

Essays on Monetary and Fiscal Policy

by

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Dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy in the Department of Economics
in the Graduate School of Duke University
2013

ABSTRACT

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Abstract

This dissertation consists of two chapters studying monetary and fiscal policy. In the first chapter, I study the welfare benefits and costs of increased central bank transparency in a dynamic model of costly information acquisition where agents can either choose to gather new costly information or remember information from the past for free. Information is costly to acquire due to an agent's limited attention. Agents face an intratemporal decision on how to allocate attention across public and private signals within the period and an intertemporal decision on how to allocate attention over time. The model embeds a coordination externality into the dynamic framework which motivates agents to be overly attentive to public information and creates the possibility of costly transparency. Interestingly, allowing for intratemporal and intertemporal tradeoffs for attention amplifies (attenuates) the benefits (costs) of earlier transparency whereas it attenuates (amplifies) the benefits (costs) of delayed transparency.

The second chapter, co-authored with Barbara Rossi and Atsushi Inoue, studies the empirical effects of unexpected changes in government spending and tax policy on heterogeneous agents. We use data from the Consumption Expenditure Survey (CEX) to estimate individual-level impulse responses as well as multipliers for government spending and tax policy shocks. The main empirical finding of this paper is that unexpected fiscal shocks have substantially different effects on consumers depending on their age, income levels, and education. In particular, the wealthiest

individuals tend to behave according to the predictions of standard RBC models, whereas the poorest individuals tend to behave according to standard IS-LM (non-Ricardian) models, due to credit constraints. Furthermore, government spending policy shocks tend to decrease consumption inequality, whereas tax policy shocks most negatively affect the lives of the poor, more so than the rich, thus increasing consumption inequality.

To my husband

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Dynamic Transparency and Information Acquisition

Expectations of random variables show up in virtually every context of dynamic models with uncertainty. When agents form expectations, they base their expectations on the information set available to them. If an agent's information set changes, so does its expectations. Expectations, in turn, impact a model's equilibrium solution and dynamics while playing a big role in how well a model fits the data. Thus, when models are evaluated for performance it is important to consider how the information sets are formed and to recognize that information acquisition and disclosure is an economic choice made by the agent.

One question of particular interest is the social value of public information disclosure, or the transparency of public institutions. Since we typically think public institutions such as the central bank or federal government care about social welfare, it is important that these institutions understand the impact their transparency has on welfare. There are many examples of public institutions that clearly choose their degree of transparency carefully, but none is as debated as the central bank's

choice for transparency. Under Chairman Bernanke's leadership the Federal Reserve has taken steps to become a more transparent central bank such as holding press conferences after FOMC meetings and beginning to release interest rate forecasts in January of 2012; however, the Federal Reserve refrains from disclosing information in many other forms such as the economic forecasts contained in the Green Book which are not released to the public until five years after they are constructed. Since public institutions are not fully transparent, then logically there must be some economic costs of being fully transparent to rationalize this decision. The debate in both the literature and in the public arena is identifying these costs.

Generally, more informed economic agents make more efficient allocations so society will tend to benefit from more information. Why then would public institutions not prefer to release more information? One possibly reason the literature has suggested is through a coordination externality. Morris and Shin (2002) show when agents have a motivation to coordinate and public and private information sources, the agents tend to overreact to public information compared to its quality of information. Intuitively, agents overreact because the public information is not only informative about the economy, but it is also informative about what the other agents know which improves coordination. The overreaction can be costly when the coordination motive, acting as an externality, is absent from the social planner. Morris and Shin's (2002) paper is an important first step in understanding the costs of transparency but it fails to consider two important aspects affecting how agents form information sets: information is not exhaustible and attention is limited. The goal of this paper is to study the costs of transparency in a model with a coordination externality in a dynamic setting with agents acquiring information under limited attention.

Information, unlike nondurable consumption goods, is not exhaustible and can be reused from one period to the next as long as the agent remembers the information.

This creates a dynamic mechanism for past transparency to matter in an otherwise static model. Agents face a choice between not only using public or private information released today but also between using public or private past information. It is entirely possible that the past information is more informative and thus more useful than the present information. Allowing for agents to remember information means the present and the past transparency of public institutions can have an impact of social welfare. Thus, it is important to consider the dynamic nature of information when evaluating the costs and benefits of transparency.

Agents faced with many information sources have limited attention and must choose how to allocate attention over their sources. This creates a scenario where information is released by the public institution but the agents do not perfectly observe this information. Since releasing information that is ignored is the same as not releasing the information at all from the agents perspective, it will be important to consider the agent's information acquisition problem when determining the costs and benefits of transparency.

Rational inattention, the idea that agents must rationally allocate limited attention across information signals or sources according to their costs and benefits, was first developed by Sims (2003). Sims applied ideas from communication theory to the problem of information acquisition by imposing a fixed channel capacity or Shannon capacity on how much information agents can process. Agents then face a tradeoff between allocating attention to one signal versus another. A good example of the idea of limited attention is an investor reading a newspaper. The newspaper is filled with many articles, but the investor with rational inattention pays more attention to the articles that are most important to them such as articles about sectors they invest in compared to sectors they do not invest in.

A large literature using this type of information acquisition has developed interesting applications of this idea. For example, recent papers in the rational inattention

literature show that when incorporating costly information processing it is optimal for price setting firms to pay more attention to shocks that are more volatile. This means firms pay more attention to an aggregate shock versus an idiosyncratic shock in Mackowiak and Wiederholt (2009) and to a technology shock versus a monetary shock in Paciello (2010). These results suggest that volatility matters when making attention choices and may have implications for central bank transparency since transparency impacts volatility.

Myatt and Wallace (2010) study endogenous publicity of signals under attention costs in a static beauty contest game. They find that as the desire to coordinate increases, agents choose to observe fewer signals but those signals are more public in nature. They exploit a linear cost function over attention instead of the entropy cost function rational inattention papers tend to use since they show the rational inattention cost function can lead to multiple equilibria in beauty contests. We follow the same convention.

Chahrour (2012) studies costly transparency in a static setting with attention costs. Instead of agents deciding between paying attention to a public or private signal, there are several public signals and no private signal. Agents must choose which of the many public signals to observe and the central bank can decide how many signals to release. Charhour finds that in order to facilitate coordination it is optimal for the central bank to release fewer signals. Importantly, none of these papers study the interaction of dynamics and attention costs for costly transparency.

