework. More specifically, the essay points to both methodological errors and errors in the interpretation of the decomposition results. It stresses the importance of using the so-called "Gini elasticities" to assess the quantitative significance of an income source or population subgroup for overall income inequality. It proposes a self-consistent method to decompose the change in the Gini coefficient by income source and contributes to the multi-decomposition literature by deriving Gini elasticities from a two-dimensional decomposition by income source and population subgroup.

The second paper — **Chapter 3: The Macroeconomic Effects of Progressive Taxes and Welfare** — studies the tax system from a macroeconomic perspective. It adds to the theoretical literature on automatic fiscal stabilizers by analyzing the business cycle and welfare effects of a progressive tax on wages (relative to a flat tax) in a New Keynesian dynamic stochastic general equilibrium (DSGE) model. Compared to the existing literature, the investigation is conducted in a non-linear setting and also features so-called "rule-of-thumb" households. The non-linearity al-

lows examining the effects of the progressive tax on both the volatility and the level of macroeconomic variables; the existence of rule-of-thumb households that base their consumption decision on disposable income adds the traditional demand-side stabilization channel of the tax system to the analysis, the latter being absent in modern DSGE models with only intertemporally optimizing or so-called "Ricardian" households. The model setting thus allows for the joint analysis of the demand-side and the supply-side stabilization channels of the progressive tax system. The model simulations show that the progressive tax system stabilizes aggregate output, but that its effect on other important macroeconomic variables (e.g. the inflation rate) crucially depends on the model configuration. In addition, for most model configurations, the progressive tax decreases economy-wide welfare.

The third paper — **Chapter 4: Revisiting the Progressive Consumption Tax: a Business Cycle Perspective** — examines the personal expenditure tax (PET), the most prominent version of a progressive consumption tax. The PET has a long intellectual tradition in economics, and the merits and demerits of this alternative to the personal income tax have been discussed at length. What has been missing in the literature so far, however, is a systematic account of its effect on the business cycle. This third paper therefore seeks to add to the theoretical literature on the PET and the wider literature on automatic fiscal stabilizers by analyzing the PET's macroeconomic properties in a modern business cycle model. To this effect, the paper introduces a highly stylized PET into a standard New Keynesian DSGE model, derives a log-linear version of the model, and draws a comparison with the existing income tax. The model simulations show that the two tax systems lead to quite different macroeconomic dynamics. Furthermore, it is found that the PET yields welfare gains, relative to the income tax, for all the demand shocks considered. The PET yields welfare losses, however, under a technology shock.

Zusammenfassung

Die vorliegende kumulative Dissertation besteht aus drei Forschungsaufsätzen. Der erste Aufsatz beschäftigt sich mit der Dekomposition des Gini-Koeffizienten. Der zweite und der dritte Aufsatz behandeln die automatischen Stabilisierungs- und Wohlfahrtseffekte der progressiven Einkommensteuer und der progressiven Konsumsteuer.

Der erste Aufsatz — **Kapitel 2: Gini Decompositions and Gini Elasticities: on Measuring the Importance of Income Sources and Population Subgroups for Income Inequality** — bezieht sich auf die Dekomposition des Gini-Koeffizienten. Der Aufsatz beschränkt sich hierbei auf Dekompositionsmethoden, die auf dem Ansatz von Rao (1969) basieren. Dieser Ansatz zerlegt den Gini-Koeffizienten in sogenannte „Konzentrationskoeffizienten“ und wird verwendet, um den Einfluss von Einkommenskomponenten (z.B. Kapital- oder Arbeitseinkommen) oder Bevölkerungsgruppen (z.B. ethnische oder linguistische Gruppen) auf die Ungleichverteilung des Gesamteinkommens zu analysieren. Die Methode kann ebenso dazu verwendet werden, die Verteilungseffekte staatlicher Steuer- und Transferpolitik zu untersuchen. Der Hauptbeitrag des Aufsatzes besteht einerseits in der Klarstellung der bestehenden Literatur zur Dekomposition des Gini-Koeffizienten und andererseits in der Entwicklung neuer Dekompositionsmethoden. Genauer gesagt weist der Aufsatz sowohl auf methodische Fehler als auch auf Fehler in der Interpretation der Dekompositionsergebnisse hin und empfielt in diesem Zusammenhang die Verwendung der sogenannten „Gini-Elastizitäten“. Der Aufsatz schlägt zudem eine konsistente Methode vor, um die Veränderung des Gini im Zeitablauf zu zerlegen und leitet Gini-Elastizitäten für eine Multi-Dekomposition nach Einkommenskomponenten und Bevölkerungsgruppen her.

