The effects of government spending under trend inflation: theory and empirics

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June 7, 2019

Abstract

This paper presents empirical evidence that long run inflation is important in explaining cross−country differences in the response of private consumption to a government spending shock. Contributing to the debate on the size of fiscal multipliers, I motivate my analysis by documenting, in a quarterly dataset of OECD countries, that countries with high long run inflation display a relatively higher response of private consumption. Then, I show that the higher the trend inflation in an economy the higher the response of private consumption to a government spending shock, using a small scale DSGE model with trend inflation. Finally, I calculate consumption multipliers. I find that the consumption multipliers in countries with low trend inflation are below one, while under high trend inflation are higher than 2. These multipliers are consistent with the empirical evidence, which I provide in the paper.

Keywords: Private consumption, Government spending, Fiscal multipliers, Trend inflation, Panel VAR.

JEL classification: E21, E31, E62,

*I would like to thank Dudley Cooke, Rish Singhania, Haytem Troug and participants at the Exeter Business School workshop 2018 for comments that helped improve this paper.

1 Introduction

In the last decade and especially after the 2008 crisis, fiscal policy gained an important place as a macro−policy. Despite a surge in research on fiscal policy, there is still lack of consensus on the effect of government spending and,thus, the size of the fiscal multiplier. Therefore it is important to understand what drives fiscal multipliers and how the mechanism in which government spending affects private consumption works. In this paper I will provide answers on the following questions: What is the size of fiscal multipliers? Does the magnitude of the multiplier depend on country characteristics? Does the long run inflation level of the country matter for the size of the multiplier? Because there is strong empirical evidence in favor of long run inflation being important in determining the effects of government spending on private consumption, I present a theoretical investigation on the implications of trend inflation into it.

This paper, focusing on nominal rigidities, makes two contributions, it contributes to the empirical literature, about the size of fiscal multipliers and in showing country characteristics importance in explaining government spending shocks reactions. It contributes to the DSGE model literature: by widening more the effects of trend inflation and its effects, and on the effects of government spending shocks and fiscal multipliers. The main result of this paper is that both empirically and in a DSGE model, long run inflation is a significant element in explaining the size of the effect of private consumption from government spending shocks.

The fiscal multiplier has been investigated empirically cross-countries, where Favero et al. (2011), argues that there is heterogeneity between countries and this heterogeneity matters for the size of fiscal multipliers. There is increasing work being done looking at state, or regions multipliers such as in Nakamura and Steinsson (2014), Farhi and Werning (2016), Dupor and Guerrero (2017) and Chodorow-Reich (2017), which show that subnational multipliers differ from aggregate multipliers. Other studies such as Dellas et al. (2005), Beetsma and Giuliodori (2011), Corsetti et al. (2012a), Born, Juessen, et al. (2013), Ilzetzki et al. (2013), Kim (2015), Farhi and Werning (2016) and Koh (2017) suggest that what makes countries heterogeneous are macroeconomic fundamentals, such as capital mobility, trade openness, exchange rate regime, level of debt, economic development and the business cycle, and because of this elements, the size of the fiscal multiplier changes across countries too[1]. These studies show that the response of private consumption to a government spending shock changes from country to country. None of the previous studies focuses on the differences in long run inflation between countries as a source of heterogeneity in explaining the differences in the response of private consumption between countries, which is what I do in this paper empirically and in a DSGE model.

In the first part of the analysis, I explore the evidence on the impacts of government spending shocks on output, private consumption, real wages and inflation in 34 OECD countries for the period 1995-2017 with a quarterly frequency. Specifically, I estimate a panel VAR and identify government spending shocks using the approach proposed by Blanchard and Perotti (2002). An exogenous increase in government spending causes a rise in output, a positive response private consumption, a positive hump shaped of real wage, which follows an initial decline in inflation for the first 10 periods, to be turned positive after, as the government spending shock goes to low levels. The positive[2] response of private consumption to government spending shock was also confirmed by Blanchard and Perotti (2002), Bouakez and Rebei (2007), Gali et al. (2007) and Lewis and Winkler (2017) concluding that, empirically private consumption is crowded in by government spending.

Secondly, I investigate if the countries that have a different long run rate of inflation have a different response on private consumption. I find that private consumption reacts more to government spending shocks in countries with high long run inflation than in countries with low long run inflation due to higher inflation expectations in those countries. On max impact, private consumption reacts almost 4 times more in high inflation countries than in low inflation countries. Due to the inflation channel, inflation expectations are higher in countries with

[1]For a more detailed review of the literature on fiscal multipliers see Ramey (2011a) and (2019)

[2]Other empirical studies such as Ramey and Shapiro (1999), Edelberg et al. (1999),Ramey (2011b) suggest that under a narrative identification of the government spending shock, a negative response on private consumption is obtained. While Burnside et al. (2004) and Mountford and Uhlig (2009) argue that the consumption response is insignificant when faced with government spending shock.

higher inflation, this leads to lower interest rates, and as consequence this leads to higher private consumption. On one level, this result confirms that the country characteristics are important in explaining the response of private consumption when faced with government spending shocks. Under different modelling choices for the panel VAR and different lag selections I test the robustness of the obtained results. All in all, the most important idea from the empirical results is confirmed, that the importance of high long run inflation in explaining the response of private consumption to a government spending shock is robust.

Evidence of such empirical results provide the core motivation which I use in explaining the response of private consumption to government spending shocks in a DSGE model. I introduce a government sector in a general New Keynesian model. I focus on a straightforward formulation where government spending is financed by lump sum taxes. Government spending is assumed to enter the utility function in a non-separable way, making it complementary with private consumption as suggested by Bouakez and Rebei (2007) [3]. The usefulness of government spending by entering it the utility function, allows to the households to get some utility out of it. Taking into account the empirical suggestion for having a higher inflation in the economy model, one perspective would be adding trend inflation into a small-scale DSGE model to explain the effects of government spending shocks on private consumption. Trend inflation causes the Philips curve being flatter and makes inflation less sensitive to current marginal costs. The Philips curve now will depend more on expected future inflation, and less on marginal costs, making the firms more forward looking.

The baseline results from the model show that for a 1% increase in government spending private consumption increases almost by 0.3% in the first period. The an increase in government spending produces a crowding in effect on private consumption, because the complimentarity

[3] They argue that when government spending and private consumption are complementary, a government spending shock is able to produce a crowding in effect on private consumption. There is a wide literature that has shown that the Real Business Cycle model and the New Keynesian model are not able to simulate an increase in private consumption after an increase in government consumption. One solution to this puzzle is to assume that private consumption and government spending are Edgeworth complementary, which I use in the baseline model.

effect is strong enough to overcome the standard negative wealth effect.[4] Further labor increases, while the real interest rate has an initial increases which drops after a few periods as the decline in inflation shows lower magnitude.

Focusing on the importance of trend inflation and its effect, the main result of this paper is that trend inflation amplifies the response of private consumption to the government spending shock. Now, for an increase of 1% in government spending, on max impact the model generates a response of 0.35% in private consumption, when trend inflation is 2%, and 0.45% and 0.6% respectively when trend inflation is 4% and 6%, increasing the persistence in the results more and more. At higher rates of trend inflation price−setting firms are more forward−looking, they react less to the increase in private consumption, so that inflation reacts less, becoming more persistent, and the interest rate increases more, by inducing a larger reaction of consumption due to the Euler equation.

As a further step I look at the behaviour of the results under different parameter specifications. I find that the influence of trend inflation in the results is subject of the persistence of the government spending shock, on how strong the complementarity between private consumption and government spending is and is highly driven by the parameter governing Frisch labour supply elasticity. On the other hand, the choice of the Taylor rule influences the magnitude of the effect of trend inflation, but not the general idea of the response of private consumption. The consumption multipliers calculated with the standard approaches as suggested by the literature[5], for both the times series results and the DSGE model are in line with previous studies[6] ranging between 0.6−1 for low inflation countries as defined empirically and in the case of the DSGE model with low trend inflation. For a higher trend inflation in the model or high long run inflation empirically, the consumption multipliers are above 1. The values of the consumption multipliers confirm empirically and theoretically that the level of inflation in countries matters

[4] An increase in government spending as argued by Baxter and King (1993), which is expected to be financed by current or future lump-sum taxes, has a negative wealth effect which decreases private consumption. While on the other side, workers want to work more, and this induces a rise in labor supply at any given wage. This will lead to a lower wage in the future, higher employment and lower output.

[5] See Blanchard and Perotti (2002) and Mountford and Uhlig (2009) for more on this topic

[6] A review of the empirical and NK models multipliers is provided in Ramey (2019)

for the effects of government spending on private consumption.

As a robustness check for the main results of the model, I rely on the assumption that the period utility function of the representative agent is assumed to be non-separable in consumption (C) and labor (N) as in Greenwood et al. (1988). In this model the wealth effect on labor supply is shut off, suggesting that government spending can influence positively private consumption as long as labor and consumption are complements. Under GHH preferences, trend inflation, when comparing the model with 0% and 4% trend inflation cases, amplifies the positive response of private consumption to the shock but with a lower magnitude than in the case where I assumed government spending and private consumption complementarity.

To bring some intuition why trend inflation is important for DSGE models in order to justify using trend inflation as a way of having more inflation in the steady state of the model, lets see some background of it. After the latest financial crisis, many economies experienced the zero lower bound constraint on monetary policy and faced its implications. One of the proposals that policy makers and economists did such as Blanchard, Dell'Ariccia, et al. (2010), was that central banks should have increased their inflation targets. In line with this development in the policy making and in the economic literature, amongst other studies[7], brings the necessity of looking at the effects of government spending shocks under higher inflation levels in the steady state[8].

This paper is organized as follows: Section 2 empirically estimates the effects of government spending shocks on private consumption using a panel SVAR model. The purpose of the panel SVAR evidence in here is to provide motivation and empirical evidence about the effects of the shocks in countries with high and low long run inflation level. Section 3 presents the model economy and its features. I discuss the dynamics of trend inflation and its implications on the economy. In section 4, I present the results and comment their importance. Further is presented an estimation of the consumption multipliers from both the DSGE model and the

[7]see Ascari and Sbordone (2014) and Cooke and Kara (2018) for the effects of monetary policy and technology shocks under trend inflation

[8]As argued by Ascari, Phaneuf, et al. (2018), "Implementing such proposals over a sufficiently long period of time would eventually lead to higher long-run or trend inflation", page 56.

Panel SVAR. In section 5, I provide an alternative model specification as robustness. Finally, Section 6 concludes.

2 Related literature

Other papers, related to the effects of government spending shocks on private consumption empirically, such as Ramey and Shapiro (1999), suggest that military spending affects consumption negatively, while Blanchard and Perotti (2002), concludes that empirically private consumption is crowded in by government spending. Similar empirical findings were also found in M. Ravn et al. (2012) and Corsetti et al. (2012a). Most of the previous mentioned studies have brought results regarding the US, while as in this study I focus on a panel of countries, a larger evidence for support is required. Monacelli and Perotti (2010) focus on 4 countries, the US, Canada, Australia and Great Britain and show that they differ in terms of the response of private consumption. On a panel approach for the same countries M. Ravn et al. (2012) report positive results on private consumption. A number of other studies tried to explain the empirical response of consumption using different states/elements of the economy, show heterogeneity among countries. Auerbach and Gorodnichenko (2012), find that in the OECD countries private consumption is crowded out in expansions and appears to be increasing in recessions. Beetsma and Giuliodori (2011), studying government purchases shocks in open and closed economies, arrive at the conclusion that the more open an economy is, the lower the response of consumption will be. Corsetti et al. (2012a) finds out that the impact on consumption is not necessarily different under a peg regime compared to a flexible one, there is no difference in the response when debt is high or low , while when in a crisis situation consumption rise almost twice as the increase of government spending. Huidrom et al. (2016) thinks differently than Corsetti et al. (2012a), where in a panel of advanced and developing economies, they show that when the fiscal position is weak, consumption falls, and when fiscal position is strong (government debt and deficits are low), the effect on consumption is positive. While Ilzetzki et al. (2013)

brings evidence that private consumption is positive in the case of the pegged regime turning negative only at a later stage, while in the case of the flexible exchange regime the response of consumption is always negative. Koh (2017) goes further where in a large panel countries data set brings evidence that in economies with high capital mobility private consumption increases.

This paper is related theoretically, mainly to other DSGE papers that study the size of fiscal multipliers under different macroeconomic fundamentals or economy features and DSGE papers that study the effects of government spending shocks in an economy and specifically on private consumption. A few papers to be mentioned that have dealt with generating a positive private consumption response to government spending shocks same as in the empirical literature are: Linnemann (2006) which relies on a utility function with not additively separable in consumption and leisure, Bouakez and Rebei (2007), who focuses on the fact that private and public spending are Edgeworth complementary, Gali et al. (2007) considers rule of thumb consumers, while M. Ravn et al. (2012) uses a model with deep habits. Corsetti et al. (2012b), uses a New Keynesian model with expected spending reversals, while Bilbiie (2011) shows that when the utility function shows certain properties and under non-separable preferences over consumption and leisure, the Real Business Cycle model can generate an increase in private consumption in response to government spending shock. Dupor, Liz, et al. (2017), demonstrates that one doesn't need any of the previous ingredients to cause an increase in consumption, it just can be done by adding nominal wage rigidity to a standard, closed economy with sticky prices. On this paper I rely on the solution provided by Bouakez and Rebei (2007) and for robustness I use the preferences of Greenwood et al. (1988), satisfying Bilbiie (2011) properties.

In terms of fiscal multipliers this paper is close to other papers such as the ones of Christiano et al. (2011), Mertens and M. O. Ravn (2014) and Farhi and Werning (2016) that argue that the size of the government spending multiplier can be larger when the nominal interest rate is on the zero lower bound[9]. Born, Juessen, et al. (2013), in a New Keynesian model find that government spending multipliers are larger under fixed exchange rate regimes than in flexible

[9] Other papers, for example, that have looked at liquidity traps and fiscal multipliers are Woodford (2011), Kara and Sin (2018), etc

exchange rate regimes. Farhi and Werning (2016) considers the multipliers in a currency union, and show that self-financed multipliers are always below unity, while outside-financed multipliers can be larger. Cacciatore and Traum (2018) shows that high trade can imply that domestic multipliers are larger than in the case of low trade dynamics. Another closely related paper to this one, is the one of Sims and Wolff (2018), that studies the effects of changes in government spending highlighting monetary passiveness situations. There is also a growing literature on fiscal multipliers taking into account heterogeneous agents models with incomplete markets, featuring that households have different marginal propensities to consume[10].

3 Panel VAR Analysis

In this section I present the empirical results of the effects of government spending on private consumption, following a Panel VAR framework. Initially, I start the analysis using a mean group estimator panel on 34 OECD countries and explain the data. Secondly, I discuss the effects of a government spending shock on private consumption, and show how the results are different when I split the country sample according to their level of long run inflation. Thirdly, I show that the results obtained from this framework are robust under different modelling choices of the Panel VAR.