Although this paper focuses on a model with a coordination externality where transparency can potentially be costly similar in nature to Morris and Shin (2002), it should be noted that Morris and Shin's model is not without its critics. Svensson (2006), among others, argues that to get costly transparency in their model the authors need unrealistically high values of complementarity and relatively precise private information. Hellwig (2006) points out that Morris and Shin's result hinges

on a welfare function that focuses on volatility which increases with transparency and not as much on price dispersion which decreases with transparency. By using a welfare function that weights price dispersion more heavily, Hellwig reverses the Morris and Shin result. Angeletos and Pavan (2004) show that the Morris and Shin result can also be reversed when the coordination motive is present at the social level as well as the individual. This means that the coordination motive is no longer an externality. The goal of their paper is to study markets in which this setup makes sense such as economies with production and demand spillovers. All of these previous papers study transparency in a static setting and without information acquisition. The goal of this paper is not to focus on different welfare functions to reverse the original result, but instead to see how incorporating a dynamic setting with attention costs changes the nature of the problem while still embedding the original Morris and Shin (2002) model as a special case. By doing this, we can see straightforwardly the contribution dynamics and attention costs bring to the discussion.

When we allow for dynamics and information acquisition, the problem agents face changes importantly. Agents face costs to allocating attention across the signals, and must make a choice between remembering old information at no cost or paying an attention cost to observe new information. In this context, the marginal benefit of more precise information is higher the earlier the information is received since agents take into account they can remember the information and use it for future periods instead of paying attention costs. If costs are too high or the earlier information is informative to a certain degree, then agents will not observe any new information and rely solely on the old information they have already observed. It turns out that the coordination externality drives a wedge between the bound where new information is ignored under the coordination externality model and where information is ignored if there was no externality. Agents with a higher degree of coordination motive will pay more attention to new information than agents with a lower degree of coordination

motive since the new information helps them coordinate.

By studying this interaction of a dynamic setting and attention costs we find several interesting results. First, we show the overreaction to public information is not the only distortion the coordination externality creates. Agents are also overly attentive to new information as they are more likely to pay attention costs in a new period in order to use the new information to coordinate instead of avoiding the attention costs by reusing old information. Second, *ceteris paribus*, agents prefer more transparency in times of greater uncertainty such as recessions and less transparency when they are already well informed. Third, attention costs amplify the benefits of earlier transparency and attenuate the benefits of delayed transparency. Therefore, a central banker who fails to acknowledge attention costs could inappropriately allocate transparency across time. For example, the central bank might determine increased transparency to be costly in a given period when considering attention costs would indicate it is beneficial. Fourth, we verify these results hold when considering the average action as a potential signal.

Including a dynamic setting and limited attention alters the costs and benefits of transparency so that we can make different conclusions on when transparency is costly than Morris and Shin (2002). Since the benefits of earlier transparency are amplified whereas the benefits of delayed transparency are attenuated, we can find cases where a public authority who does not acknowledge attention costs would find transparency beneficial but with attention costs transparency is costly. The opposite scenario is also possible where the public authority thinks transparency is costly but allowing for attention costs shows it is beneficial. Thus, it is important to allow for a dynamic setting with attention costs when concluding whether or not transparency is costly. These results suggest determining when transparency is costly is not as straightforward as looking at a static problem with no attention costs. Agents face constraints on how much information they can process. They also can remember

information across time. These innovations taken together significantly impact the costs of transparency.

Section 1.1 describes the model. Section 1.2 details the linear symmetric equilibrium and Section 1.3 details the welfare results. Section 1.4 considers the extension where the average action serves as a signal. Section 1.5 concludes.

1.1 Model

In the dynamic beauty contest game, an agent i chooses an action $a_{i,n} \in R$ in each period $n = 1, 2$ to maximize its lifetime payoff function. There is a continuum of agents over the unit interval $[0, 1]$ where \mathbf{a}_n is the set of actions across all agents. The instantaneous payoff function is a composition of a payoff from predicting an unobservable aggregate state θ and a payoff from predicting the average action chosen by others:

$$u_{in} \equiv -(1 - r)(a_{in} - \theta)^2 - r(a_{in} - \bar{a}_n)^2 \quad (1.1)$$

where $0 < r < 1$ and $\bar{a}_n \equiv \int_0^1 a_{jn} d_j$.¹ The first component of the payoff function is a quadratic loss in how far away the agent's prediction is from the state. The second component is the beauty contest term which measures how far away the agent's action is from the average action. The constant parameter r measures the degree of complementarity in the model. Higher levels of r increase the level of complementarity in choosing a_{in} .

Agents may gather information about θ from either a public or a private source. The public source, such as a central bank, makes an announcement equal to the state plus some noise in each period:

$$\tilde{s}_{CBn} = \theta + \epsilon_{CBn} \quad (1.2)$$

¹ This instantaneous payoff function is taken from Myatt and Wallace (2011). It is very similar to Morris and Shin's (2002) loss function and yields the same solution for the action a_{in} .

where $\epsilon_{CBn} \sim N\left(0, \frac{1}{P_{Tn}}\right)$ and $E(\theta\epsilon_{CBn}) = E(\epsilon_{CB1}\epsilon_{CB2}) = 0$.² Transparency is defined here to be the precision of the central bank's announcement, P_{Tn} . If the precision increases, the central bank is releasing a more transparent signal to the public and thus giving them more information. The private source of information is also a noisy signal about the state but each agent can only observe its unique signal:

$$\tilde{s}_{Pn}^i = \theta + \epsilon_{Pn}^i \quad (1.3)$$

where $\epsilon_{Pn}^i \sim N\left(0, \frac{1}{P_{Pn}}\right)$, $E(\theta\epsilon_{Pn}^i) = E(\epsilon_{P1}^i\epsilon_{P2}^i) = 0$, $E(\epsilon_{Pn}^i\epsilon_{Pn}^j) = 0$, and $E(\epsilon_{Pn}^i\epsilon_{CB2}) = 0$. Here the precision of the signal is interpreted as noise from nature.

If agents were free to observe both the private and public signal, this information structure would be the same as Morris and Shin (2002) except for the dynamic setup. However, agents face an attention cost that induces a tradeoff between allocating attention across the two information sources and across time. Specifically, agents cannot observe the public announcement and private signal from nature perfectly. Instead they observe:

$$s_{CBn}^i = \tilde{s}_{CBn} + \eta_{CBn}^i \quad (1.4)$$

$$s_{Pn}^i = \tilde{s}_{Pn}^i + \eta_{Pn}^i \quad (1.5)$$

where $\eta_{CBn}^i \sim N\left(0, \frac{1}{Z_{CBn}^i}\right)$ and $\eta_{Pn}^i \sim N\left(0, \frac{1}{Z_{Pn}^i}\right)$. Agents observe a more precise signal if they increase their attention level, Z_{CBn}^i or Z_{Pn}^i . These additional error terms make it so the public signal is no longer completely public in the sense that everyone gets different realizations of s_{CBn}^i ; however, we will still refer to this signal as 'public' since this signal is still informative about the other agents' information sets making it useful for coordination.