Der zweite Aufsatz — **Kapitel 3: The Macroeconomic Effects of Progressive Taxes and Welfare** — untersucht das Steuersystem aus makroökonomischer Perspektive. Der theoretische Beitrag zur Literatur der automatischen Stabilisatoren analysiert die Konjunktur- und Wohlfahrtseffekte einer progressiven Lohnsteuer (relativ zu einer „flachen“ Steuer) in einem neukeynesianischen allgemeinen Gleichgewichtsmodell (DSGE-Modell). Im Vergleich zur bestehenden Literatur wird die Analyse in einem nichtlinearen Modell durchgeführt und berücksichtigt zudem sogenannte „rule-of-thumb“ Haushalte. Die Nichtlinearität ermöglicht es, sowohl den Effekt der Steuer auf die Volatilitäten der Modellvariablen als auch auf deren Durchschnittswerte zu studieren; die Berücksichtigung von rule-of-thumb Haushalten, welche per Definition ihre Konsumnachfrage nur vom verfügbaren Einkommen abhängig machen, führt den traditionellen nachfrageseitigen Stabilisierungsmechanismus des progressiven Steuersystems in die Modellökonomie ein. Letzterer Mechanismus ist in typischen DSGE-Modellen mit lediglich intertemporal optimierenden bzw. sogenannten „ricardianischen“ Haushalten nicht enthalten. Der Modellaufbau erlaubt somit die simultane Analyse der angebots- und nachfrageseitigen Stabilisierungseffekte des progressiven Steuersystems. Die Modellsimulationen zeigen, dass das progressive Steuersystem die gesamtwirtschaftliche Produktion stabilisiert, dessen Effekt auf andere makroökonomische Variablen (wie z.B. die Inflationsrate) jedoch stark von der verwendeten Modellkonfiguration abhängt. Für die meisten Modellkonfigurationen führt die progressive Steuer zudem zu einer Wohlfahrtsverschlechterung.

Der dritte Aufsatz dieser Dissertation — **Kapitel 4: Revisiting the Progressive Consumption Tax: a Business Cycle Perspective** — beschäftigt sich mit der sogenannten „persönlichen Ausgabensteuer“ (engl. PET: personal expenditure tax), der gebräuchlichsten Formulierung einer progressiven Konsumsteuer. Die PET hat eine lange intellektuelle Tradition in der Volkswirtschaftslehre und die Vor- und Nachteile dieser Alternative zur bestehenden persönlichen Einkommensteuer wurden ausgiebig diskutiert. Bisher fehlt jedoch eine systematische Erörterung ihrer Konjunktureffekte. Der dritte Aufsatz versucht deshalb, diese bestehende Lücke in der Literatur zu schließen und analysiert die automatischen Stabilisierungseigenschaften dieser Steuer auf theoretischer Ebene. Zu diesem Zweck wird eine stilisierte PET in ein neukeynesianisches DSGE-Modell eingebaut, eine log-lineare Version des Modells hergeleitet und ein Vergleich mit der bestehenden Einkommensteuer gezogen. Die Modellsimulationen zeigen, dass die beiden Steuersysteme recht unterschiedliche makroökonomische Dynamiken generieren. Die Analyse zeigt zudem, dass die PET Wohlfahrtsgewinne in der Gegenwart aller betrachteter Nachfrageschocks erzeugt (relativ zur Einkommensteuer). Es kommt jedoch zu Wohlfahrtsverlusten in der Gegenwart eines Angebotsschocks.

Ehrenwörtliche Erklärung

Hiermit erkläre ich, Wolfgang Strehl, dass ich die vorliegende Dissertation selbständig verfasst und alle Quellen ordnungsgemäß gekennzeichnet habe.

Ich versichere, dass die Dissertation nicht bereits in einem früheren Promotionsverfahren angenommen oder als ungenügend beurteilt wurde.

Berlin, 5. Juni 2018