3.1 Specification

a. A mean group estimator panel VAR. In this paper, in order to obtain the pooled results from the impulse responses I use a mean group estimator as described by in Pesaran and Smith (1995)[11]. This estimator, which relies in a maximum likelihood framework, allows taking into account the cross sectional dimension of the data and doesn't require information about the economic structure of the countries and neither about their differences. Pesaran and Smith (1995) estimator allows for country heterogeneity and produces parameters which are

[10]For more on this see Mitman et al. (2017), Auclert et al. (2018) and Bilbiie (2017)

[11]To estimate this panel VAR I use the BEAR toolbox v. 4.2 as documented in Dieppe et al. (2016)

means of the group of countries used. The panel VAR model that I consider has the following representation:

$$y_{i,t} = A_i^p y_{i,t-p} + C_i x_t + \varepsilon_{i,t} \tag{1}$$

where the errors are normally distributed and the residual variance-covariance matrix is heterogeneous across countries, but characterized by a common mean $\varepsilon_{i,t} \sim N(0, \sum_i)$. $y_{i,t}$ denotes a vector comprising the n endogenous variables of unit i at time t, while p shows the lag of the variable. x_t is the vector of exogenous variables, while A and C are respectively matrices of coefficients providing the response of unit i to the p^{th} lag of variable m of unit j at period t and the response of the endogenous variables to the exogenous ones, $\varepsilon_{i,t}$ is a vector of residuals for the variables of unit i. Transposing (1) and writing it in a compact form after vectorizing it, brings the following equation:

$$y_i = \bar{X}_i \beta_i + \varepsilon_i \tag{2}$$

For each unit of i the mean group estimator assumes:

$$\beta_i = b + b_i \tag{3}$$

which shows that the coefficients of the VAR in different units will differ, while the means and variances will be similar. Since the parameter of interest is the mean effect b,the mean group estimator would be:

$$\hat{b} = \frac{1}{N} \sum_{i=1}^{N} \hat{\beta}_i \tag{4}$$

A similar approach is done for the mean-group estimate of the residual variance $-$ co-variance matrix $\sum$.

b. Identification strategy. This paper uses the Blanchard and Perotti (2002) approach, adopting a Cholesky decomposition where government spending are ordered first. Government spending is predetermined relative to the other variables, responding with min one lag delay to other shocks than to itself. The ordering of the endogenous variables will be as follows:

$$\bar{X}_i = \begin{pmatrix} G \\ Y \\ C \\ W \\ \pi \end{pmatrix} \tag{5}$$

Where G denotes government consumption, Y is the GDP, C private consumption, W denotes wages and π is the y-o-y quarterly inflation growth. Identifying government spending shocks has been a challenge in the literature in the last decade, where many influential papers have lead the area, deepening the debate on fiscal shocks. Alternative identification methods are summarised by Ramey (2016) for government spending shocks as follows: SVARs with contemporaneous restrictions, sign restrictions, medium horizons restrictions, narrative methods, and using DSGE models. The use of different identification techniques has not always been producing consistent results on the response of consumption, as pointed out by Hebous (2011). The choice of identification does matter, but on this paper I will be focusing on the first method as it allows me to compare results from different samples more clearly.

c. Data. The data are all used in real term dollars[12], in logarithmic form, re-scaled[13], seasonally adjusted and detrended using a linear trend in order to deal with the problem of non-stationarity[14]. I used the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) to chose the number of lags to be included in the panel VARs reported. The tests are more prone to using 1 or 2 lags rather than 3 or 4 which are often more used in quarterly datasets as in the case of this paper, though the results change only slightly with

[12] A summary statistics of the data is presented in Appendix A

[13] Multiplied by 100

[14] The Breitung panel unit root test suggest that the panels contain unit roots, while the Im-Pesaran-Shin panel unit root test indicates that all the panels have unit roots in the cases of government spending and wages. The empirical results proved that detrending the variables with a linear trend, except for the case of Inflation which I do not detrend as it is on growth values, proves superior in obtaining the standard hump shaped response of private consumption, compared to the case of detrending with a hp filter.

adding more lags. As results prove to be more consistent on different samples when I use 2 lags, this choice is kept in all the estimations, making sure that results on different case are not driven by a different lag choice. The data set used, includes a quarterly balanced panel of 34 OECD countries[15] from 1995Q1 − 2017Q4. I split the countries in low and high inflation countries, depending on the long run inflation rate, calculated as an average of the period that the panel is estimated. If a country has an average long run inflation of more than 2.5, the country is considered to be a high inflation country while below this line the country is considered to be low inflation country[16]. The quarterly feature in the data is important for the identification of shocks, especially when using the Blanchard and Perotti (2002) identification technique, as it allows ruling out the contemporaneous response of government spending. Ilzetzki et al. (2013) argues that " while... fiscal authorities require a quarter to respond to shocks , it is unrealistic to assume that an entire year is necessary" (p.241). Though, the use of yearly frequencies is not ruled out by the empirical evidence of Born and Mueller (2012), the government spending shocks on a yearly basis might be influenced by the anticipated effects suggested by Ramey (2011b). The data for the 5 endogenous variables are taken from the OECD statistics database[17].

3.2 Empirical results

In Figure 1 I report the impulse responses from the baseline panel VAR model for the 34 OECD countries. The blue line displays the point of the estimate, while the red lines asides give the 90% confidence bands. On the left side of each graph is found the name of each variable, while the vertical axes show the amplitude of the impulse responses in %. In the horizontal axes is given the periods of study, which amount to a total of 30 quarters. On Figure 1 are shown the impulse responses of 5 variables G, Y, C, W and π, in response to a government

[15]Turkey and the US is left out of the sample as the first has a more volatile inflation rate, while the second is characterized as a large economy

[16]19 countries from the sample fit into the criteria of being low inflation countries, while 15 of them are considered high inflation countries

[17]The notion of private consumption it refers to the notion of "$P31S14_{S1}5$ Private final consumption expenditure " and of government spending it refers to "$P3S13$ General government final consumption expenditure " as used by the OCED statistics

spending shock of around 1.2%. On impact output and consumption responds positively to the government spending shock both by around 0.14%. On all periods both the response of consumption and output is positive, and shows a to have a hump shaped response, though the effect on output ends sooner than in the case of consumption. The positive response of consumption on direction seems to be in line with many other studies such as Blanchard and Perotti (2002), Gali et al. (2007) etc, while the size of the response is similar to the ones seen in Bouakez and Rebei (2007), M. Ravn et al. (2012) and Lewis and Winkler (2017). The real wage also increases following the shock, displaying a hump shaped response with a max at its 5th quarter, an increase also seen in Fatas and Mihov (2001) and Bouakez and Rebei (2007).

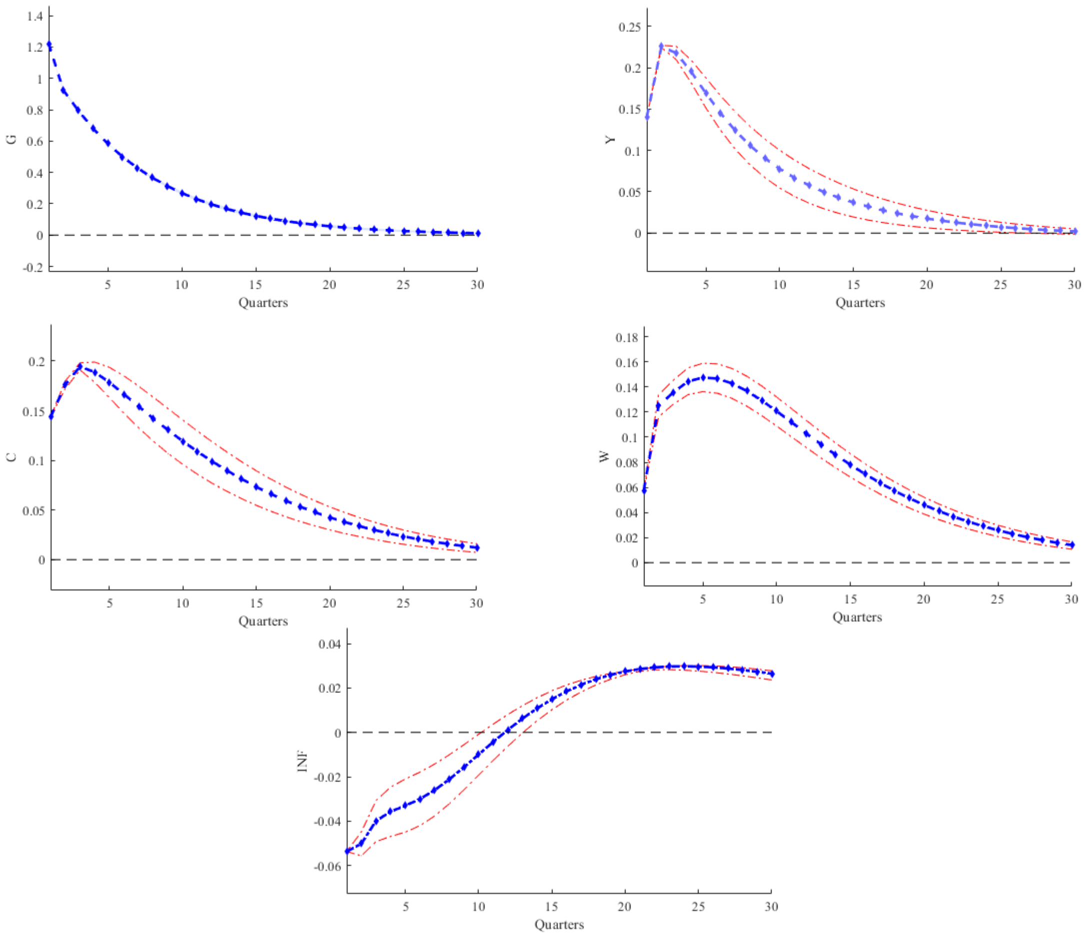

Figure 1: Impulse Responses to a Government Spending Shock in a Panel VAR

NOTES: The figure presents the impulse responses of output (Y), private consumption (C), Wages (W) and the quarterly Inflation y-o-y growth rate (INF) to a 1.2% government spending shock. One period corresponds to 1 quarter on the horizontal axis and the response in percentage is reported on the vertical axis. Red lines represent 90% confidence intervals based on Monte Carlo simulations.

The response of inflation is almost significant, where after the impact period the value of inflation is negative till the 12fth period, becoming positive after but close to zero. Similar response, but less volatile of inflation[18] to a government spending shock is also seen in Corsetti et al. (2012b) and Erceg and Linde (2014).

As discussed in the data description I have divided the sample according to the long run inflation rate[19] and I have run the panel VAR on each of the samples. The panel VAR is run on the same variables as on the baseline panel and the same log choice is kept as in the baseline. In Figure 2, I present only the responses of private consumption to a government spending shock on both cases and compare them. On the left hand side an increase in government spending induces an initial impact of 0.25% in private consumption, corresponding to the response in high inflation countries. The response of private consumption in this case is statistically significant and shows a higher response than in the baseline case. On the right hand side a shock in government spending causes an initial effect of 0.015% in private consumption in low inflation countries, being almost 10 times lower than in the case of the increase in private consumption in the baseline results.

On max impact point, there is a response of private consumption to the government consumption shocks of 0.32% and 0.08% respectively in the cases of high and low inflation countries, almost 4 times higher response. The maximum response happens around the 3rd period for both cases while it continues its marginal effects toward zero. The dynamic adjustment is hump−shaped under both country cases, but more strongly so in countries with high long run inflation rates. The main results in here is that, private consumption increases less in low inflation countries than in high inflation countries. The difference in the impulse responses is 3-4 times between the two cases and continues to persist almost all the period.

[18] A detailed survey of the response of Inflation to government spending shocks is given in Jorgensen and S. H. Ravn (2018), which themselves they find that the reponse of inflation is mainly negative

[19] The long run inflation rate is calculated as the average inflation rate for the whole period

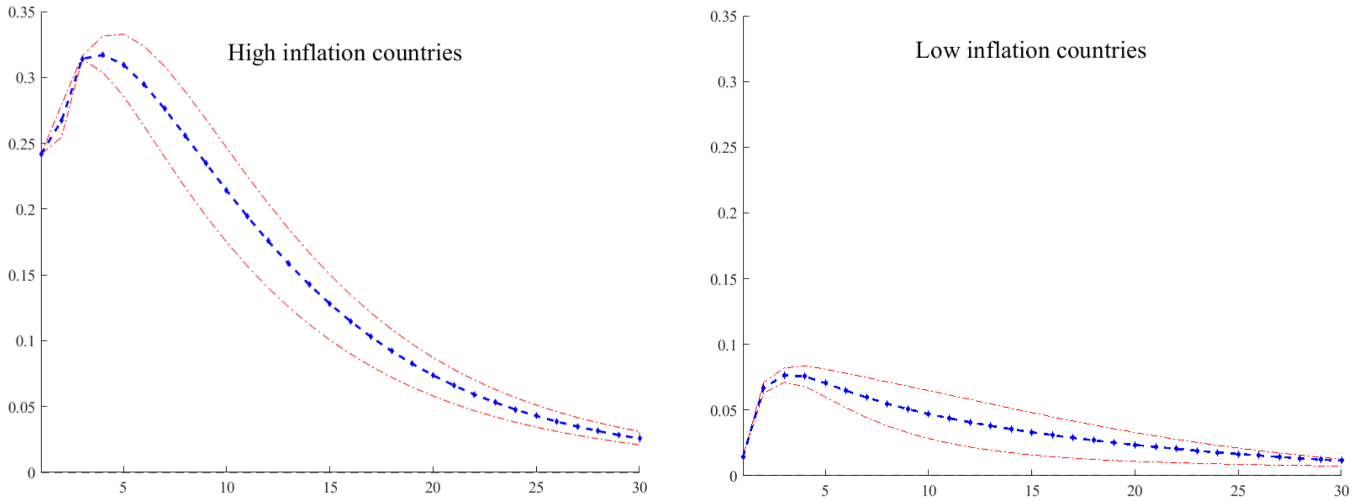

Figure 2: Impulse Responses of Private Consumption to a Government Spending Shock in High and Low Inflation Countries

NOTES: The figure presents the impulse responses of private consumption (C) to a 1.2% government spending shock. One period corresponds to 1 quarter on the horizontal axis and the response in percentage is reported on the vertical axis. On the left are presented the High inflation countries and on the right the Low inflation countries. Red lines represent 90% confidence intervals based on Monte Carlo simulations.

A possible explanation to these results could be the fact that in countries with high long run inflation, as argued by Dupor and Li (2015), due to higher inflation expectations, the interest rate goes down, and this leads to an increase in private consumption. Alternatively, due to the monetary policy high effectivity being larger in low inflation countries, fiscal policy becomes less expansionary, and lower fiscal multipliers are expected.