The lifetime payoff function is the discounted sum of instantaneous payoff functions with the addition of a cost over attention. The expected lifetime payoff function

² We assume the public authority has perfect knowledge of the state θ .

is:

$$E[U_i(\mathbf{a}_{i1}, \mathbf{a}_{i2}, \theta | I_i)] = E[u_{i1}(\mathbf{a}_{i1}, \theta) | I_i] + \beta E[u_{i2}(\mathbf{a}_{i1}, \mathbf{a}_{i2}, \theta) | I_i] - C(Z_{CB1}^i, Z_{P1}^i, Z_{CB2}^i, Z_{P2}^i) \quad (1.6)$$

where $0 < \beta \leq 1$ is the time discount factor,

$$C(Z_{CB1}^i, Z_{P1}^i, Z_{CB2}^i, Z_{P2}^i) = c(Z_{CB1}^i + Z_{P1}^i + Z_{CB2}^i + Z_{P2}^i)$$

is a linear cost function over attention with the constant marginal cost $c > 0$, and $I_i = P_{T1}, P_{T2}, P_{P1}, P_{P2}$ is agent i 's information set known at time zero.³ Myatt and Wallace (2011) use this type of attention cost to study the endogenous publicity of signals. Here we distinguish between a public and a private signal to answer the question: when is transparency costly? In general, this attention cost is motivated by the large literature on Rational Inattention which applies the information theory idea of a capacity constraint to economic agents.⁴ Agents face a limit on how much information they can process at one time and must allocate their attention across different information sources. Agents choose to pay attention to the signals that are the more informative about the objects that are most important to the agent. We could also think about other information costs such as a monetary cost for gathering information, but this type of cost is not very appealing in a public information context since public information does not have a monetary cost.

1.1.1 Remembering Information

In the first period agents can choose to allocate attention to either the public announcement or the private signal, both made in period one. In the second period,

³ Notice that since the payoff function is quadratic only the precision of the signals matter, not the realizations of the signal. Thus, the agents can make all of their decisions for weights and attentions at time zero before the signals are realized. We assume the public authority commits to the precision of the signals at time zero and does not deviate.

⁴ See Sims (2003).

agents can allocate attention to the new public and private signals made in period two, but they can also remember information from the past. This means they can use the signals from period one to make decisions in period two free of any information cost. Thus, remembering old information is a cheaper alternative to gathering new information. Old information is still useful in the second period since the state has not changed.⁵

1.1.2 Welfare Function

In order to maintain a comparison with the previous literature, we define the welfare function in a similar fashion as Morris and Shin (2002):

$$\frac{1}{1-r} \int_0^1 U^i(\mathbf{a}_1, \mathbf{a}_2, \theta) di = - \int_0^1 (a_{i1} - \theta)^2 - \beta(a_{i2} - \theta)^2 di \quad (1.7)$$

$$-c(Z_{CB1} + Z_{P1} + Z_{CB2} + Z_{P2}).$$

Specifically, Morris and Shin (2002) measure welfare as a normalized sum over all the agents' payoff functions. We apply the same method to our dynamic payoff function with attention costs to yield Equation 1.7. The welfare function brings to light the inherit coordination externality. Agents care about coordinating with other agents and maintaining similar actions, but aggregating over agents this desire drops out. The social planner only cares about being as close to the aggregate state as possible.

1.2 Equilibrium Solution

We solve for a symmetric equilibrium for the attention choices for each period and a linear symmetric equilibrium for the actions. We can write the equilibrium actions

⁵ If we allow for a state that changes over time, the old information will always be useful in the second period as long as the state is not i.i.d.

linear in the signals as:

$$a_{i1} = w_{CB1}s_{CB1}^i + w_{P1}s_{P1}^i \quad (1.8)$$

$$a_{i2} = wa_{i1} + w_{CB2}s_{CB2}^i + w_{P2}s_{P2}^i \quad (1.9)$$

where w_{CBn} is the weight given to the public signal in period n , w_{Pn} is the weight given to the private signal in period n , and w is the weight given to the old information from period 1 summarized by a_{i1} .⁶ The weights are constrained to sum to one and to be between zero and one.

Solving for the equilibrium actions a_{i1} and a_{i2} is equivalent to solving for the weights on each signal. Thus, we can rewrite the expected payoff function in terms of weights and attention choices:

$$\begin{aligned} E[U_i|I_i] = & -(1 + \beta w^2)(w_{CB1}^i)^2 \left(\frac{1-r}{P_{T1}} + \frac{1}{Z_{CB1}} \right) \\ & -(1 + \beta w^2)(w_{P1}^i)^2 \left(\frac{1}{P_{P1}} + \frac{1}{Z_{P1}} \right) \\ & -(w_{CB2}^i)^2 \left(\frac{1-r}{P_{T2}} + \frac{1}{Z_{CB2}} \right) - (w_{P2}^i)^2 \left(\frac{1}{P_{P2}} + \frac{1}{Z_{P2}} \right) \\ & -c(Z_{CB1} + Z_{P1} + Z_{CB2} + Z_{P2}) \end{aligned} \quad (1.10)$$

⁶ This is equivalent to assigning new weights to the old information, $\widehat{w_{CB1}}$, $\widehat{w_{P1}}$. Solving the problem this way we would get, $\widehat{w_{x1}} = ww_{x1}$.

by using the following substitutions:

$$\begin{aligned}
E[(a_{i1} - \theta)^2 | I_i] &= (w_{CB1})^2 \left(\frac{1}{P_{T1}} + \frac{1}{Z_{CB1}} \right) + (w_{P1})^2 \left(\frac{1}{P_{P1}} + \frac{1}{Z_{P1}} \right) \\
E[(a_{i1} - \bar{a}_1)^2 | I_i] &= (w_{CB1}^i)^2 \frac{1}{P_{T1}} + (w_{CB1}^i - \overline{w_{CB1}})^2 \frac{1}{P_{T1}} + (w_{P1}^i)^2 \frac{1}{P_{P1}} \\
&= (w_{CB,1}^i)^2 \frac{1}{P_{T,1}} + (w_{P,1}^i)^2 \frac{1}{P_{P,1}} \\
E[(a_{i2} - \theta)^2 | I_i] &= (ww_{CB1})^2 \left(\frac{1}{P_{T1}} + \frac{1}{Z_{CB1}} \right) + (ww_{P1})^2 \left(\frac{1}{P_{P1}} + \frac{1}{Z_{P1}} \right) \\
&\quad + (w_{CB2})^2 \left(\frac{1}{P_{T2}} + \frac{1}{Z_{CB2}} \right) + (w_{P2})^2 \left(\frac{1}{P_{P2}} + \frac{1}{Z_{P2}} \right) \\
E[(a_{i2} - \bar{a}_2)^2 | I_i] &= (ww_{CB1}^i)^2 \frac{1}{P_{T1}} + (ww_{CB1}^i - \overline{ww_{CB1}})^2 \frac{1}{P_{T1}} + (ww_{P1}^i)^2 \frac{1}{P_{P1}} \\
&\quad + (w_{CB2}^i)^2 \frac{1}{P_{T2}} + (w_{CB2}^i - \overline{w_{CB2}})^2 \frac{1}{P_{T2}} + (w_{P2}^i)^2 \frac{1}{P_{P2}} \\
&= (ww_{CB1}^i)^2 \frac{1}{P_{T1}} + (ww_{P1}^i)^2 \frac{1}{P_{P1}} + (w_{CB2}^i)^2 \frac{1}{P_{T2}} + (w_{P2}^i)^2 \frac{1}{P_{P2}}.
\end{aligned}$$

The agents maximization problem is now to maximize Equation 1.10 by choosing w_{CBn} , w_{Pn} , Z_{CBn} , and Z_{Pn} for each period $n = 1, 2$ and w subject to the constraints that weights must sum to one in both periods and each weight is non-negative.