3.3 Robustness

In this subsection I perform robustness checks for the main results obtained in the baseline panel VAR investigating private consumption in low vs high inflation environment. As I already discussed in the data subsection about the choice of different lags, I focus here on robustness related with the modelling choices of the Panel VAR. I consider three alternative choices[20].

a. Countries VARs. Initially I run separate VARs on each country on the sample, keeping the same number of lags, and other specifications mentioned on the data description. According to the definition of low and high inflation countries, further I take the averages of the impulses responses of both groups.

b. A pooled Bayesian estimator. Secondly, I relax all the properties of the Panel VAR, and I use a Bayesian pooled estimator to re-obtain the results from the baseline panel VAR. In this model the data comes all as from many units, and the dynamic coefficients are homogeneous across units. The identification strategy used for the priors relies on a normal-Wishart distribution.

c. A hierarchical panel VAR. Thirdly, focusing more on the issue of heterogeneity between countries, I estimate a hierarchical panel VAR as proposed by Jarocinski (2010). This model recognizes and uses the heterogeneity among the countries and brings estimations for each of the countries allowing for cross country comparisons. This methodology relies on Bayesian estimation where the coefficients of the VAR differ across units, but are drawn from a distribution with similar mean and variance.

$$\beta_i \sim N(b, \sum_b) \tag{6}$$

The distribution of the vectors for the coefficients β_i is still normal, but now with a common mean b and common variance $\sum_b$. As in the case of the single countries VARs, here as well for comparison reasons I take the averages of the impulses responses of both groups.

d. Robustness Results. Overall, the key findings from the benchmark specification on

[20]The VARs and panel VARs in this section are estimated using the BEAR toolbox v. 4.2 as documented in Dieppe et al. (2016)

the response of private consumption to a government spending shock under specific environment of inflation, stand and are confirmed. In figure 3, I present the results of the impulse responses for all the three alternative modelling choices, grouping the responses of private consumption to a government spending shock on high inflation countries on the left, while on the right the responses in low inflation countries. In each case, I present the point estimates of the impulse responses obtained under the alternatives, which are statistically significant on a 90% confidence interval.

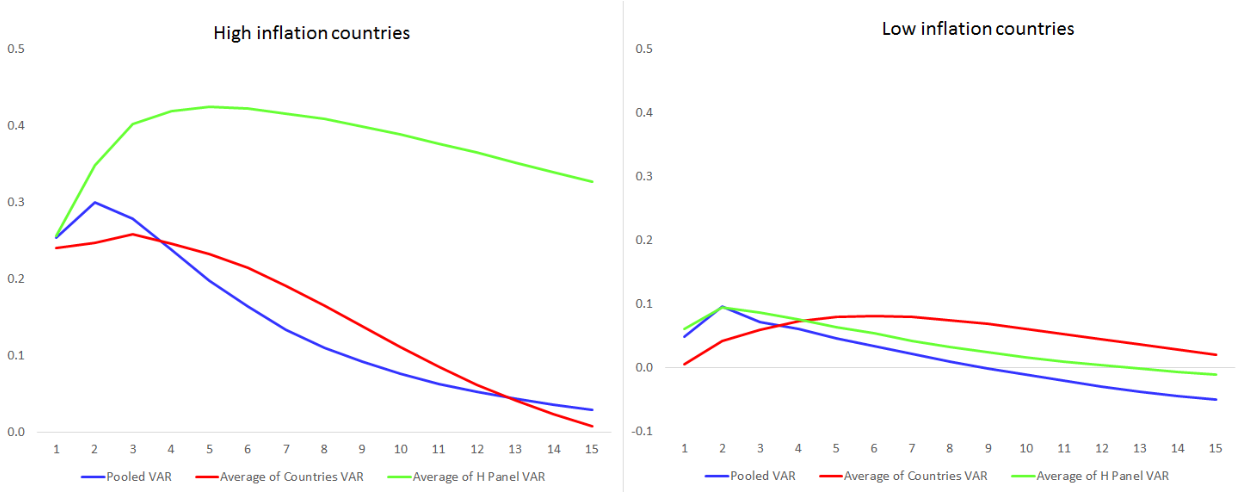

Figure 3: Impulse Responses of Private Consumption to a Government Spending Shock in High and Low Inflation Countries under Alternative Modelling Choices

NOTES: The figure presents the impulse responses of private consumption (C) to a 1.2% government spending shock. One period corresponds to 1 quarter on the horizontal axis and the response in percentage is reported on the vertical axis. On the left are presented the High inflation countries and on the right the low inflation countries. Blue lines represent the impulse responses from the Pooled VAR, the red lines represent the impulses from the average of all individual countries VAR and the green lines represent the impulses of the average of the countries from the Hierarchical Panel VAR

For all the alternative modelling choices, a positive government spending shock is found to be followed by a positive response of private consumption. All in all, the response of private consumption is higher in countries with high long run inflation under all the modelling choices. There does not seem to be high differences between the three alternative approaches and the baseline one, with the exception that the response of private consumption on high inflation countries on average is higher when the results are obtained with a hierarchical panel VAR than with a mean group estimator panel[21].

4 Small-scale DSGE model with trend inflation

This section describes the features of the model, which I develop to rationalize the empirical evidence presented in the previous section.. The model that I use is a generalized New Keynesian model with trend inflation, and with a government sector. I study the effect of the government spending shocks on private consumption and the size of the fiscal multipliers. I explain how an increase in trend inflation amplifies the response of private consumption to a government spending shock. In what follows I introduce the sectors of the economy, the dynamics of the model, present pricing equations, discuss the role of trend inflation and the specifications of fiscal policy. A more detailed description of the economy is given in the Appendix.

4.1 Households

The economy is populated by a representative agent, that is infinitely lived, and derives a utility function, which is assumed to be non-separable in consumption (C_t) and government spending (G_t). I follow Bouakez and Rebei (2007) in assuming non-separability[22] between private consumption and government spending to get a positive response of private consumption to a government spending shock[23]. This specification would allow for usefulness of government spending and would make possible generating a crowding in effect of government spending. The

[21] As an additional robustness measure I tried different versions of splitting the sample of countries and I wasn't able to find much action in the impulse response as in the case where I take into account the level of inflation.

[22] Here is assumed public spending shows Edgeworth complementarity with the private ones.

[23] Other way of obtaining a positive response of private consumption to government spending I would as well be having a utility function with GHH prefernces, where the labor effect is shut down and consumption (C_t) and labor (N_t) are complements.

typical representative agent seeks to maximize the following utility function:

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j U(\widetilde{C}_t, N_t) \tag{7}$$

The utility function is assumed to be continuous and twice differentiable. $\widetilde{C}_t$ is the aggregate consumption bundle, and $\widetilde{C}_t$ is a constant elasticity of substitution aggregate consisting of private consumption C_t and government consumption G_t:

$$\widetilde{C}_t = \left[\delta^{\chi} C_t^{1-\chi} + (1-\delta)^{\chi} G_t^{1-\chi}\right]^{\frac{1}{1-\chi}} \tag{8}$$

Where δ is the share of private consumption in the aggregate consumption bundle, and χ is the inverse elasticity of substitution between private consumption and government consumption[24]. The utility function is non-decreasing in government consumption G_t.

C_t is the private consumption of goods and this composite consumption good is given by: $C_t = \left[\int_0^1 C_{t,j}^{1-\frac{1}{\varepsilon}}\right]$, where $C_{t,j}$ represents the quantity of good j consumed by the household in period t, and it is assumed that the existence of a continuum of goods is given by the interval $[0,1]$. The household allocates its consumption expenditures among the different goods, by maximizing C_t for any given level of expenditures $\int_0^1 P_{t,j} C_{t,j} dj$[25]. The solution of this problem would yield the demand for good j, $C_{t,j} = \left(\frac{P_{t,j}}{P_t}\right)^{-\varepsilon} C_t$ for all $j \epsilon [0,1]$, and with ϵ being the elasticity between the goods in the economy. The aggregate price index is given as $P_t \equiv \left[\int_0^1 P_{t,j}^{1-\varepsilon} dj\right]^{1-\frac{1}{\varepsilon}}$, and the total consumption expenditures can be written as the product of the price index times the quantity index $\int_0^1 P_{t,j} C_{t,j} dj = P_t C_t$.

The maximization of utility function is subject to the following budget constraint:

$$P_t C_t + (1+i_t)^{-1} B_t = W_t N_t + D_t + B_{t-1} - T_t \tag{9}$$

[24] A similar modified form to is seen also in Troug (2017) and Pieschacon (2012)

[25] The proof of this is shown appendix 3.1 in Gali (2008b)

where i_t is the nominal interest rate, B_t is one-period bond holdings, W_t is the nominal wage rate, N_t is the labor input, and D_t is profits (distributed dividends), and the households pays taxes to the government, where T_t is a lump sum tax and doesn't influence the household decisions or working or not. Each period the household is endowed with one unit of time, which is divided between work and leisure $N_t + L_t = 1$. Obtaining the first order condition from the optimization problem of the agent would yield the following Euler equation:

$$1 = \beta(1+i_t)\mathbb{E}_t\left[\left(\frac{P_t}{P_{t+1}}\right)\left(\frac{\widetilde{C}_{t+1}}{\widetilde{C}_t}\right)^{\chi-\sigma}\left(\frac{C_{t+1}}{C_t}\right)^{-\chi}\right] \tag{10}$$

The Euler equation shows the smoothing of consumption over time and depends from the two parameters χ and σ. The complementarity between government spending and private consumption doesn't depend only on the value of χ, but also on the interaction with σ. In order for government spending and private consumption to be considered complementary, it is necessary that $\chi > \sigma$. If $\chi = \sigma$, the Euler equation would transform in its standard form. The case where $\chi < \sigma$, makes government spending and private consumption being substitutes of each other. The aggregate consumption bundle variable also appears in the equation, prior to the standard elements of the equation. And the labor supply equation is:

$$\frac{W_t}{P_t} = d_n e^{\varsigma_t} N^{\varphi} \overline{C}_t^{\sigma}\left(\frac{C_t}{\widetilde{C}_t}\right)^{\chi}\delta^{-\chi} \tag{11}$$

where ς_t is the labor supply shock, β is the intertemporal discount factor, σ is the intertemporal elasticity of substitution in consumption, φ is the inverse Frisch elasticity of labor supply. While the labor supply equation presented in nominal terms, shows that it depends on the aggregate consumption bundle, additional to the consumption variable, the labor supply which is governed by the inverse Frisch elasticity parameter, and the parameters related to the behaviour of consumption and government spending. A similar interpretation regarding the parameters χ and σ is done also for the labor supply equation. When $\chi > \sigma$, which is crucial for obtaining government spending and private consumption complementarity as discussed above, government spending will have a negative effect on real wages, as it influences positively labour supply.

4.2 Firms

The firms in this economy chose prices in order to maximize their profits, subject to three constraints, their production function summarizing the available technology, second the constraint given by the demand curve each firm faces, and the third that in each period some firms are not able to adjust their prices. while others can.

a.Technology. In each period t, a final good, Y_t, is produced by perfectly competitive firms, which combine a continuum of intermediate inputs $Y_{j,t}, j \in [0,1]$, via the technology: $Y_t = \left[\int_0^1 y_{j,t}^{\frac{\varepsilon-1}{\varepsilon}} dj\right]^{\frac{\varepsilon-1}{\varepsilon}}$ where $\varepsilon > 1$ is the elasticity of substitution among intermediate goods following the standard constant elasticity of substitution (CES) production function. The zero profit condition and profit maximization implies that the price index associated with the final good Y_t which is a CES aggregate of the prices of the intermediate inputs $P_{i,t}$ where: $P_t = \left[\int_0^1 P_{j,t}^{1-\varepsilon} dj\right]^{\frac{\varepsilon-1}{\varepsilon}}$, and the optimal demand for intermediate inputs is $Y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon} Y_t$. The production function of intermediate goods and the labor demand of firm j are respectively:

$$Y_{j,t} = A_t N_{j,t} \text{ and } N_{j,t}^d = \left[\frac{Y_{j,t}}{A_t}\right] \tag{12}$$

where A_t is an exogenous process for the level of technology. The labor demand of firm is positive to the production function and is related inversely to the level of technology. While on the other hand, intermediate inputs are produced by a continuum of firms with a simple linear technology in labor, which is the only input of production. The total cost and real marginal costs are given by:

$$TC_{j,t}^r = \frac{W_t}{P_t} N_{j,t} \text{ and } MC_{j,t}^r = \frac{W_t}{A_t P_t} \tag{13}$$

Nominal wages are set in perfectly competitive markets and are the same across firms. An increase in real wage would as consequently increase the marginal costs of the firm, while a better technology would enable the firm to produce at a better level of marginal costs, decreasing them.

b. Profit maximization. The prices are based on the specific model of price stickiness used by Calvo (1983), where a fraction of firms re-optimize their nominal price with fixed probability $1-\theta$, while with probability θ it maintains the price charged in the previous period. The parameter θ measures the degree of nominal rigidity; a higher θ means that fewer firms re-optimize their price each period and a longer time is needed for the price changes to happen.

The problem of firm j who re-optimizes prices is to choose $P^*_{j,t}$ to maximize expected profits, and it can do so by solving the problem:

$$\max_{P^*_{j,t}} \mathbb{E}_t{}_{l=0}^{\infty}\theta^j D_{t,t+l}\left[\frac{P^*_{j,t}}{P_{t+l}}Y_{i,t+l} - \frac{W_{t+l}}{P_{t+l}}\frac{Y_{j,t+l}}{A_{t+l}}\right] \quad \text{s.t the demand constraint } Y_{j,t+l} = \left(\frac{P^*_{j,t}}{P_{t+l}}\right)^{-\varepsilon} Y_{t+l} \tag{14}$$

where $D_{t,t+l} \equiv \beta^l \frac{\lambda_{t+l}}{\lambda_0}$ is the stochastic discount factor, and λ_{t+l}, the marginal utility of consumption. The firm's first order condition by re-arranging would yield:

$$p^*_{j,t} = \frac{\varepsilon}{(\varepsilon-1)}\frac{\psi_t}{\phi_t} \tag{15}$$

The auxiliary variables ψ_t and ϕ_t can be written recursively following Ascari and Ropele (2009) and Ascari and Sbordone (2014) as:

$$\psi_t = MC_t Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left[\pi^{\varepsilon}_{t+1}\psi_{t+1}\right] \text{ and } \phi_t = Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left[\pi^{\varepsilon-1}_{t+1}\phi_{t+1}\right] \tag{16}$$

They depend both on output and future expectations of inflation. ψ_t can be interpreted as the present discounted value of the marginal costs when the optimal reset price changes, while ϕ_t can be considered as the marginal revenues. ϵ and $\epsilon-1$ are respectively treated as the weights of the marginal costs and marginal revenues on resetting the optimal price in equation (15). As suggested by because $\epsilon > \epsilon - 1$, the future expected rate of inflation has a higher impact on the marginal costs of setting the price than on the marginal revenues. Returning to the aggregate price level, it evolves as Calvo (1983) prices and it can be expressed as:

$$P_t = \left[\int_0^1 P_{j,t}^{1-\varepsilon} di\right]^{1/(1-\varepsilon)} = \left[\theta P_{t-1}^{1-\varepsilon} + (1-\theta)\, P_{j,t}^{*\ 1-\varepsilon}\right]^{1/(1-\varepsilon)} \tag{17}$$

And a $\theta = 0$, would show the expression in the standard case with flexible prices. Reformulating the aggregate price equation, allows me to express it as follows:

$$p_{j,t}^{*} = \left(\frac{1-\theta\pi_t^{\varepsilon-1}}{1-\theta}\right)^{\frac{1}{1-\varepsilon}} \tag{18}$$

4.3 The Government and Monetary policy

Now I assume that the government[26] purchases quantity $G_t(j)$ of good j, for all $j \in [0,1]$:

$$G_t \equiv \left[\int_0^1 G_{t,j}^{1-\frac{1}{\varepsilon}} dj\right]^{\varepsilon/(\varepsilon-1)} \tag{19}$$

where the government seeks to maximize for any level of expenditures $\int_0^1 P_{t,j}G_{t,j}dj$. [27] Next, the government expenditures are financed by means of lump-sum taxes $P_{t,j}T_{t,j}$. Government spending evolves exogenously according to the following first order autoregressive process:

$$G_t = G_{t-1}^{\rho_G} \exp(\mu_{Gt}) \tag{20}$$

μ_{Gt} is an independent and identically distributed shock with zero mean and a constant variance.

Regarding monetary policy, the economy has a central bank that follows a conventional Taylor rule, with weight ϕ_π on deviations of inflation from target $\overline{\pi}$ and weight ϕ_y on output deviations from steady state output[28] $\widehat{Y}$:

[26] The government does not consume from the same market as households

[27] The government is assumed to allocate expenditures across goods in order to minimize total cost, acting in the same way as the household.

[28] There exists a debate on whether to use output growth or output gap as a measure of economic activity in the interest rules. When the model takes into account for positive trend inflation, it can lead to substantial welfare losses according to Sims (2013). Because I do not deal with welfare issues on this paper I use the output

$$\left(\frac{1+i_t}{1+\bar{i}}\right) = \left(\frac{1+i_{t-1}}{1+\bar{i}}\right)^{\rho_i} \left(\left(\frac{\pi_t}{\overline{\pi}}\right)^{\phi_\pi} \left(\frac{Y_t}{\overline{\overline{Y}}}\right)^{\phi_Y}\right)^{1-\rho_i} e^{v_t} \tag{21}$$

where v_t is a monetary policy shock which is *iid* with zero mean and a constant variance, and ϕ_π , $\overline{\pi}$ and ϕ_y are non-negative parameters. Some inertia is also added to the Taylor rule. $\bar{i}$ is the steady state interest rate and ρ_i is the inertia parameter.

4.4 Aggregation and price dispersion

The market clearing in the goods market requires: $Y_{t,j} = C_{t,j}$ for all $j \in [0, 1]$ and all t, or can be written as: $Y_t = C_t$. Further log-linearizing the Euler equation (10) and substituting there the log linear form of equation (9), I would obtain the dynamic IS curve as follows:

$$\widehat{C}_t = \mathbb{E}_t\widehat{C}_{t+1} - \frac{1}{\sigma_\delta}(i_t - \mathbb{E}_t\{\widehat{\pi}_{t+1}\}) + \frac{(\sigma - \sigma_\delta)}{\sigma_\delta}\mathbb{E}_t\Delta\widehat{G}_{t+1} \tag{22}$$

The Euler equation now is free from the aggregate consumption bundle variable, and is expressed in terms of C_t and G_t. $\sigma_\delta = (\chi(1-\delta) + \sigma\delta)$, and $\frac{1}{\sigma_\delta}$ gives the slope of the IS curve, which in the case that $\sigma_\delta > \sigma$, because $\chi > \sigma$ (government spending and private consumption are complementary) the slope of the IS curve decreases and the IS curve becomes flatter. Adding government spending into this economy, adds an extra term to the IS curve and causes a shift of the curve more into the right. When $\sigma_\delta = \sigma$, this would cause $\sigma_\delta = \sigma$. As consequence the government spending term would drop, and the slope of the IS curve would the same as in the standard case $\frac{1}{\sigma_\delta} = \frac{1}{\sigma}$. The same result would be obtained if the share of private consumption in the aggregate consumption bundle would be $\delta = 1$, which would mean that there is no government spending into this economy.

From the individual firms production function, and combining it with equation (12), by

gap.

aggregating over j, I derive the aggregate labor demand as:

$$N_t^d = \int_0^1 N_{j,t} dj = \int_0^1 \frac{Y_{j,t}}{A_t} dj = \frac{Y_t}{A_t} \underbrace{\int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon} dj}_{s_t} = \frac{Y_t}{A_t} s_t \tag{23}$$

As shown by equation (23), price dispersion influences the relationship between labor demand and output. I define the relative price dispersion measure as $s_t = \int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon} di$. The higher the dispersion of relative prices, the higher price dispersion s_t, and therefore a higher amount of labor input is needed for the production of a certain level of output (Ascari and Sbordone (2014). A increase in price dispersion, keeping constant output and the level of technology, from equation (11) would mean a higher wage which would convert in higher marginal costs for the firm (equation (13)) and therefore a higher discounted value of the marginal costs $\widehat{\psi}_t$ (equation (16)). As in Schmitt-Grohe and Uribe (2007), s_t can be written under the assumption of the Calvo model as follows:

$$s_t = (1-\theta)(p_{j,t}^*)^{-\varepsilon} + \theta \pi_t^{\varepsilon} s_{t-1} \tag{24}$$

Itself, price dispersion is dependent on inflation expectations, and increases the higher ε and θ.

4.5 The Generalized New Keynesian Philips Curve

In order to obtain the GNKPC in terms of marginal costs I log-linearize the firms equilibrium conditions around a steady state characterized by a shifting trend inflation. And then, following the standard approach I would have[29]:

$$\widehat{\pi}_t = k(\overline{\pi})\widehat{mc}_t + b_1(\overline{\pi})\mathbb{E}_t\widehat{\pi}_{t+1} + b_2(\overline{\pi})\left[(1-\sigma)\widehat{C}_t - \mathbb{E}_t\widehat{\psi}_{t+1}\right] \tag{25}$$

Where $\overline{\pi}$ represents trend inflation and the equation gives the Philips curve with the dynamics of inflation. The parameters on the Philips curve depending on trend inflation are respectively: $k(\overline{\pi}) = \frac{(1-\theta\overline{\pi}^{\varepsilon-1})(1-\theta\beta\overline{\pi}^{\varepsilon})}{\theta\overline{\pi}^{\varepsilon-1}}$, $b_1(\overline{\pi}) = \beta\left[1+\varepsilon(\overline{\pi}-1)(1-\theta\overline{\pi}^{\varepsilon-1})\right]$ and $b_2(\overline{\pi}) = \beta[1-\overline{\pi}](1-\theta\overline{\pi}^{\varepsilon-1})$.

[29] Variables with hat are expressed in log-linear form

Focusing on the New Keynesian Philips Curve in terms of the marginal costs, one can notice that compared to the standard Philip curve seen in textbooks such as Gali (2008b), it has some additional terms, which are functions of trend inflation. The extra term $\overline{\pi}$ on the term $k(\overline{\pi})$ which is the parameter governing the slope makes the Philips curve flatter. An increase in trend inflation $\overline{\pi}$ decreases the slope $k(\overline{\pi})$, and makes inflation less sensitive to current marginal costs. A value of trend $\overline{\pi} = 1$, which means that the steady state of inflation is zero, would cause $k(1) = \frac{(1-\theta)(1-\theta\beta)}{\theta}$ transforming the parameter as in the standard slope of New Keynesian Philips. Trend inflation reduces the weight of determining inflation from current marginal costs by reducing $k(\overline{\pi})$ and on the other side by increasing $b_1(\overline{\pi})$, increases the weight on expected future inflation. Now the curve depends more on expected future inflation, and less on marginal costs[30]. In the standard case $b_1 = \beta$, and in this case the curve would depend less on expected future inflation.

An additional term appears on the Philips curve on the right hand side which shifts at some level the Philips curve depending positively by the level of private consumption and negatively by the discounted value of the marginal costs at period $t+1$ and governed by the parameter $b_2(\overline{\pi}) = \beta\left[1-\overline{\pi}\right]\left(1-\theta\overline{\pi}^{\varepsilon-1}\right)$ dependent on trend inflation, which shows the dynamics changes happening in the marginal costs and private consumption. A value of trend $\overline{\pi} = 1$, which means that the steady state of inflation is zero, would cause a $b_2 = 0$, $k(\overline{\pi}) = \frac{(1-\theta)(1-\theta\beta)}{\theta}$ and $b_1(\overline{\pi}) = \beta$, transforming the New Keynesian Philips curve in its standard form.

Further the evolution of the present discounted value of future marginal costs and marginal revenues would be:

$$\widehat{\psi}_t = \left(1-\theta\beta\overline{\pi}^{\varepsilon}\right)\left[\widehat{mc}_t + (1-\sigma)\widehat{C}_t\right] + \theta\beta\overline{\pi}^{\varepsilon}\left[\varepsilon\mathbb{E}_t\widehat{\pi}_{t+1} + \mathbb{E}_t\widehat{\psi}_{t+1}\right] \tag{26}$$

and:

$$\widehat{\phi}_t = \left(1-\theta\beta\overline{\pi}^{\varepsilon-1}\right)(1-\sigma)\,\widehat{C}_t + \theta\beta\overline{\pi}^{\varepsilon-1}\left[(\varepsilon-1)\mathbb{E}_t\widehat{\pi}_{t+1} + \mathbb{E}_t\widehat{\phi}_{t+1}\right] \tag{27}$$

[30]for further discussion see Ascari and Sbordone (2014)

The second part of both equations on the right hand side represents the forward looking part of the equations and they are both dependent on trend inflation.

The Generalized New Keynesian Philips Curve can also be expressed in terms of private consumption[31]. To express the GNKPC as an inflation-consumption relationship, I first substitute the marginal costs and using the fact that there is the following relationship between consumption and price dispersion: $\widehat{N}_t = (\widehat{C}_t - \widehat{A}_t) + \widehat{s}_t$. I substitute $\widehat{N}_t$ into the expression for the real wage $w_t = \varsigma_t + \varphi\widehat{N}_t + \sigma_\delta\widehat{C}_t + (\sigma - \sigma_\delta)\,\widehat{G}_t$, and following the same procedure as in the case of the GNKPC in terms of marginal costs would bring:

$$\widehat{\pi}_t = \lambda(\overline{\pi})\widehat{C}_t + k(\overline{\pi})\left[\varsigma_t + \varphi\widehat{s}_t - (\varphi+1)\widehat{A}_t + (\sigma - \sigma_\delta)\,\widehat{G}\right] + b_1(\overline{\pi})\mathbb{E}_t\widehat{\pi}_{t+1} + b_2(\overline{\pi})\left[(1-\sigma)\,\widehat{C}_t - \mathbb{E}_t\widehat{\psi}_{t+1}\right] \tag{28}$$

with one additional parameters $\lambda(\overline{\pi})$ which is the slope of the curve with respect to consumption and is equal to: $\lambda(\overline{\pi}) = (\varphi + \sigma_\delta - 1 + \sigma)\,k(\overline{\pi})$. The New Philips Curve expresses the relationship between inflation and consumption and has an additional term compared to the previous curve in terms of marginal costs, which includes in it also government spending and shifts the Philips curve depending on the parameter $k(\overline{\pi})$.

5 Model results

In this section I present the results from the New Keynesian model with trend inflation and a government sector. Firstly, I show analytically how government spending affects private consumption. I discuss the implications of the complementarity between private consumption and government spending, on the effect of the government spending shock on private consumption and show how trend inflation changes the effects of fiscal policy and the dynamics of the response to shocks. Secondly, I present the parameter values and discussion regarding it. Third, I show the impulse responses of private consumption, inflation, real interest rate, price dispersion

[31] Expressing the Philips curve into this form comes into hand in showing analytically the effects of government spending on private consumption through the method of undetermined coefficients discussed in the next subsection 3.6

and labor to a government spending shock and show the implications of trend inflation in this results. Fourth, I argue that the results are prone to different parameter specifications. Lastly, I calculate and discuss the consumption multipliers from the model and the panel VAR.

5.1 Macroeconomic dynamics

In this subsection I discuss the effects of government on private consumption under some implications related to parameter values or trend inflation. Initially I focus in showing analytically the effects that government spending shocks bring on private consumption and I discuss the implications of the complementarity between private consumption and government spending, on the effect of the government spending shock on private consumption. Secondly, I argue that trend inflation changes the effects of fiscal policy and the dynamics of the response to shocks. I explain the size of the effect on private consumption of the government spending shock relying on higher trend inflation values.

Proposition 1. An increase in government spending g_t produces a crowding in effect on private consumption $\widehat{C}_t$. While an increase in the inverse elasticity of substitution between private consumption and government spending χ, which leads to higher complementarity between them ($\lim_{\chi \longrightarrow \infty} \frac{1}{\chi} = 0$), increases the positive response of private consumption to a government spending shock.

Proof. See Appendix C.

Relying on the method of undetermined coefficients where I assume the government spending shock is assume to be i.i.d. standard normal process as in subsection (3.3), assuming log preferences in consumption ($\sigma = 1$) and indivisible labor ($\phi = 0$), the response of private consumption to a government spending shock would be:

$$c_g = \frac{bk(\overline{\pi}) + e}{[a + (\phi_\pi - \rho_g) \, k(\overline{\pi})]} \tag{29}$$

where I have defined as: $b = -\frac{(1-\sigma_\delta)(\phi_\pi - \rho_g)}{\sigma_\delta}$ and $e = \frac{(1-\sigma_\delta)(1-\delta)}{\sigma_\delta}(\rho_g - 1)$ and $a = 1 - \rho_g + \frac{1}{\sigma_\delta}\phi_Y - \frac{1}{\sigma_\delta}(1-\sigma_\delta)\left[\delta\rho_g - \delta - \frac{\delta}{(1-\delta)}(\rho_g - 1)\right]$. For a trend inflation value of $\overline{\pi} = 1$ which corresponds to a steady state value of 0 inflation, $k(\overline{\pi})$ is transformed into $k(1) = \frac{(1-\theta)(1-\theta\beta)}{\theta} > 0$ and represents the standard $k(\overline{\pi})$ in the Philips curve. Since $(\phi_\pi - \rho_g) > 0$[32], $k(1) > 0$, $a > 0$, $b > 0$ and $e > 0$, then $c_g > 0$. An increase in g_t, from $\widehat{C}_t = c_g g_t$, suggests that this leads to an increase in $\widehat{C}_t$.

For log preferences in consumption, when the inverse elasticity of substitution between private consumption and government spending is $\chi > 1$, an increase in government spending, ceteris paribus, increases the marginal utility of consumption, suggesting that government spending has a positive effect on private consumption, due to the Edgeworth complementarity between private consumption and government spending. For a high enough value of χ, the complementarity effect overpasses the negative wealth effect, suggesting that on aggregate, private consumption is crowded in by government spending.