1.2.1 Weights Period 1

By taking first order conditions for the agent's maximization problem with respect to weights and attention choices we can solve for closed form solutions for the equilibrium choices. Proposition 1 yields solution for the weights for the first period.

Proposition 1 (Weights Period 1). *The solution for period 1 weights that maximizes*

the agent's expected lifetime payoff function is:

$$w_{CB1} = \frac{P_{T1}}{P_{T1} + (1-r)P_{P1}}$$

$$w_{P1} = \frac{(1-r)P_{P1}}{P_{T1} + (1-r)P_{P1}}.$$

Proof. By taking the ratio of the first order conditions for w_{CB1} and w_{P1} and rearranging we have $w_{CB1}(1-r)/P_{T1} + w_{CB1}/Z_{CB1} = w_{P1}/P_{P1} + w_{P1}/Z_{P1}$. The first order conditions for the attention choices in the first period yield $Z_{CB1}/w_{CB1} = Z_{P1}/w_{P1} = \sqrt{(1 + \beta w^2)/c}$. Substituting this expression in the ratio of the weights we get $w_{CB1}/w_{P1} = P_{T1}/P_{P1}(1-r)$. Since the weights must sum to one, we know they take the form of $w_{CB1} = \psi_{CB1}/(\psi_{CB1} + \psi_{P1})$ and $w_{P1} = \psi_{P1}/(\psi_{CB1} + \psi_{P1})$. Thus, $\psi_{CB1} = P_{T1}$ and $\psi_{P1} = P_{P1}(1-r)$ and we get the expressions for the period 1 weights in Proposition 1. \square

The weight on each signal is increasing the the precision of its own signal and decreasing in the precision of the other signal. Looking at the relative weight of the central bank signal relative to the private signal in period one we see the relative weight is $P_{T1}/P_{P1}(1-r)$. In comparison, the relative Bayesian weights, which is the same the social planner will choose, is the relative precisions P_{T1}/P_{P1} . The agent overreacts to the precision of the public signal by $\frac{1}{1-r} > 1$. This phenomenon that agents overact to public information to help their coordination desire was first documented by Morris and Shin (2002). Agents overreact to the public signal because everyone observes the public signal with some noise (due to attention costs) so the signal is not only information about the state, but it is also informative about the other agents' information sets.

1.2.2 Attention

Proposition 2 gives the equilibrium solution for the attention choices in both periods. The first thing to notice is the attention choice for any given signal is proportional to the weight given to that signal. Thus, if the signal is not useful for the agent to either learn about θ or to learn about the average action \bar{a}_n , then the agent will not pay any attention cost to observe the signal. Second, the total attention allocated in period one, $Z_{CB1} + Z_{P1} = \sqrt{\frac{1+\beta w^2}{c}}$, is generally greater than the total attention allocated in period two, $Z_{CB2} + Z_{P2} = (1-w)\sqrt{\frac{\beta}{c}}$. They are only equal if $\beta = 1$ and $w = 0$. This result is stated formally in Corollary 3. Third, both period one attention choices and period two attention choices are increasing in β . As agents care more about the future, they increase their attention to period two signals and they increase attention to the period one signals because they know that information will be useful in the future too. Additionally, if agents do not care about the future at all, $\beta = 0$, then agents will not pay any attention to period two signals. Fourth, all the attention choices are decreasing in c , the marginal cost of paying more attention to a signal.

Proposition 2 (Equilibrium Attention Choices).

$$Z_{CB1} = w_{CB1} \sqrt{\frac{1 + \beta w^2}{c}}$$

$$Z_{P1} = w_{P1} \sqrt{\frac{1 + \beta w^2}{c}}$$

$$Z_{CB2} = w_{CB2} \sqrt{\frac{\beta}{c}}$$

$$Z_{P2} = w_{P2} \sqrt{\frac{\beta}{c}}$$

Proof. These expressions are derived straight forwardly from the first order condi-

tions for each attention choice. □

Corollary 3 (Total Attention). *Let total attention in period one be denoted by $TOTZ_1 = Z_{CB1} + Z_{P1} = \sqrt{\frac{1+\beta w^2}{c}}$ and total attention in period two be denoted by $TOTZ_2 = Z_{CB2} + Z_{P2} = (1-w)\sqrt{\frac{\beta}{c}}$. Then,*

$$TOTZ_1 \geq TOTZ_2 \text{ and } TOTZ_1 = TOTZ_2 \iff \beta = 1 \text{ and } w = 0.$$

Proof. Square and expand both expressions to get $TOTZ_1^2 = 1 + \beta w^2$ and $TOTZ_2^2 = (1 - 2w + w^2)\beta$. From here, we can see that comparing the expressions is identical to comparing $(1 - 2w)\beta$ to 1. We can split the proof into two cases. In Case 1 we assume $w = 0$ and in Case 2 we assume $0 < w \leq 1$. Recalling that $0 < \beta \leq 1$ we see in Case 1, $(1 - 2w)\beta = \beta \leq 1$ and $TOTZ_1 \geq TOTZ_2$. The two expressions are equal if and only if $\beta = 1$. Since $TOTZ_1$ is monotonically increasing in w and $TOTZ_2$ is monotonically decreasing in w we can see that in Case 2, $TOTZ_1 > TOTZ_2$. □

1.2.3 Weights Period 2

Solving for the weights in period two is more complicated since we can have two solutions possible depending on the parameters in the model. Specifically, it will depend on the marginal cost, c and the bound $\Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta)$. If we let $x = P_{P1}(1 - r) + P_{T1}$ and $y = P_{P2}(1 - r) + P_{T2}$, then

$$\Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta) = \frac{1}{2} \frac{\beta(\frac{y}{x})}{\sqrt{(x+y)^2 + \beta x^2} - (x+y)\sqrt{1+\beta} + y\sqrt{\beta}}.$$

Proposition 4 contains the solutions for the weights in period 2.

Proposition 4 (Weights Period 2). *1. If $\sqrt{c} > \Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta)$, then agents will ignore all new information in the second period: $w = 1$ and $w_{CB2} = w_{P2} = Z_{CB2} = Z_{P2} = 0$.*

2. If $\sqrt{c} < \Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta)$, then agents gather new information:

$$\begin{aligned} w &= \frac{P_{T1} + (1-r)P_{P1}}{P_{T1} + P_{T2} + (1-r)(P_{P1} + P_{P2})} \\ w_{CB2} &= \frac{P_{T2}}{P_{T1} + P_{T2} + (1-r)(P_{P1} + P_{P2})} \\ w_{P2} &= \frac{(1-r)P_{P2}}{P_{T1} + P_{T2} + (1-r)(P_{P1} + P_{P2})} \end{aligned}$$

3. If $\sqrt{c} = \Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta)$, then agents are indifferent between the two equilibria.