On the other hand, a higher χ, leads to an increase in σ_δ keeping in mind that $\sigma_\delta = (\chi(1-\delta) + \sigma\delta)$, which means that $\frac{1}{\sigma_\delta}$ the slope of the IS curve goes down, with the curve becoming more flatter. In this case a, b and e all increase. The increase in government spending, from the labor supply equation (11), suggests that government spending influences positively the labor supply even more, which as consequence amplifies the decline in the real wage more as well. Now the complementarity effect is higher than before, widening the difference with the negative wealth effect, leading to a higher effect of government spending on private consumption c_g, and therefore higher $\widehat{C}_t$.

Proposition 2. An increase in trend inflation $\overline{\pi}$ increases the value of the positive response of private consumption $\frac{\partial c_g}{\partial \overline{\pi}} > 0$.

Proof. See Appendix C.

Under the same parameter values as in Proposition 1, the effect of the trend inflation on the response of private consumption from a government spending shock would be:

[32] The inflation response parameter ϕ_π can not be lower than 1 in order for the solution of the model to be unique, as shown by Bullard and Mitra (2002)

$$\frac{\partial c_g}{\partial \pi} = \frac{\partial \frac{bk(\overline{\pi})-e}{[a+(\phi_\pi-\rho_g)k(\overline{\pi})]}}{\partial \overline{\pi}} = \frac{(\phi_\pi - \rho_g)\, e - ba}{[a+\phi_\pi k(\overline{\pi})]^2} \frac{\partial k(\overline{\pi})}{\partial \overline{\pi}} > 0 \tag{30}$$

where $\frac{\partial k(\overline{\pi})}{\partial \overline{\pi}} < 0$ and $(\phi_\pi - \rho_g)\, e - ba < 0$, because $1 > b > a > e > 0$[33], then $\frac{\partial c_g}{\partial \overline{\pi}} > 0$. Therefore, trend inflation amplifies the impact of the government spending shock on private consumption. Similar results are also seen in the case of the monetary policy shock discussed in Ascari and Sbordone (2014). The intuition behind these results come from the fact that with trend inflation, the Philips curve will be flatter, making inflation less sensitive to current marginal costs. The Philips curve now will depend more on expected future inflation, and less on marginal costs, making the firms more forward−looking. At higher rates of trend inflation priceâsetting firms are more forward−looking, they react less to the increase in private consumption happening due to the complementarity effect, so that inflation reacts less, becoming more persistent, as consequence the interest rate increases more, by inducing a larger reaction of consumption due to the Euler equation.

5.2 Baseline Results

Parametrization. Table 1 below displays the values assigned to the parameters in the baseline model with non-separability between government spending and private consumption. Each period I assume to correspond to a quarter. I chose a value for the discount factor $\beta = 0.99$, which means that the annual interest rate is equal to 4% in the steady state, as used also in Gali et al. (2007). I keep a value of $\sigma = 1$ for the inverse elasticity of intertemporal substitution of consumption as in Ascari and Sbordone (2014), which implies that the preferences are separable in leisure and consumption. The value of the inverse Frisch labour supply elasticity is set as the standard value used in macro, following the evidence of Domeij and Floden (2006), $\varphi = 3$.

[33] The proof comes from substituting the parameter values into the expression

Table 1: Parameter values used in baseline model

β	Discount factor	0.99
σ	inverse elasticity of intertemporal substitution	1
φ	inverse Frisch labour supply elasticity	3
ε	elasticity of substitution	10
θ	Calvo parameter	0.75
ρ_g	AR(1) coefficient of government expenditure	0.9
ρ_v	AR(1) coefficient of monetary policy	0.85
ρ_A	AR(1) coefficient of technology	0.95
ρ_ζ	AR(1) coefficient of labor supply shock	0.95
ϕ_π	inflation elasticity of the nominal interest rate	2
ϕ_Y	output gap elasticity of the nominal interest rate	0.125
ρ_i	inertia parameter with past interest rate	0.8
χ	inverse elasticity of substitution between C and G	20
δ	share of private consumption in the aggregate consumption bundle	0.8

I use standard parameter values as in Ascari and Sbordone (2014), for elasticity of substitution $\varepsilon = 10$, which corresponds to a steady state mark up of 1.1 and the Calvo parameter of price stickiness $\theta = 0.75$. I do not change either from , the values related to the Taylor rule. Though a value of $\phi_\pi = 1.5$ is more standard following Taylor (1993), a value of 2 is needed to allow for determinacy for the 6% trend inflation case. I define the value for the inverse elasticity of substitution between government spending and private consumption $\chi = 20$ following Bouakez and Rebei (2007), Pieschacon (2012) and Troug (2017), while for the size of household's consumption in the aggregate consumption bundle $\delta = 0.8$ as in Bouakez and Rebei (2007) and Sims and Wolff (2018).

To capture the persistence of government spending, I set a value $\rho_g = 0.9$ as in Corsetti et al. (2012b) and Gali et al. (2007). I set standard persistence values as well for the productivity shock, labor supply shock and the monetary policy shock, respectively $\rho_v = 0.85$, $\rho_A = 0.95$ and $\rho_\zeta = 0.95$.

Impulse Responses. Figure 4 depicts the impulse responses functions of private consumption, annual inflation, annual real interest rate, price dispersion and labor to a positive 1 percent government spending shock for four values of trend inflation: 0, 2, 4 and 6 percent.

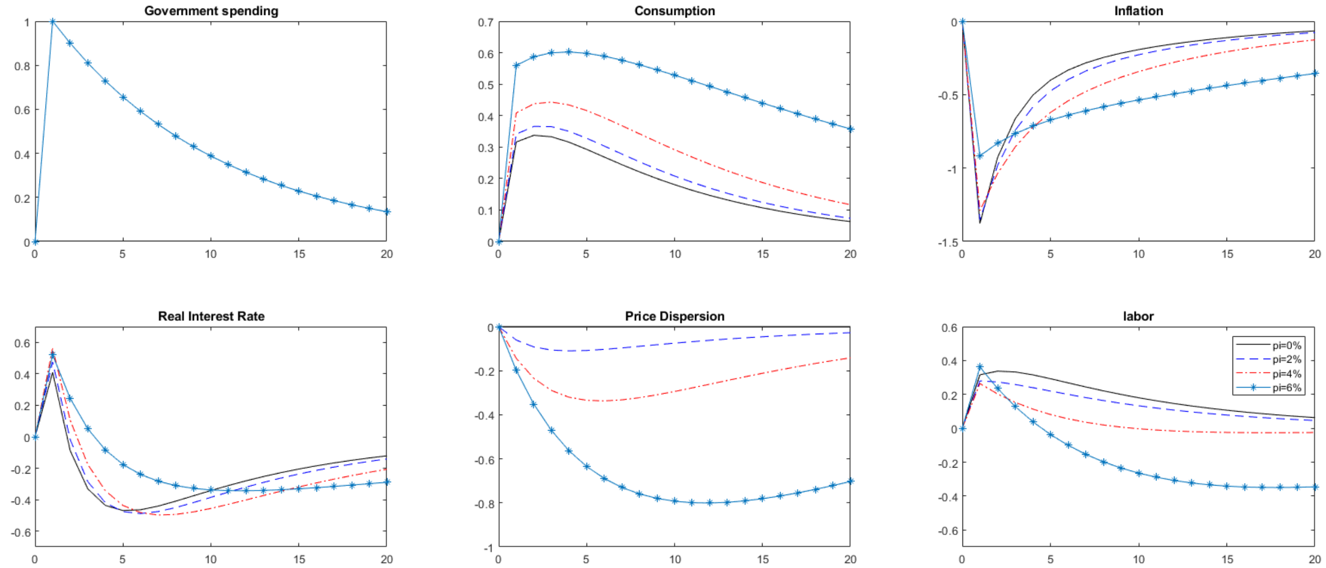

Figure 4: Impulse responses from a government spending shock in a small scale DSGE model

NOTES: The figure presents the impulse responses of Consumption, Annual Inflation, Annual Real Interest Rate, Price Dispersion, and Labor to a 1% Government Spending Shock in a Small Scale DSGE model. One period corresponds to 1 year on the horizontal axis and the response in percentage is reported on the vertical axis. The lines four lines represent respectively the impulse responses under a level of 0, 2, 4 and 6% of trend inflation. In this case the government spending shock displays high persistence[34] $\rho_g = 0.9$

Figure 2 shows that on average a positive government spending shock increases private consumption, labor and it has an initial positive impact on the real interest rate for the first 2-3 periods. An increase of 1% in government spending produces on max impact almost a response of 0.3% in private consumption, displaying a hump shaped form of the impulse responses. Because private and public spending are treated as Edgeworth complements, as government spending increases it raises the marginal utility of consumption, the complimentarity effect is strong enough to overcome the negative wealth effect, and private consumption increases. On the other hand the shock effects follow a decline in inflation, price dispersion and the real interest rate after the first three periods. The increase in consumption will be mirrored by output, following the market clearing condition therefore I do not present the response of output in the figure. Labor because of the linear function of technology, will increase as private consumption increases.

Focusing on the importance of trend inflation and its effect, the higher the trend inflation moving from 0 to 6% values, the higher the response of private consumption to the government spending shock. An increase of 1% in government spending produces on max impact almost a response of 0.35% in private consumption, when trend inflation is 2%, and 0.45% and 0.6% respectively when trend inflation is 4% and 6%, increasing the persistence in the results more and more. Trend inflation amplifies the impact of the government spending shock on private consumption because price-setting firms are more forward looking. Trend inflation reduces the slope of the Philips curve, and therefore reduces initially the impact of the government spending shock on inflation, by increasing as well its persistence. Because there is a mutual feedback between price dispersion and inflation the persistence increases even more, by reducing inflation. The larger increase in the interest rate, in the first periods brings a larger reaction of consumption as suggested by the Euler equation.

The main result from this section is that the higher the trend inflation the higher the effects of a government spending shock in this economy. Trend inflation amplifies the increase in private consumption, the decline in price dispersion and inflation, it amplifies initial the effect on labor supply, to later reducing the increase more than in the previous case. This results support Ascari and Sbordone (2014) idea that higher trend inflation amplifies economic shocks and increases their persistence.

Further on, I discuss some other implications of trend inflation in amplifying the effects of a government spending shock on private consumption by considering some alternative parameter specifications. In figure 5 I present four different cases where I change the values of ρ_g, χ, φ and lastly I simplify the Taylor rule by assuming $\phi_Y = 0$, which makes it a CPI Taylor rule.

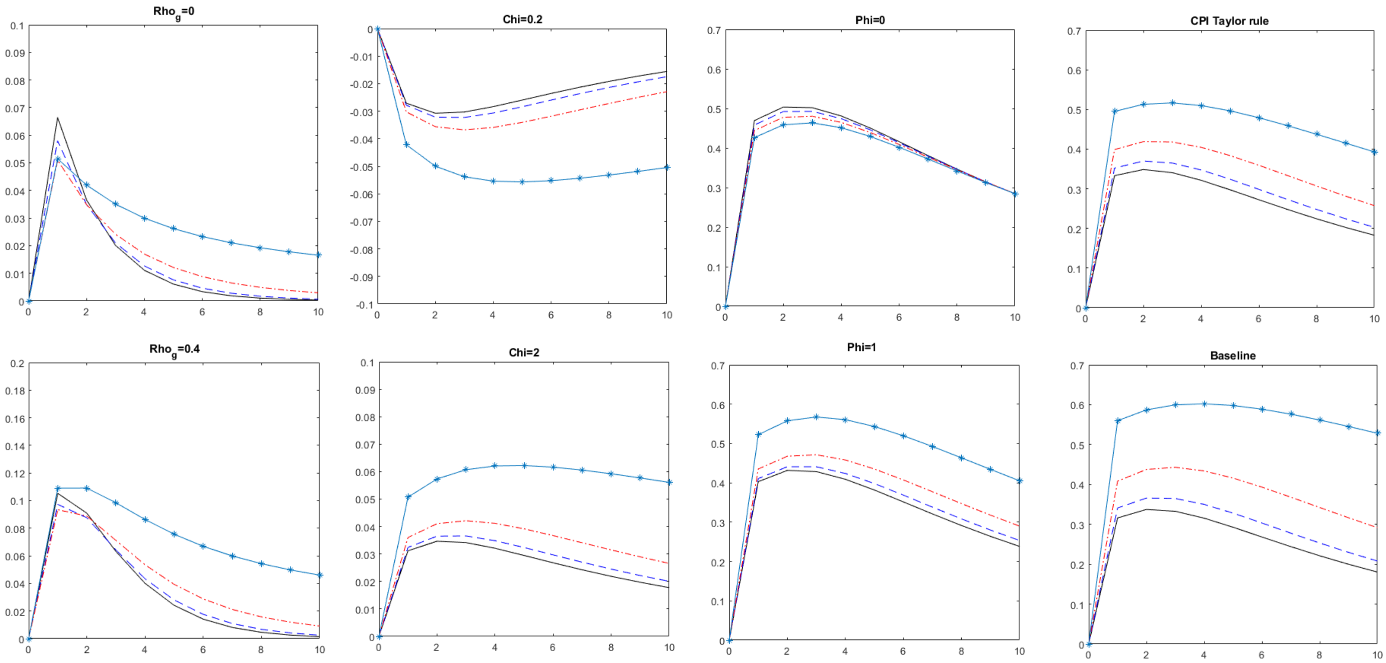

Figure 5: Impulse responses from a government spending shock in a small scale DSGE model

NOTES: The figure presents the impulse responses of Consumption to a 1% Government Spending Shock under alternative parameter choices for ρ_g, χ, φ and by assuming $\phi_Y = 0$ in the Taylor rule. The first column presents the case of changing ρ_g from 0 to 0.4, second column changing χ from 0.2 to 2, third column changing φ from 0 to 1, and the fourth column presents the case os a simple Taylor rule and then the baseline where $\rho_g = 0.9$, $\chi = 20$, $\varphi = 3$ and $\phi_Y = 0.125$. One period corresponds to 1 year on the horizontal axis and the response in percentage is reported on the vertical axis. The lines four lines represent respectively the impulse responses under a level of 0, 2, 4 and 6% of trend inflation.

In the first column, it is presented the case where the persistence of the shock of government spending is initially put to 0 and then increased to 0.4. In the first case when the shock persistence is equal to zero, in the first periods where the shock happens trend inflation diminishes the response of private consumption to the shock, and after the shock ends trend inflation amplifies the increase in private consumption. In the second case where the persistence of the shock is increased to 0.4 trend inflation as the shock happens, starts in the second period to amplify the effect on private consumption, more similar to the response attitude in the baseline case where the persistence of the shock is high 0.9. The persistence of the shock matters as well for the size of the response of private consumption, where the response in the baseline in the case of zero trend inflation is almost 3 to 4 times higher than in the cases of the persistence of the shock is low.

In the second column, it is presented the case where inverse elasticity of substitution χ is changed. Initially it is given the value of 0.2, which makes government spending and private consumption slightly substitutes, and then the value of 2 which makes government spending and private consumption slightly complements. In the first case compared to the baseline the response of private consumption to a government spending shock is slightly negative, and trend inflation amplifies the negative results of the government spending shock. In the second case, when private consumption and government spending becomes complements the response of private consumption becomes positive as in the baseline, and trend inflation amplifies the positive response of private consumption moving from 0 to 6 case of trend inflation. In both cases the size of the response is relatively low compared to the baseline case where private consumption and government spending are strongly complements, being in the case of 6% from $8-10$ times higher.

In the third column, it is presented the case where inverse Frisch labour supply elasticity φ is changed. Initially it is given the value of 0, and then the value of 1, where the baseline itself has a value of 3. In the first case the wealth effect of the labor supply is shut down, while in the second case the Frisch elasticity is higher. In the first case compared to the baseline the response of private consumption to a government spending shock is is still positive, but now higher trend inflation brings a slightly lower positive response of private consumption. To be noticed is that in this case, the importance of trend inflation in affecting the size of the response of private consumption is not that significant in size as before. When the inverse Frisch labour supply elasticity φ takes the value of 1, trend inflation amplifies the response of private consumption as in the baseline though not on the same magnitude. In the trend inflation case of 0 when $\varphi = 1$ the response of private consumption is slightly higher than in the case of $\varphi = 3$.

In the fourth column, it is presented the case where output elasticity of the nominal interest rate is $\phi_Y = 0$ compared to the baseline where $\phi_Y = 0.125$. This change in the parameter converts the Taylor rule into a CPI rule, where the interest rate is decided only by taking into account of the level of inflation in the economy. Simplifying the Taylor rule into a CPI rule, doesn't seem to matter for the results as no bog changes are noticed in the response of private consumption to the government spending shock and neither on the influence of trend inflation on the shock. Despite all, some small differences are noticed where in the CPI rule case, when trend inflation is equal to zero the response of private consumption is slightly higher than in the baseline case, while the amplifying effects of trend inflation on the response of private consumption, on the 6% trend inflation case seem to be slightly lower in size compared to the baseline case.

5.3 Consumption multipliers

Consumption multipliers: model vs panel VAR. In order to compare the results on private consumption obtained from the baseline GNK model with the empirical results from the benchmark panel VAR, in this section I calculate the consumption multipliers. A consumption multiplier measures the impact on private consumption due to a change in government spending. Blanchard and Perotti (2002), calculates the multipliers in the case of the output as the ratio of the output response to the initial government spending shock. While Mountford and Uhlig (2009), suggests calculating the multiplier by discounting it to the present value using the long

− run average interest rate. As both in the model and in the Panel VAR both government spending and private consumption are taken in log form, to obtain the multipliers in dollars, requires converting the impulse responses into dollars, and for this I use the standard conversion technique of multiplying the multiplier by the ratio of consumption to government spending:

$$M_{\max\_impact} = \frac{(c_t - c)}{(g_t - g)} \frac{c}{g} \tag{31}$$

$$M_{Cumulative} = \frac{\sum_{i=0}^{N}(c_{t+i} - c)}{\sum_{i=0}^{N}(g_{t+i} - g)} \frac{c}{g} \tag{32}$$

$$M_{Cumulative\_present\_value} = \frac{\sum_{i=0}^{N}(1+r)^{-i}(c_{t+i} - c)}{\sum_{i=0}^{N}(1+r)^{-i}(g_{t+i} - g)} \frac{c}{g} \tag{33}$$

I calculate three types of multipliers the max impact multiplier, the cumulative multiplier and the cumulative multiplier at the present value. The maximum impact multiplier it refers to the point where the response of private consumption to government spending shock is the highest. The consumption multiplier results are shown in Table 2.

Table 2: Consumption multipliers

	Empirical multipliers		Model multipliers	
	Low Inflation	High Inflation	0% Trend Inflation	6% Trend Inflation
Max Impact	0.4	0.8	0.54	0.98
Cumulative	0.8	2.1	0.69	2.88
Cumulative present value	0.7	2.0	0.69	2.33

The consumption multipliers coming from the panel VAR are calculated according to the sample division done of the countries in low and high inflation countries, while for the model case I calculate them for the cases of 0% and 6% trend inflation[35]. The max impact multipliers is 0.4 for low inflation, while is slightly higher for 0% trend inflation with about 0.54. In the

[35]For the DSGE model multipliers I chose a value of 0.95 for the parameter δ as this value allows producing from the model, multipliers closer to the empirical multipliers. In case of a $\delta = 0.8$ as in Sims and Wolff (2018) then the multipliers would be higher than 1 due to estimated complementarity of government spending with private consumption

case of high inflation and 6% trend inflation the multipliers are respectively 0.8 and 0.98 being in both cases almost twice higher than in the cases of low inflation and 0% trend inflation. The long run consumption multipliers represented by the cumulative present value multipliers are respectively 0.7 and 0.69 for low trend inflation case and 0% trend inflation case, while the values for the high inflation case and 6% trend inflation are respectively 2.0 and 2.33.

All the three empirical consumption multipliers show that they are 2-3 times higher in countries with high long run inflation compared to countries with low inflation. In the case of the model consumption multipliers the difference between the cases of low trend inflation vs high trend inflation is 2-4 times higher, under the specific parameters of the model. This multipliers are close to the ones suggested by Ramey (2019), where on a review of the work done on fiscal multipliers she argues that on average government spending multipliers vary from 0.6-1 for both time series and DSGE models estimates, without taking into account country characteristics.

6 Robustness model results

In this subsection the period utility function of the representative agent is assumed to be non-separable in consumption (C) and labor (N) as in Greenwood et al. (1988). In this model the wealth effect on labor supply is shut off, suggesting that government spending can influence positively private consumption. Monacelli and Perotti (2008), also relies on GHH preferences in crowding in private consumption, but with the difference of using GHH preferences on the form introduced by Jaimovich and Rebelo (2009). I consider here the form of the utility function used in Lewis and Winkler (2017).

$$U(C_t, N_t) = \ln(C_t - \frac{\varsigma}{1+\widetilde{\varphi}} N_t^{1+\widetilde{\varphi}}) + h(G_t) \tag{34}$$

$h(G_t)$ represents the utility the household gets from government spending, where the wealth effect of labor supply χ is expressed as $\chi = -\frac{U_{cc}C}{U_c} + \frac{U_{c(1-N)}C}{U_{(1-N)}}$ and $\widetilde{\chi} = \frac{\chi}{c_y}$, and c_y is the steady-state share of private consumption to output. Additional definitions would be $\upsilon = \frac{U_{c(1-N)}N}{U_c}$ and $\varphi = \frac{U_{(1-N)(1-N)}N}{U_{(1-N)}}$. The inverse of the constant-consumption labor supply elasticity is defined as: $\frac{1}{\widetilde{\varphi}} = \frac{1}{\varphi+\upsilon-\frac{\upsilon\chi}{\widetilde{\chi}-\upsilon}}$. Under this preferences government spending can crowd in private consumption only when Bilbiie (2011); (2018) conditions are fulfilled [36] $\widetilde{\chi} \geq 0$, $\widetilde{\varphi} \geq 0$ and $\upsilon \leq \frac{\widetilde{\varphi}\widetilde{\chi}}{\widetilde{\chi}+\widetilde{\varphi}}$. Dealing with GHH preferences, requires that the wealth effect on labor supply is $\chi = 0$ and $\upsilon < 0$, so labor and consumption are complements[37].

I chose a value of $\upsilon = -3.2$, almost an average value compared to the choices of Bilbiie (2011) and Furlanetto and Seneca (2014), respectively -1.29 and -5. Keeping the same value for the inverse Frisch elasticity $\varphi = 3$ as in the baseline model, would bring a value for the constant-consumption labor supply elasticity $\widetilde{\varphi} = 0.2$. Regarding the monetary policy rule, I decide to keep a simple one to allow for determinacy in each of the cases of trend inflation, but at the same time I keep the same inertia. Some inertia in the Taylor rule in this model is determinant for obtaining crowding in on private consumption.

In this model with GHH preferences the negative wealth effect problem, which happens in a model with separable preferences is not present, and this allows for government spending to induce a crowding in effect on private consumption. An increase in government spending in the standard case, cause a negative wealth effect, because it will be associated with higher taxes, which on the other hand shifts the labor supply down, because the household now consumes less and works more, this leads to a rise in working hours, rise in output, and a decline in private consumption and real wage. As argued by Monacelli and Perotti (2008) in the case of GHH preferences the wealth effect on labor supply is shut down, and the labor supply curves doesn't shift. On the firms side, the increase in government spending, cause the firms product demand to increase, and this leads to a shift out in the labor demand, causing hours, and real wages to increase, followed by an increase in inflation. When the hours and consumption are complementary, the hours and private consumption must increase when government spending

[36] for details see Lewis and Winkler (2017)

[37] The main log-linearized equations the IS curve, labor supply and Philips curve can be found in the appendix

increases because of the aggregate resource constraint that I assumed in this model.

Additionally, in this subsection I discuss the results from the New Keynesian model with non-separable preferences in consumption and labor, and with government spending in the utility function under different values of trend inflation.

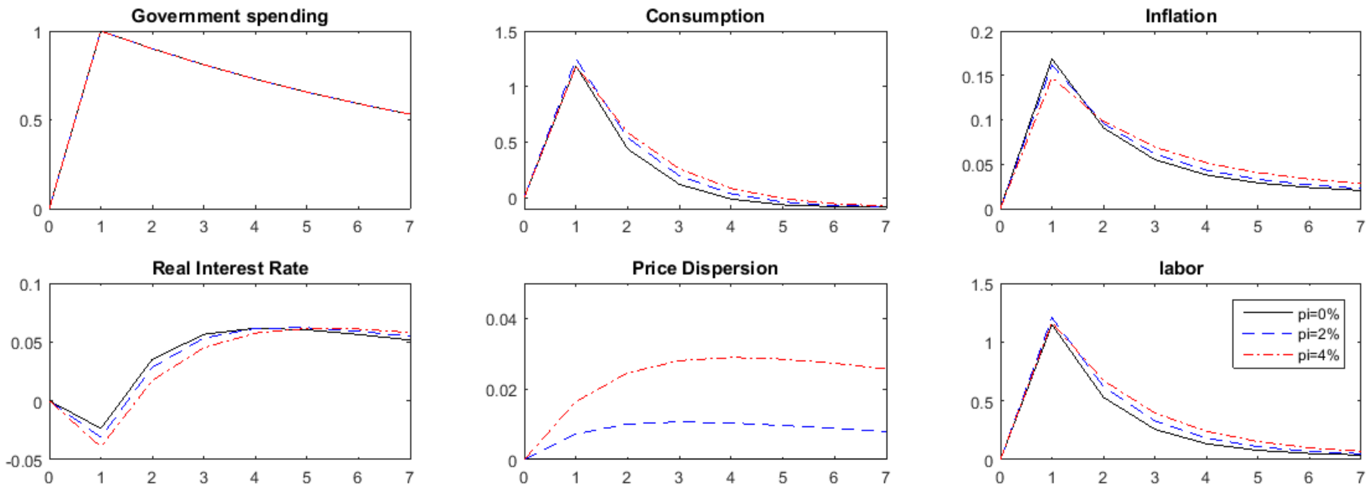

Figure 6: Responses of private consumption to a government spending shock from alternative models

Figure 5 shows the impulse responses functions of private consumption to a government spending shock for three values of trend inflation: 0, 2, and 4 percent. A government spending shock here induces a positive response of private consumption, an increase in inflation, price dispersion and labor supply, while it suggest an initial decline in the real interest rate, which turns positive after 1-2 periods.

Under a government spending shock, higher trend inflation again, facing more forward looking firms, under a new Philips curve which depends more on expected inflation, amplifies price dispersion, causes inflation to increase after 2 periods, with a higher persistence. This increase in inflation reflects into lower real interest rates, and as consequence the response of private consumption is higher. Under GHH preferences, trend inflation, when comparing the model with 0% and 4% trend inflation, amplifies the positive response of private consumption to the shock but with a lower magnitude than in the case where I assumed government spending and private consumption complementarity. A similar effect, though not on the same size was also seen, in the empirical analysis when comparing low vs high inflation countries. Overall, I can say that the results from the baseline DSGE model are robust when compared with this alternative under different preference choice.

7 Conclusion

This paper has dealt with an old question but still of interest in macroeconomics "What are the effects of government spending shocks on consumption?". Though there exists high theoretical and empirical work done, there is still space in investigating further on this matter. This paper focuses on particular in proving that heterogeneity among countries coming from country characteristics highly matters in the effects of government spending in private consumption. When estimating a panel VAR in a quarterly panel data set of 34 OECD countries, from 1995 − 2017 I find that in countries with high long run inflation the response of private consumption is higher than in countries with low long run inflation. This results are proven to be robust under three different modelling choices. On a second step I investigate the empirical results in a small-scale DSGE New Keynesian model with trend inflation I find that an increase in trend inflation increases the positive response of private consumption. Overall, when long run inflation is used to explain the heterogeneity between countries, the response of private consumption to a government spending shock reflects this differences.

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Appendix

Appendix A.

Table 3: Summary Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
G	3128	12.7	1.44	8.9	15.4
Y	3128	11.1	1.42	7.6	13.8
C	3128	12.1	1.48	8.4	14.8
W	3128	10.4	0.67	8.1	11.4
INF	3128	3.0	4.23	−6.1	48.7

Appendix B.