Proof. We start by taking first order conditions of the loss function (expected utility subject to the weights summing to one and non-negativity constraints on the weights) but assume the non-negativity constraints on the weights do not bind. Under this assumption, we can solve for w_{CB2} and w_{P2} in the same fashion as Proposition 1 to get $w_{CB2}/w_{P2} = \psi_{CB2}/\psi_{P2} = P_{T2}/P_{P2}(1-r)$. The first order condition for w yields $w = (\widetilde{\psi}_{CB1} + \widetilde{\psi}_{P1})/(\widetilde{\psi}_{CB1} + \widetilde{\psi}_{P1} + \widetilde{\psi}_{CB2} + \widetilde{\psi}_{P2})$ where

$$\begin{aligned} \widetilde{\psi}_{CBn} &= \frac{1}{\frac{1-r}{P_{Tn}} + \frac{1}{Z_{CBn}}} \\ \widetilde{\psi}_{Pn} &= \frac{1}{\frac{1}{P_{Pn}} + \frac{1}{Z_{Pn}}}. \end{aligned}$$

We can redefine the problem to split the weight on old information, w , into the weight on old public and old private information by defining $\widehat{w}_{CB1} = w w_{CB1}$ and $\widehat{w}_{P1} = w w_{P1}$. The ratio of these two weights along with what we showed in Proposition 1 gives us $\widehat{w}_{CB1}/\widehat{w}_{P1} = w_{CB1}/w_{P1} = \widetilde{\psi}_{CB1}/\widetilde{\psi}_{P1} = \psi_{CB1}/\psi_{P1} = P_{T1}/P_{P1}(1-r)$. Combining this with the linearity assumption on the weights we get the expressions listed in the second part of Proposition 4.

Next we must check to see if the non-negativity constraints on the weights bind. If one or more of the non-negativity constraints on w , w_{CB2} , w_{P2} bind, then one

or more of the weights must equal 0. We can check this by comparing an agent's utility function given the solutions for the weights in part 2 of the proposition to the different combinations of one or more of the weights equalling zero. We then either determine a bound for when utility is higher under one of the weights as an exterior solution or we rule out the solution in favor of the interior solution given in part 2. Following this method, we derive the inequality listed in part 1 for the solution where $w = 1$, $w_{CB2} = 0$, and $w_{P2} = 0$. \square

From Proposition 4 we can see that when agents do not use new information, $w_{CB2} = w_{P2} = 0$, they do not gather new information either, $Z_{CB2} = Z_{P2} = 0$. Intuitively, when attention costs are high enough, agents will not pay to allocate attention to new information and, in turn, will not weight the new information when deciding their action since the signals will have infinite variance. This is optimal for agents to do since they can remember the old information at no cost. However, if costs are small enough, agents will want to pay attention to new information and use this information to decide their action since the new information can help them make a better choice for their action.

Proposition 5 shows how the bound that determines whether or not agents use new information depends on the parameters in the model. We see that the bound is decreasing in period one information, P_{T1} and P_{P1} , and increasing in β and period two information, P_{P2} and P_{T2} . Whenever Φ increases the inequality guaranteeing no new information is used is less likely to hold. Intuitively, when period two information is better, agents are more likely to use new information and are more likely to pay attention to the new information. When period one information is better agents are less likely to use new information and less likely to pay attention to it. If agents care more about the future, which translates into a higher β , then they are more likely to use and pay attention to new information.

Proposition 5 (Φ 's Dependence on Parameters). 1. Φ is decreasing in P_{P1}, P_{T1} .

2. Φ is increasing in P_{P2}, P_{T2}, β .

3. Consider the class of parameterizations consisting of $P_{Pn} = \alpha P_{Tn}$ for $n = [0, 1]$ where $\alpha > 0$. Then,

$$\Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta) = \hat{\Phi}(P_{T1}, P_{T2}, \beta) \frac{1}{1 + \alpha(1 - r)}$$

and Φ is increasing in r .

Proof. We take the derivative of Φ with respect to x to show Φ is decreasing in x and hence it is also decreasing in P_{P1} and P_{T1} . Similarly, we can take the derivative of Φ with respect to y and β to show it is increasing in P_{T2}, P_{P2} , and β . Part 3 of the proposition follows straightforwardly from substituting in $P_{Pn} = \alpha P_{Tn}$ for private information precision and taking the derivative of Φ with respect to r . \square

When we consider the class of parameterizations consisting of $P_{Pn} = \alpha P_{Tn}$ for $n = [0, 1]$ with $\alpha > 0$, we see that Φ is also increasing in the coordination parameter r . The intuition is that as r increases, agents care more about coordinating and there are only two signals that can help them coordinate: s_{CB1} and s_{CB2} . When they care more about coordinating they are more willing to pay the attention cost to observe s_{CB2} in addition to observing s_{CB1} . We could extend Proposition 5 to consider other classes of parameterizations, but we choose to focus on this class of parameterizations as it will prove to be an interesting and useful case to consider in the later sections.

Part 3 of Proposition 5 indicates an interesting result. Since Φ is increasing in r , there exists parameterizations such that $w_{r1} < 1$ and $w_{r2} = 1$ where w_r is the weight on old information for a model with coordination parameter r and $r1 > r2$. This means the coordination externality has the additional distorting mechanism

where agents pay more attention to newer information than a model with a lower coordination motive.

Now that we have the solutions for all the weights and attention choices we can see that the coordination externality extends to the attention choices as well. Since agents overreact to public information through their weights, they also give more attention to it than what the information quality of the public signal would indicate. This result is stated in Corollary 6.

Corollary 6 (Coordination Externality in Attention). *1. Agents are overly attentive to public information in period 1:*

$$\frac{Z_{CB1}}{Z_{P1}} = \frac{w_{CB1}}{w_{P1}} = \frac{P_{T1}}{P_{P1}(1-r)} > \frac{P_{T1}}{P_{P1}}.$$

2. If $\sqrt{c} < \Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta)$, then agents are overly attentive to public information in period 2:

$$\frac{Z_{CB2}}{Z_{P2}} = \frac{w_{CB2}}{w_{P2}} = \frac{P_{T2}}{P_{P2}(1-r)} > \frac{P_{T2}}{P_{P2}}.$$

3. If $\sqrt{c} > \Phi(P_{P1}, P_{T1}, P_{P2}, P_{T2}, r, \beta)$, then $w = 1$ and $w_{CB2} = w_{P2} = Z_{CB2} = Z_{P2} = 0$ and agents are not overly attentive to public information in period 2 but still are overly attentive to period 1 information.