B.1 Households optimization problem

$$\max_{C_t, N_t, B_t} \frac{\widetilde{C}_t^{1-\sigma}}{1-\sigma} - d_n e^{\varsigma_t} \frac{N^{1+\varphi}}{1+\varphi} \qquad \text{s.t} \qquad P_t C_t + (1+i_t)^{-1} B_t = W_t N_t + D_t + B_{t-1} - T_t \tag{35}$$

$\widetilde{C}_t$ where the aggregate consumption bundle is:

$$\widetilde{C}_t = \left[\delta^{\chi} C_t^{1-\chi} + (1-\delta)^{\chi} G_t^{1-\chi} \right]^{\frac{1}{1-\chi}} \tag{36}$$

I can form a Lagrangian:

$$L = \frac{C_t^{1-\sigma}}{1-\sigma} - d_n e^{\varsigma_t} \frac{N^{1+\varphi}}{1+\varphi} + \lambda \left[W_t N_t + D_t + B_{t-1} - T_t - P_t C_t - (1+i_t)^{-1} B_t \right] \tag{37}$$

The first order conditions are:

$$\frac{\partial L}{\partial C_t} = \delta^{\chi}\overline{C}_t^{-\sigma}\left(\frac{C_t}{\widetilde{C}_t}\right)^{-\chi} - \lambda_t P_t,\ \frac{\partial L}{\partial N_t} = -d_n e^{\varsigma_t} N^{\varphi} + \lambda_t W_t \text{ and } \frac{\partial L}{\partial B_t} = \lambda_t\left(1+i_t\right)^{-1} - \beta\lambda_{t+1}$$

where the Labor supply equation would be:

$$\text{from } \lambda_{1t} = \lambda_{2t} \text{ I get } \frac{W_t}{P_t} = d_n e^{\varsigma_t} N^{\varphi}\overline{C}_t^{\sigma}\left(\frac{C_t}{\widetilde{C}_t}\right)^{\chi}\delta^{-\chi} \tag{38}$$

I find the Euler equation starting from: $\lambda_t = \beta(1+i_t)\lambda_{t+1}$

$$\text{and then I get } \frac{\delta^{\chi}\widetilde{C}_t^{-\sigma}\left(\frac{C_t}{\widetilde{C}_t}\right)^{-\chi}}{P_t} = \beta(1+i_t)^{-1}\frac{\delta^{\chi}\widetilde{C}_{t+1}^{-\sigma}\left(\frac{C_{t+1}}{\widetilde{C}_{t+1}}\right)^{-\chi}}{P_{t+1}} \tag{39}$$

which I express as:

$$1 = \beta(1+i_t)\mathbb{E}_t\left[\left(\frac{P_t}{P_{t+1}}\right)\left(\frac{\widetilde{C}_{t+1}}{\widetilde{C}_t}\right)^{\chi-\sigma}\left(\frac{C_{t+1}}{C_t}\right)^{-\chi}\right] \tag{40}$$

B.2 Recursive formulation of the optimal price-setting equation

I use a recursive formulation of the optimal price-setting equation to find ψ_t and ϕ_t as discussed in the text. First, I start from:

$$p^*_{j,t} = \frac{\varepsilon}{(\varepsilon-1)} * \frac{\mathbb{E}_t{}_{l=0}^{\infty}\theta^l D_{t,t+l}Y_{t+l}\Pi^{\varepsilon}_{t,t+l}\frac{W_{t+l}}{A_{t+l}P_{t+l}}}{\mathbb{E}_t{}_{l=0}^{\infty}\theta^l D_{t,t+l}Y_{t+l}\Pi^{\varepsilon-1}_{t,t+l}} \text{ and I write } p_{j,t} = \frac{\varepsilon}{(\varepsilon-1)}\frac{\psi_t}{\phi_t}$$

where, denoting the real wage as $w_t = \frac{W_t}{P_t}$; using the definition of the discount factor $D_{t,t+l} \equiv \beta^l\frac{\lambda_{t+l}}{\lambda_0}$, and the fact that $\lambda_{t+l} = C^{-\sigma}_{t+l}$, or $D_{t,t+1} = \beta\frac{C^{-\sigma}_{t+1}}{C^{-\sigma}_t}$, where ($C_t = Y_t$), the auxiliary variables ψ_t and ϕ_t are defined, respectively, as:

$$\psi_t = \mathbb{E}_t{}_{l=0}^{\infty}(\theta\beta)^l Y^{1-\sigma}_{t+l}w_{t+l}(A_{t+l})^{-1}\Pi^{\varepsilon}_{t,t+l} \text{ and } \phi_t = \mathbb{E}_t{}_{l=0}^{\infty}(\theta\beta)^l Y^{1-\sigma}_{t+l}\Pi^{\varepsilon-1}_{t,t+l} \tag{41}$$

I can write the two above infinitive summations recursively, starting first with ψ_t:

$$\psi_t = w_t {A_t}^{-1} Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left[w_{t+1}{A_{t+1}}^{-1}Y_{t+1}^{1-\sigma}\Pi_{t,t+1}^{\varepsilon}\right] + \theta\beta^2\mathbb{E}_t\left[w_{t+2}{A_{t+2}}^{-1}Y_{t+2}^{1-\sigma}\Pi_{t,t+2}^{\varepsilon}\right] + \cdots. \quad (42)$$

The above equation can be readjusted as:

$$\psi_t = w_t {A_t}^{-1} Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left\{\pi_{t+1}^{\varepsilon}\left[w_{t+1} * {A_{t+1}}^{-1}Y_{t+1}^{1-\sigma} + \theta\beta\Pi_{t+1,t+2}^{\varepsilon} w_{t+2}{A_{t+2}}^{-1}Y_{t+2}^{1-\sigma} + \cdots.\right]\right\} \quad (43)$$

The expression in the square brackets is exactly the definition for $\mathbb{E}_t\psi_{t+1}$ and because of this I would have:

$$\psi_t = w_t {A_t}^{-1} Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left[\pi_{t+1}^{\varepsilon}\psi_{t+1}\right] \quad (44)$$

replacing the $MC_t = w_t A_t^{-1}$ the equation would be:

$$\psi_t = MC_t Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left[\pi_{t+1}^{\varepsilon}\psi_{t+1}\right] \quad (45)$$

Now the recursive form of ϕ_t following the same procedure, it is possible to quasi-differentiate the equation $\phi_t = \mathbb{E}_t{}_{l=0}^{\infty}(\theta\beta)^l\Pi_{t,t+l}^{\varepsilon-1}Y_{t+l}^{1-\sigma}$, would bring:

$$\phi_t = Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left[\Pi_{t,t+1}^{\varepsilon-1}Y_{t+1}^{1-\sigma}\right] + \mathbb{E}_t\left[(\theta\beta)^2\Pi_{t,t+2}^{\varepsilon-1}Y_{t+2}^{1-\sigma}\right] + \cdots \quad (46)$$

$$\phi_t = Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left\{\pi_{t,t+1}^{\varepsilon-1}\left[Y_{t+1}^{1-\sigma} + \theta\beta\Pi_{t+1,t+2}^{\varepsilon-1}Y_{t+2}^{1-\sigma} + \cdots\right]\right\} \quad (47)$$

and obtain:

$$\phi_t = Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t\left[\pi_{t+1}^{\varepsilon-1}\phi_{t+1}\right] \quad (48)$$

These variables ψ_t and ϕ_t can be interpreted as the present discounted value of marginal costs and marginal revenues (for a unit change in the optimal reset price), respectively.

B.3 The complete non-linear system

To summarize, the complete non-linear model, which I reproduce here for convenience:

$$Y_t = C_t \tag{49}$$

$$1 = \beta(1+i_t) * \mathbb{E}_t \left[\left(\frac{P_t}{P_{t+1}} \right) \left(\frac{\widetilde{C}_{t+1}}{\widetilde{C}_t} \right)^{\chi-\sigma} \left(\frac{C_{t+1}}{C_t} \right)^{-\chi} \right] \tag{50}$$

$$w_t = d_n e^{\varsigma_t} N^{\varphi} \widetilde{C}_t^{\sigma} \left(\frac{C_t}{\widetilde{C}_t} \right)^{\chi} \delta^{-\chi} \tag{51}$$

$$\widetilde{C}_t = \left[\delta^{\chi} C_t^{1-\chi} + (1-\delta)^{\chi} G_t^{1-\chi} \right]^{\frac{1}{1-\chi}} \tag{52}$$

$$p_{j,t}^* = \left(\frac{1-\theta\pi_t^{\varepsilon-1}}{1-\theta} \right)^{\frac{1}{1-\varepsilon}} \tag{53}$$

$$p_{j,t}^* = \frac{\varepsilon}{(\varepsilon-1)} \frac{\psi_t}{\phi_t} \tag{54}$$

$$\psi_t = MC_t Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t \left[\pi_{t+1}^{\varepsilon} \psi_{t+1} \right] \tag{55}$$

$$\phi_t = Y_t^{1-\sigma} + \theta\beta\mathbb{E}_t \left[\pi_{t+1}^{\varepsilon-1} \phi_{t+1} \right] \tag{56}$$

$$MC_t = w_t A_t^{-1} \tag{57}$$

$$N_t = s_t \frac{Y_t}{A_t} \tag{58}$$

$$s_t = (1-\theta)(p_{j,t}^*)^{-\varepsilon} + \theta\pi_t^{\varepsilon} s_{t-1} \tag{59}$$

$$\left(\frac{1+i_t}{1+\bar{i}} \right) = \left(\frac{1+i_{t-1}}{1+\bar{i}} \right)^{\rho_i} \left(\left(\frac{\pi_t}{\overline{\pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{\overline{\overline{Y}}} \right)^{\phi_Y} \right)^{1-\rho_i} e^{v_t} \tag{60}$$

The model has nine endogenous variable: Y_t,C_t, G_t, i_t, π_t, w_t, N_t, $p_{i,t}$, ψ_t, ϕ_t, s_t and four exogenous shocks: A_t, ς_t, v_t, G_t.

B.4 The log-linearization of the resource constraint and obtaining the IS curve

Market clearing in the goods market requires: $Y_{t,j} = C_{t,j}$, for all $j \in [0,1]$ and all t or

$Y_t = C_t$. The log-linearized Euler equation would be:

$$\log C_t^{-\chi} = \log\beta + \log\left(1+i_t\right) + \log \mathbb{E}_t \pi_{t+1}^{-1} + \log\log \mathbb{E}_t \left(\frac{\widetilde{C}_{t+1}}{\widetilde{C}_t}\right)^{\chi-\sigma} + \log\log \mathbb{E}_t C_{t+1}^{-\chi} \qquad (61)$$

Where I substitute $\widehat{\widetilde{C}}_t = \delta\widehat{C}_t + (1-\delta)\widehat{G}_t$ which is the log-linear version of $\widetilde{C}_t = \left[\delta^{\chi} C_t^{1-\chi} + (1-\delta)^{\chi} G_t^{1-\chi}\right]^{\frac{1}{1-\chi}}$ and this gives:

$$\widehat{C}_t = \mathbb{E}_t \widehat{C}_{t+1} - \frac{1}{\sigma_\delta}\left(i_t - \mathbb{E}_t\left\{\widehat{\pi}_{t+1}\right\}\right) + \frac{(\sigma-\sigma_\delta)}{\sigma_\delta}\mathbb{E}_t \Delta\widehat{G}_{t+1} \qquad (62)$$

Integrating the Euler equation over $i\epsilon\left[0,1\right]$ and combining the resulting difference equation with $\widehat{Y}_t = \widehat{C_t}$, yields the union wide dynamic IS equation:

$$\widehat{Y}_t = \mathbb{E}_t \widehat{Y}_{t+1} - \frac{1}{\sigma_\delta}\left[\widehat{i}_t - \mathbb{E}_t\left\{\widehat{\pi}_{t+1}\right\}\right] + \frac{(\sigma-\sigma_\delta)}{\sigma_\delta}\mathbb{E}_t\left\{\Delta\widehat{G}_{t+1}\right\} \qquad (63)$$

B.5 The complete log-linear equations

$$\widehat{Y}_t = \mathbb{E}_t \widehat{Y}_{t+1} - \frac{1}{\sigma_\delta}\left[\widehat{i}_t - \mathbb{E}_t\left\{\widehat{\pi}_{t+1}\right\}\right] + \frac{(\sigma-\sigma_\delta)}{\sigma_\delta}\mathbb{E}_t\left\{\Delta\widehat{G}_{t+1}\right\} \qquad (64)$$

$$w_t = \varsigma_t + \varphi\widehat{N}_t + \sigma_\delta\widehat{C}_t + \left(\sigma-\sigma_\delta\right)\widehat{G}_t \qquad (65)$$

$$\widehat{N}_t = (\widehat{Y}_t - \widehat{A}_t) + \widehat{s}_t \qquad (66)$$

$$\widehat{i}_t = \rho_i i_{t-1} + (1-\rho_i)\left(\phi_\pi\widehat{\pi}_t + \phi_Y\widehat{Y}_t\right) + \upsilon_t \qquad (67)$$

$$\widehat{p}_{i,t}^{*} = \widehat{\psi}_t - \widehat{\phi}_t \qquad (68)$$

$$\widehat{\psi}_t = (1-\theta\beta\overline{\pi}^{\varepsilon})\left[\widehat{w}_t - \widehat{A}_t + (1-\sigma)\widehat{Y}_t\right] + \theta\beta\overline{\pi}^{\varepsilon}\left[\varepsilon\mathbb{E}_t\widehat{\pi}_{t+1} + \mathbb{E}_t\widehat{\psi}_{t+1}\right] \qquad (69)$$

$$\widehat{\phi}_t = \left(1-\theta\beta\overline{\pi}^{\varepsilon-1}\right)\left(1-\sigma\right)\widehat{Y}_t + \theta\beta\overline{\pi}^{\varepsilon-1}\left[(\varepsilon-1)\mathbb{E}_t\widehat{\pi}_{t+1} + \mathbb{E}_t\widehat{\phi}_{t+1}\right] \qquad (70)$$

$$\widehat{s}_t = -\varepsilon\left(1-\theta\overline{\pi}^{\varepsilon}\right)\widehat{p}_{i,t}^{*} + \theta\overline{\pi}^{\varepsilon}(\varepsilon\widehat{\pi}_t + \widehat{s}_{t-1}) \qquad (71)$$

$$\widehat{\pi}_t = k(\overline{\pi})\widehat{mc}_t + b_1(\overline{\pi})\mathbb{E}_t\widehat{\pi}_{t+1} + b_2(\overline{\pi})\left[(1-\sigma)\widehat{Y}_t - \mathbb{E}_t\widehat{\psi}_{t+1}\right] \tag{72}$$

This gives a Philips curve that comprises the dynamics of inflation. Where: $k(\overline{\pi}) = \frac{\left(1-\theta\overline{\pi}^{\varepsilon-1}\right)\left(1-\theta\beta\overline{\pi}^{\varepsilon}\right)}{\theta\overline{\pi}^{\varepsilon-1}}$, $b_1(\overline{\pi}) = \beta\left[1+\varepsilon\left(\overline{\pi}-1\right)\left(1-\theta\overline{\pi}^{\varepsilon-1}\right)\right]$, $b_2(\overline{\pi}) = \beta\left[1-\overline{\pi}\right]\left(1-\theta\overline{\pi}^{\varepsilon-1}\right)$. While price dispersion is written as:

$$\widehat{s}_t = \left(\frac{\varepsilon\theta\overline{\pi}^{\varepsilon-1}}{\left(1-\theta\overline{\pi}^{\varepsilon-1}\right)}\left(\overline{\pi}-1\right)\right)\widehat{\pi}_t + \theta\overline{\pi}^{\varepsilon}\widehat{s}_{t-1} \tag{73}$$

The log-linearized aggregate resource constraint would be:

$$\widehat{Y}_t = \widehat{C}_t \tag{74}$$

For the aggregate consumption bundle I have:

$$\widehat{\widehat{C}} = \delta\widehat{C}_t + (1-\delta)\widehat{G}_t \tag{75}$$

The shocks of the economy can be expressed as: the technology shock $\widehat{A}_t = \rho_A\widehat{A}_{t-1} + \mu_{At}$, the labor supply shock $\varsigma_t = \rho_\sigma\varsigma_{t-1} + \mu_{\varsigma_t}$, the monetary policy shock in the Taylor rule $\upsilon_t = \rho_\upsilon\upsilon_{t-1} + \mu$ and the government spending shock: $\widehat{G}_t = \rho_G\widehat{G}_{t-1} + \mu_{Gt}$. The innovations μ_{At}, μ_{ς_t}, $\mu_{\upsilon t}$, and μ_{Gt} are assumed to be i.i.d. standard normal processes.

B.6 The key log-linear equations for the GHH preferences case

The main log-linearized equations the IS curve, labor supply and Philips curve would be: The IS curve

$$\widehat{Y}_t = E\left\{\widehat{Y}_{t+1}\right\} - \gamma E\left\{\Delta\widehat{G}_{t+1}\right\} + (1-\gamma)((\mathbb{E}_t\left(\widehat{\pi}_{t+1}\right) - \widehat{i}_t) - \left(1+\widetilde{\varphi}\right)\Delta\mathbb{E}_t\widehat{N}_{t+1}) \tag{76}$$

The labor supply curve

$$\widehat{w}_t = \widetilde{\varphi}\widehat{N}_t \tag{77}$$

GNKPC for GHH preferences

$$\widehat{\pi}_t = k(\overline{\pi})\widehat{mc}_t + b_1(\overline{\pi})\mathbb{E}_t\widehat{\pi}_{t+1} + b_2(\overline{\pi})\left[(\frac{(-\gamma)\widehat{Y}_t + \gamma\widehat{G}_t}{(1-\gamma)} - \mathbb{E}_t\widehat{\psi}_{t+1}\right] \quad (78)$$

Appendix C.

Proof: In order to prove that a government spending shock crowds in private consumption and then that an increase in trend inflation amplifies the response of consumption, I start by making some basic assumptions to simplify my calculations, where: log preferences in consumption ($\sigma = 1$), indivisible labor ($\varphi = 0$), and no persistence in the shocks ($\rho_\sigma = 0$ for $i = A,\varsigma,\upsilon$), while I keep the persistence for . For the Taylor rule I assume no inertia . The log-linearized GNK model now can be described by the following main equations, seen in Appendix B:

$$\widehat{\pi}_t = k(\overline{\pi})\left[\sigma_\delta\widehat{Y}_t + \varsigma_t - \widehat{A}_t + (1-\sigma_\delta) * \widehat{G}\right] + b_1(\overline{\pi})\mathbb{E}_t\widehat{\pi}_{t+1} - b_2(\overline{\pi})\left[\mathbb{E}_t\widehat{\psi}_{t+1}\right] \quad (79)$$

$$\widehat{Y}_t = \mathbb{E}_t\widehat{Y}_{t+1} - \frac{1}{\sigma_\delta}\left[\widehat{i}_t - \mathbb{E}_t\left\{\widehat{\pi}_{t+1}\right\}\right] + \frac{1}{\sigma_\delta}(1-\sigma_\delta)\,\mathbb{E}_t\left\{\Delta\widehat{G}_{t+1}\right\} \quad (80)$$

$$\widehat{\overline{C}} = \delta\widehat{C}_t + (1-\delta)\widehat{G}_t \quad (81)$$

$$\widehat{\psi}_t = (1-\theta\beta\overline{\pi}^{\varepsilon})\left[\varsigma_t + \sigma_\delta\widehat{Y}_t + (1-\sigma_\delta)\,\widehat{G}_t - \widehat{A}_t\right] + \theta\beta\overline{\pi}^{\varepsilon}\left[\varepsilon\mathbb{E}_t\widehat{\pi}_{t+1} + \mathbb{E}_t\widehat{\psi}_{t+1}\right]$$

$$\widehat{i}_t = \phi_\pi\widehat{\pi}_t + \phi_Y\widehat{Y}_t + \upsilon_t \quad (82)$$

Price dispersion, $\widehat{s}_t$, does not affect the dynamics of the above system, because of the assumption made where linear utility in labor is ($\varphi = 0$). In this economy I specify the following auto-regressive processes for the 4 shocks of the baseline model, technology, labor supply, monetary and government spending shocks, which are specified as AR(1) processes and the innovations μ_{At}, $\mu_{\varsigma t}$, μ_{Gt} and $\mu_{\upsilon t}$ are assumed to be i.i.d. standard normal processes.

$\widehat{A}_t = \rho_A\widehat{A}_{t-1} + \mu_{At}$ and $\varsigma_t = \rho_\sigma\varsigma_{t-1} + \mu_{\varsigma_t}$ and $\upsilon_t = \rho_\upsilon\upsilon_{t-1} + \mu_{\upsilon t}$ and $\widehat{G}_t = \rho_G\widehat{G}_{t-1} + \mu_{Gt}$

Given that the shocks are i.i.d., there are no transitional dynamics and the economy returns to the steady state in the period after the shock. Focusing on the effect of trend inflation on private consumption, I use the method of undetermined coefficients to solve the system of equations, the impact of the government spending shock is derived as follows: First I write $z_t = \varsigma_t - \widehat{A}_t$, secondly I substitute the Taylor equation into the IS curve, obtaining:

$$\widehat{Y}_t = \mathbb{E}_t \widehat{Y}_{t+1} - \frac{1}{\sigma_\delta} \left[\phi_\pi \widehat{\pi}_t + \phi_Y \widehat{Y}_t + v_t - \mathbb{E}_t \left\{ \widehat{\pi}_{t+1} \right\} \right] + \frac{1}{\sigma_\delta} (1 - \sigma_\delta) * \mathbb{E}_t \left\{ \widehat{G}_{t+1} - \widehat{G}_t \right\} \tag{83}$$

and

$$\widehat{\pi}_t = k(\overline{\pi}) * \left[\sigma_\delta \widehat{Y}_t + z_t + (1 - \sigma_\delta) * \widehat{G} \right] + b_1(\overline{\pi}) \mathbb{E}_t \widehat{\pi}_{t+1} - b_2(\overline{\pi}) \left[\mathbb{E}_t \widehat{\psi}_{t+1} \right] \tag{84}$$

Then I express the system of equations as:

$$\mathbb{E}_t \begin{bmatrix} \widehat{\pi}_{t+1} \\ \widehat{Y}_{t+1} \\ \widehat{\psi}_{t+1} \\ \widehat{\overline{C}}_{t+1} \\ \widehat{i}_{t+1} \end{bmatrix} = \begin{bmatrix} \widehat{\pi}_z & \widehat{\pi}_v & \widehat{\pi}_g \\ \widehat{Y}_z & \widehat{Y}_v & \widehat{Y}_g \\ \widehat{\psi}_z & \widehat{\psi}_v & \widehat{\psi}_g \\ \widehat{\overline{C}}_z & \widehat{C}_z & \widehat{C}_z \\ \widehat{i}_z & \widehat{i}_v & \widehat{i}_g \end{bmatrix} \begin{bmatrix} \rho z_t \\ \rho_v v_t \\ \rho_g g_t \end{bmatrix} \tag{85}$$

I would have now the new equations:

$$\pi_z z_t + \pi_v v_t + \pi_g g_t = k(\overline{\pi}) \left(\sigma_\delta \left(c_z z_t + c_v v_t + c_g g_t \right) + z_t + (1 - \sigma_\delta) * g_t \right) + \tag{86}$$

$$b_1(\overline{\pi}) \left(\pi_z \rho z_t + \pi_v \rho_v v_t + \pi_g \rho_g g_t \right) \tag{87}$$

$$-b_2(\overline{\pi}) \left[\left(\psi_z \rho z_t + \psi_v \rho_v v_t + \psi_g \rho_g g_t \right) \right] \tag{88}$$

$$c_z z_t + c_v v_t + c_g g_t = c_z \rho z_t + c_v \rho_v v_t + c_g \rho_g g_t \quad - \tag{89}$$

$$\frac{1}{\sigma_\delta}\left[\begin{array}{c} \phi_\pi\left(\pi_z z_t + \pi_v v_t + \pi_g g_t\right) + \phi_Y\left(c_z z_t + c_v v_t + c_g g_t\right) + \\ v_t - \left(\pi_z \rho z_t + \pi_v \rho_v v_t + \pi_g \rho_g g_t\right) \end{array}\right] \tag{90}$$

$$\frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right) \tag{91}$$

$$\left\{\begin{array}{c} d_z \rho z_t + d_v \rho_v v_t + d_g \rho_g g_t - d_z z_t + d_v v_t + d_g g_t - \\ \frac{\delta}{(1-\delta)}\left(c_z \rho z_t + c_v \rho_v v_t + c_g \rho_g g_t - c_z z_t + c_v v_t + c_g g_t\right) \end{array}\right\} \tag{92}$$

$$\psi_z z_t + \psi_v v_t + \psi_g g_t \quad = \quad \left(1-\theta\beta\overline{\pi}^{\varepsilon}\right)\left[\sigma_\delta\left(c_z z_t + c_v v_t + c_g g_t\right) + \left(1-\sigma_\delta\right) * g_t + z_t\right] + \tag{93}$$

$$\theta\beta\overline{\pi}^{\varepsilon}\left[\varepsilon\left(\pi_z \rho z_t + \pi_v \rho_v v_t + \pi_g \rho_g g_t\right) + \psi_z \rho z_t + \psi_v \rho_v v_t + \psi_g \rho_g g_t\right] \tag{94}$$

$$d_z z_t + d_v v_t + d_g g_t = \delta\left(c_z z_t + c_v v_t + c_g g_t\right) + (1-\delta) g_t \tag{95}$$

Since everything is linear I can group the terms in z, v and g and then solve them separately. Focusing only on the government spending shock and dividing on both sides by g I would have the equations once more:

$$\pi_g = k(\overline{\pi})\left(\sigma_\delta c_g + (1-\sigma_\delta)\right) + b_1(\overline{\pi})\pi_g \rho_g - b_2(\overline{\pi})\psi_g \rho_g \tag{96}$$

$$c_g = c_g \rho_g - \frac{1}{\sigma_\delta}\left[\phi_\pi \pi_g + \phi_Y c_g - \pi_g \rho_g\right] + \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left\{d_g \rho_g - d_g - \frac{\delta}{(1-\delta)}\left(c_g \rho_g - c_g\right)\right\} \tag{97}$$

$$\psi_g = \left(1-\theta\beta\overline{\pi}^{\varepsilon}\right)\left[\sigma_\delta c_g + (1-\sigma_\delta)\right] + \theta\beta\overline{\pi}^{\varepsilon}\left[\varepsilon\pi_g \rho_g + \psi_g \rho_g\right] \tag{98}$$

$$d_g = \delta c_g + (1-\delta) \tag{99}$$

I solve for the undetermined coefficients π_g, ψ_g, y_g, c_g, first I substitute d_g to c_g:

I substitute d_g to c_g

$$
\begin{aligned}
c_g &= c_g\rho_g - \frac{1}{\sigma_\delta}\left[\phi_\pi\pi_g + \phi_Y c_g - \pi_g\rho_g\right] + \qquad (100)\\
&\frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left\{\left(\delta c_g + (1-\delta)\right)\rho_g - \left(\delta c_g + (1-\delta)\right) - \frac{\delta}{(1-\delta)}\left(c_g\rho_g - c_g\right)\right\} \qquad (101)
\end{aligned}
$$

which I rearrange into:

$$
\begin{aligned}
& c_g\left[1-\rho_g+\frac{1}{\sigma_\delta}\phi_Y - \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left(\delta\rho_g - \delta - \frac{\delta}{(1-\delta)}\left(\rho_g - 1\right)\right)\right]\\
= & -\frac{1}{\sigma_\delta}\left[\phi_\pi\pi_g - \pi_g\rho_g\right] + \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left\{(1-\delta)\rho_g - (1-\delta)\right\}
\end{aligned}
$$

and then substitute π_g to c_g:

$$
\begin{aligned}
& c_g\left[1-\rho_g+\frac{1}{\sigma_\delta}\phi_Y - \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left(\delta\rho_g - \delta - \frac{\delta}{(1-\delta)}\left(\rho_g - 1\right)\right)\right]\\
= & -\frac{1}{\sigma_\delta}k(\overline{\pi})\sigma_\delta c_g\left(\phi_\pi - \rho_g\right) - \frac{1}{\sigma_\delta}k(\overline{\pi})\left(1-\sigma_\delta\right)\left(\phi_\pi - \rho_g\right) + \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left\{(1-\delta)\rho_g - (1-\delta)\right\}
\end{aligned}
$$

I would finally obtain the effect of the government spending shock on private consumption:

$$
c_g = \frac{-\frac{1}{\sigma_\delta}k(\overline{\pi})\left(1-\sigma_\delta\right)\left(\phi_\pi-\rho_g\right) + \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left(1-\delta\right)\left\{\rho_g - 1\right\}}{\left[1-\rho_g+\frac{1}{\sigma_\delta}\phi_Y - \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\left(\delta\rho_g-\delta-\frac{\delta}{(1-\delta)}\left(\rho_g-1\right)\right) + k(\overline{\pi})\left(\phi_\pi-\rho_g\right)\right]}
$$

Which I can simply by grouping some of the parameters into:

$$
c_g = \frac{bk(\overline{\pi}) + e}{\left[a + \left(\phi_\pi - \rho_g\right)k(\overline{\pi})\right]} \qquad (102)
$$

where $a = 1-\rho_g+\frac{1}{\sigma_\delta}\phi_Y - \frac{1}{\sigma_\delta}\left(1-\sigma_\delta\right)\delta\left(\rho_g - 1 - \frac{1}{(1-\delta)}\left(\rho_g-1\right)\right)$, $b = -\frac{(1-\sigma_\delta)(\phi_\pi-\rho_g)}{\sigma_\delta}$ and $e = \frac{(1-\sigma_\delta)(1-\delta)}{\sigma_\delta}\left\{\rho_g - 1\right\}$

and then $\widehat{C}_t = c_g g_t$ shows how government spending affects private consumption. An increase in government spending, substituting the parameter values discussed in the Parametrization section, induces an increase in private consumption. Now it is easy to look at the effects of trend inflation on the impact of the government spending shocks. What I am looking for is $\frac{\partial c_g}{\partial \overline{\pi}}$, which is

$$\frac{\partial c_g}{\partial \overline{\pi}} = \frac{\partial \frac{bk(\overline{\pi})-e}{[a+(\phi_\pi-\rho_g)k(\overline{\pi})]}}{\partial \overline{\pi}} \tag{103}$$

$$\frac{\partial c_g}{\partial \overline{\pi}} = \frac{(\phi_\pi-\rho_g)\,bk(\overline{\pi})+(\phi_\pi-\rho_g)\,e-ba-(\phi_\pi-\rho_g)\,bk(\overline{\pi})}{[a+\phi_\pi k(\overline{\pi})]^2} = \frac{(\phi_\pi-\rho_g)\,e-ba}{[a+\phi_\pi k(\overline{\pi})]^2}\frac{\partial k(\overline{\pi})}{\partial \overline{\pi}} \tag{104}$$

$$\frac{\partial c_g}{\partial \overline{\pi}} = \frac{(\phi_\pi-\rho_g)\,e-ba}{[a+\phi_\pi k(\overline{\pi})]^2}\frac{\partial k(\overline{\pi})}{\partial \overline{\pi}} > 0 \tag{105}$$

where $\frac{\partial k(\overline{\pi})}{\partial \overline{\pi}} < 0$, $k(\overline{\pi}) = \frac{\left(1-\theta\overline{\pi}^{\varepsilon-1}\right)(1-\theta\beta\overline{\pi}^{\varepsilon})}{\theta\overline{\pi}^{\varepsilon-1}}$ and $(\phi_\pi-\rho_g)\,e-ba < 0$ because $1 > b > a > e > 0$[38], then $\frac{\partial c_g}{\partial \overline{\pi}} > 0$. Since $\frac{\partial c_g}{\partial \overline{\pi}}>0$, it follows that an increase in trend inflation increases the value of the positive response of consumption.

[38]The proof comes from substituting the parameter values into the expression