1.3 Welfare Results

The main question of this paper is: When is increasing transparency costly for welfare? To answer this question, we take the derivative of the welfare function, Equation 1.7, with respect to P_{T1} and P_{T2} separately. The sign of this derivative tells the central bank facing a given path of transparency whether or not they should be more transparent. If the sign is positive, then more information is beneficial for

welfare. If the sign is negative, more information is harmful. Since the original welfare cost Morris and Shin (2002) identified is a special case of our setup, we will analyze the welfare function building up from this special case. Specifically, we will start with the dynamic counterpart to Morris and Shin (2002) which consists of a model where agents forget old information and there are no attention costs. Next, we will allow agents to remember information. Finally, we will analyze the general setup with agents remembering information and attention costs.

Previewing our results, we show that extending the static model to a dynamic setting with or without remembering information yields similar conditions for costly transparency as Morris and Shin (2002). Specifically, we need the private signal to be relatively more precise in at least one period and for the coordination parameter to be large enough. Considering the dynamic setting gives us the added intuition that the central bank has a motive to endogenously time transparency. If we consider recessions as a time of increased uncertainty in the private sector, then the central bank improves welfare by being more transparent in recessions and less transparent in booms. When we allow for attention costs, the conditions for transparency are no longer similar to Morris and Shin (2002). Attention costs amplify (reduce) the benefits (costs) of earlier transparency while they attenuate (amplify) the benefits (costs) of delayed transparency. The main result here is if we do not consider attention costs, earlier public information is undervalued and delayed public information is overvalued. We can find cases where increased transparency without considering attention costs is costly but allowing for attention costs is beneficial and vice versa. Thus, the central bank could adversely affect welfare when deciding its transparency policy if it does not consider attention costs in a dynamic setting.

1.3.1 No Rememberance and No Attention Costs

The dynamic counterpart of Morris and Shin's (2002) static setting is a special case of our setup which entails no attention costs and agents forgetting information from period one so they cannot reuse old information in period two. We can achieve this from the original setup by forcing $w = c = 0$. With no attention costs, agents will choose $Z_{CBn} = Z_{Pn} = \infty$ for both periods and observe the central bank announcement and the private signal without additional noise from inattention. We denote this special case by DMS for dynamic Morris and Shin. In this special case, the welfare function from Equation 1.7 can be rewritten as:

$$E[W_{DMS}|\theta] = \underbrace{-\frac{P_{T1} + (1-r)^2 P_{P1}}{(P_{T1} + (1-r)P_{P1})^2}}_{\text{Period 1 Welfare}} - \beta \underbrace{\frac{P_{T2} + (1-r)^2 (P_{P2})}{(P_{T2} + (1-r)P_{P2})^2}}_{\text{Period 2 Welfare}}. \quad (1.11)$$

The term in the first bracket is the portion of the welfare function from period one while the term in the second bracket is the portion of the welfare function from period two. Since agents cannot remember information there, period one information only impacts the first period. When we take the derivative with respect to transparency in either period we get:

$$\frac{\partial E[W_{DMS}|\theta]}{\partial P_{Tn}} = \frac{P_{Tn} - (2r - 1)(1 - r)P_{Pn}}{[P_{Tn} + (1 - r)P_{Pn}]^3}. \quad (1.12)$$

In Proposition 7, we see the sign of this derivative is positive if the private precision for the given time period is relatively large enough and if the desire to coordinate is large enough. This proposition is the dynamic counterpart of Morris and Shin's (2002) result. Since agents overreact to public information, increasing public information can actually be harmful if the coordination desire is strong enough and private information is relatively precise. Notice that if there is no coordination externality here ($r = 0$), then increasing transparency is never costly.

The stipulations that we need a relatively high degree of coordination motive and private precision relatively precise have drawn criticism from the literature. Svensson (2006) criticizes these stipulations as unrealistic. He points out that we do not have a good idea on what values for r are reasonable and even if $r > \frac{1}{2}$ we still need private precision to be relatively more precise than public precision. For the example of the central bank, Svensson argues it seems unlikely that private agents are more informed than the central bank. For certain values for r , it turns out that not only do we need private precision to be relatively precise, but we need that it is much more precise. For example, if $r = 3/4$ the condition in Proposition 7 will hold for period n if the private signal is more than 8 times more precise than the public signal. However, as r tends to $1/2$ or 1 , $\frac{1}{\gamma}$ tends to infinity indicating the private signal must be infinitely more precise than the public signal.

Proposition 7 (Transparency’s Effect on Welfare for DMS). *Let $\gamma = (2r - 1)(1 - r)$. If agent’s cannot remember any information and there are no attention costs, then*

$$\frac{\partial E[W_{DMS}|\theta]}{\partial P_{Tn}} < 0 \iff r > \frac{1}{2} \text{ and } P_{Pn} > \frac{1}{\gamma} P_{Tn}$$

Proof. We see from Equation 1.12 that the derivative can only negative when the inequality $P_{Pn} > \frac{1}{\gamma} P_{Tn}$ holds. We also need the condition $r > 1/2$ since the right hand side of the inequality is undefined when $r = 1/2$ and the numerator of the derivative is always positive when $r < 1/2$. \square

1.3.2 Remembering Information and No Attention Costs

In the previous subsection, there was nothing truly dynamic about the model as agents do not remember information. The model is just a repeated static game. Now, we allow agents to remember information at no cost but still eliminate any attention costs by setting $c = 0$. This allows us to separate the welfare effects of

remembering information from the attention costs we will add in the next subsection. Equation 1.13 is the welfare function for this special case of the general setup:

$$\begin{aligned}
E[W_{DR}|\theta] &= \underbrace{-\frac{P_{T1} + (1-r)^2 P_{P1}}{(P_{T1} + (1-r)P_{P1})^2}}_{\text{Period 1 Welfare}} \\
&\quad - \underbrace{\beta \frac{P_{T1} + P_{T2} + (1-r)^2(P_{P1} + P_{P2})}{(P_{T1} + P_{T2} + (1-r)^2(P_{P1} + P_{P2}))^2}}_{\text{Period 2 Welfare}}.
\end{aligned} \tag{1.13}$$

As we can see, the portion of the welfare function from period one is the same as in the DMS case; however, the portion of welfare from period two is not dependent on period one and period two information. This means increasing period one transparency will have both an intratemporal effect and an intertemporal effect on welfare since period one information affects welfare in period two as well as period one. Equations 1.14 and 1.15 are the derivatives of the welfare function with respect to P_{T1} and P_{T2} , respectively:

$$\begin{aligned}
\frac{\partial E[W_{DR}|\theta]}{\partial P_{T1}} &= \underbrace{\frac{P_{T1} - (2r-1)(1-r)P_{P1}}{(P_{T1} + (1-r)P_{P1})^3}}_{\text{Intratemporal Effect on Welfare}} \\
&\quad + \underbrace{\beta \left(\frac{P_{T1} + P_{T2} - (2r-1)(1-r)(P_{P1} + P_{P2})}{(P_{T1} + P_{T2} + (1-r)(P_{P1} + P_{P2}))^3} \right)}_{\text{Intertemporal Effect on Welfare}}
\end{aligned} \tag{1.14}$$

$$\frac{\partial E[W_{DR}|\theta]}{\partial P_{T2}} = \beta \left(\frac{P_{T1} + P_{T2} - (2r-1)(1-r)(P_{P1} + P_{P2})}{(P_{T1} + P_{T2} + (1-r)(P_{P1} + P_{P2}))^3} \right). \tag{1.15}$$

The intratemporal effect of increasing P_{T1} is the impact period one transparency has on period one welfare whereas the intertemporal effect is the impact period one transparency has on period two welfare. Clearly, the intertemporal effect of period one

transparency is equal to the intratemporal effect of increasing P_{T_2} since both period one transparency and period two transparency enter the welfare function (Equation 1.13) in the same way. This will have an important role to play in determining the marginal benefits and costs of increasing transparency over time. Depending on the scenario, agents may prefer to increase P_{T_1} over increasing P_{T_2} or vice versa. This creates a motive for the central bank to endogenously time transparency. Proposition 8 contains necessary and sufficient conditions for when increasing P_{T_n} is costly. Notice the sufficient condition is the same as the necessary and sufficient conditions for costly transparency in the DMS case. The main difference here is that we could relax this sufficient condition and have at most one time period where this restriction that the private signal be relatively more precise does not hold. The tradeoff is that in the other period the private signal would have to be relatively more precise and by more than $1/\gamma$.

Proposition 8 (Costly Transparency Conditions for DR). *In the model where agents can remember information but there are no attention costs a necessary condition for costly transparency is $P_{P_n} > \frac{1}{\gamma}P_{T_n}$ for at least one period n and $r > 1/2$. A sufficient condition for costly transparency is $P_{P_n} > \frac{1}{\gamma}P_{T_n}$ for both periods $n = [1, 2]$ and $r > 1/2$.*

Proof. Looking at the derivatives in Equations 1.14 and 1.15 we see if $P_{P_n} \leq \frac{1}{\gamma}P_{T_n}$ for both periods then the derivatives will never be negative. If $P_{P_n} > \frac{1}{\gamma}P_{T_n}$ for both periods, then the derivatives will be positive as long as $1/\gamma$ exists which requires $r > 1/2$. □

It is obvious that the impact of period one and period two transparency will not necessarily be of the same magnitude nor the same sign. In both this case and in the DMS case, we can have $\frac{\partial E[W_{DR}|\theta]}{\partial P_{T_1}} > 0$ and $\frac{\partial E[W_{DR}|\theta]}{\partial P_{T_2}} < 0$ for example.

Here, a social planner would increase period one transparency and decrease period two transparency. This suggests that when we consider the public authority who is deciding the path of transparency, they will have a motive to endogenously time transparency. In the case where period one transparency is beneficial and period two is costly, we have $P_{P1} < \frac{1}{\gamma}P_{T1}$ and $P_{P2} > \frac{1}{\gamma}P_{T2}$. Thus, agents are better off when they get more information in the period where their private signal is not very precise. If we think of recessions as times of increased uncertainty for individual households or firms, then the central bank should be more transparent in recessions versus booms.

1.3.3 Remembering Information and Attention Costs

In this subsection we consider the general case where agents can remember information and there are costs to allocating attention, $c > 0$. Remember from Proposition 4 that depending on the parameters of the model we will either have $w = 1$ or $w < 1$. For now we will focus on the case when $w < 1$. In this case, the welfare function is a combination of the welfare from costless attention (W_{DR}) and the welfare due to attention costs:

$$\begin{aligned}
 E[W|\theta] &= \text{Period 1 Welfare under Costless Attention} & (1.16) \\
 &+ \text{Period 2 Welfare under Costless Attention} \\
 &\underbrace{-2c(Z_{CB1} + Z_{P1} + Z_{CB2} + Z_{P2})}_{\text{Welfare from Attention Costs} = W_B}.
 \end{aligned}$$

Comparing this welfare function to the previous subsection we see the portion of the welfare function due to attention costs is found in W_B . Thus, we can focus on the derivative of W_B with respect to P_{Tn} since $\frac{\partial W}{\partial P_{Tn}} = \frac{\partial W_{DR}}{\partial P_{Tn}} + \frac{\partial W_B}{\partial P_{Tn}}$. Proposition 9 shows the signs of the derivatives of W_B taken with respect to period one and period two transparency. The Proposition states that the benefits (costs) of period one

transparency are always amplified (reduced) when we consider attention costs and the benefits (costs) of period two transparency are always attenuated (amplified). The intuition is agents must pay the same marginal cost to allocate attention to period one and period two information, but they can reuse period one information in the second period at no cost. Thus, when the central bank increases period one transparency the benefits are amplified because agents can use this information in two periods by remembering it. When the central bank increases period two information, the benefits are reduced because agents give more weight and attention to new information that is as costly to allocate attention to as old information but can only be used in one period. Of course, the benefit of paying more attention to this new information is the improved quality of information. Agents are optimal and will only increase weight and attention to new information when the marginal benefit outweighs the marginal cost. However, when we have a coordination externality, $r > 0$, increasing transparency can be costly.

The main result here is if we do not consider attention costs, earlier public information is undervalued and delayed public information is overvalued. When we combine this result with the results in the previous subsection we see there are cases where increased transparency without considering attention costs is costly but allowing for attention costs the increase in transparency is beneficial and vice versa. Thus, the central bank could adversely affect welfare when deciding its transparency policy if it does not consider attention costs.

Proposition 9 (Attention Costs and Welfare). *The derivative of the portion of the welfare function due to attention costs taken with respect to P_{Tn} is:*

$$\frac{\partial W_B}{\partial P_{Tn}} = -2\sqrt{c}\beta \frac{\partial w}{\partial P_{Tn}} \left[\frac{w}{\sqrt{1 + \beta w^2}} - 1 \right].$$

The sign of these derivatives are:

$$\frac{\partial W_B}{\partial P_{T1}} > 0 \text{ and } \frac{\partial W_B}{\partial P_{T2}} < 0$$

Proof. The weight on old information is increasing in period one transparency and decreasing in period two transparency: $\frac{\partial w}{\partial P_{T1}} > 0$ and $\frac{\partial w}{\partial P_{T2}} < 0$. Since $w \leq \sqrt{1 + \beta w^2}$, we get $\frac{w}{\sqrt{1 + \beta w^2}} - 1 \leq 0$. Combining the signs together we get the result in Proposition 9. \square

When we consider the case of $w = 0$, it is clear that period two transparency has no affect on welfare since agents do not allocate any attention to period two information. However, period one transparency still matters and can be costly according to the same conditions in the dynamic counterpart to Morris and Shin's model since the agent behaves as if there is only one signal from the central bank.

1.4 Average Action as Signal

In this section, we consider again the dynamic beauty contest game with attention costs but now agents observe the average action with a delay instead of remembering information. They can then use this information as another signal in the second period with no cost. This signal is similar to the idea in Amador and Weill (2010) that agents can learn about the state of the economy from aggregate prices. We could also include the option for agents to remember information, but we can show that if both old information and the aggregate action are costless in the second period, remembering information is redundant, thus $w = 0$.

From the model with old information, a_{i1} is the same, but now $a_{i2} = w_{\overline{a_1}} \overline{a_{12}} + w_{CB2} s_{CB2} + w_{P2} s_{P2}$ where $\overline{a_{12}}$ is the average action from period one observed in period two. Specifically,

$$\overline{a_{12}} = \theta + w_{CB1} \epsilon_{CB1} = \overline{a_1}. \tag{1.17}$$

Note that if there was no private signal, $w_{CB1} = 1$, the agents would observe the central bank's announcement from period one by observing \bar{a}_{12} . Solving for the weights for this model in a similar fashion as before, we get the same weights for period one and two possible solutions for period two (see Proposition 10).

Proposition 10 (Weights: Aggregate Action). *Notice the precision of \bar{a}_{12} is*

$$P_{\bar{a}_{12}} = 1/Var(\bar{a}_{12}|\theta) = \frac{(P_{T1} + P_{P1}(1-r))^2}{P_{T1}} = \frac{(P_{T1} + P_{P1}(1-r))}{w_{CB1}}. \quad (1.18)$$

Let $\Psi(P_{T1}, P_{P1}, r, \beta) = \frac{1}{2} \frac{\beta^{3/2}}{P_{\bar{a}_{12}}}$.

1. If $\sqrt{c} > \Psi(P_{T1}, P_{P1}, r, \beta)$, then $w_{\bar{a}} = 1$ and $w_{CB2} = w_{P2} = Z_{CB2} = Z_{P2} = 0$.
2. If $\sqrt{c} < \Psi(P_{T1}, P_{P1}, r, \beta)$, then $w_{\bar{a}} < 1$ and agents allocate attention to second period signals. Specifically,

$$w_{\bar{a}} = \frac{P_{\bar{a}_{12}}}{P_{T2} + P_{P2}(1-r) + P_{\bar{a}_{12}}} \quad (1.19)$$

$$w_{CB2} = \frac{P_{T2}}{P_{T2} + P_{P2}(1-r) + P_{\bar{a}_{12}}} \quad (1.20)$$

$$w_{P2} = \frac{P_{P2}(1-r)}{P_{T2} + P_{P2}(1-r) + P_{\bar{a}_{12}}}. \quad (1.21)$$

3. If $\sqrt{c} = \Psi(P_{T1}, P_{P1}, r, \beta)$, then agents are indifferent between the two solutions.
4. For the case of no coordination externality, let $\Psi_{r=0} = \frac{1}{2} \frac{\beta^{3/2}}{P_{\bar{a}_{12}}^{r=0}}$ where $P_{\bar{a}_{12}}^{r=0} = \frac{(P_{T1} + P_{P1})^2}{P_{T1}}$. Then, $\Psi_{r=0} < \Psi$ and there exists parameterizations where $w_{\bar{a}} < 1$ and $w_{\bar{a}}^{r=0} = 1$.

Proof. This proposition can be established in the same manner as Proposition 4 by first solving for the weights assuming no non-negativity constraints bind, and then

checking for the exterior solutions for the weights by comparing utility under the different solutions. We either rule out these other solutions or, in the case of the solution given in part 1, we can show the exterior solution is preferred by the agents as long as acquiring information is costly enough. The bound Ψ is derived from the point where the difference in utility from choosing the solution in part 2 and the utility from choosing the solution in part 1 is zero making the agent indifferent. Part 4 of the proposition is seen straightforwardly from plugging in $r = 0$ into Ψ . \square

If the marginal cost of allocation attention is high enough, if β is low enough, and if period one information is good enough agents will not allocate attention to any new information in the second period. Instead, they will put all of their weight on the average action they can observe at no cost. Similar to the previous model, the bound determining when $w_{\bar{a}} = 1$ is lower for the case of lower coordination motives. Thus, there exists parameterizations where agents with a lower coordination motive would not allocate attention in the second period, while agents with higher coordination motives would.

As we saw before, agents overreact to the public signal in comparison to the private signal due to the coordination externality. Interestingly, the coordination parameter does not affect the weight on the aggregate action signal directly, but indirectly. As r increases, the precision of \bar{a}_{12} decreases indicating a larger coordination externality leads to a less informative signal. An increase in period one transparency may or may not increase the quality of the signal. In Corollary 11, we see the quality of the signal increases if and only if $P_{T1} > (1 - r)P_{P1}$.

Corollary 11 (Precision of the Aggregate Action). *The precision of \bar{a}_{12} is increasing in P_{T1} if and only if $P_{T1} > (1 - r)P_{P1}$. If the precision is increasing in P_{T1} , then so is the weight, $w_{\bar{a}}$.*

Proof. This corollary is established by first taking the derivative of $P_{\bar{a}_{12}}$ with respect

to P_{T1} . Then, take the derivative of $w_{\bar{a}}$ with respect to P_{T1} to get the numerator of this derivative, $\frac{\partial P_{\bar{a}12}}{\partial P_{T1}}(P_{T2} + P_{P2}(1 - r))$. This expression makes it obvious that the sign of the derivative depends only if the precision of \bar{a}_{12} is increasing in P_{T1} . \square

When we solve for attention choices we get:

$$Z_{CB1} = \frac{w_{CB1}}{\sqrt{c}} \quad (1.22)$$

$$Z_{P1} = \frac{w_{P1}}{\sqrt{c}} \quad (1.23)$$

$$Z_{CB2} = w_{CB2} \sqrt{\frac{\beta}{c}} \quad (1.24)$$

$$Z_{P2} = w_{P2} \sqrt{\frac{\beta}{c}}. \quad (1.25)$$

In Proposition 12, we see agents give more attention in the first period than in the second, similar to the previous model.

Proposition 12 (Total Attention: Aggregate Action). *Let total attention in period one be denoted by $\widehat{TOTZ1} = Z_{CB1} + Z_{P1}$ and $\widehat{TOTZ2} = Z_{CB2} + Z_{P2}$. Then,*

$$\widehat{TOTZ1} = Z_{CB1} + Z_{P1} = \frac{1}{\sqrt{c}} \geq (1 - w_{\bar{a}}) \sqrt{\frac{\beta}{c}} = Z_{CB2} + Z_{P2} = \widehat{TOTZ2}$$

Total attention in both periods are equal if and only if $w_{\bar{a}} = 0$ and $\beta = 1$.

Proof. This inequality holds since both $1 - w_{\bar{a}} \leq 1$ and $\beta \leq 1$. It holds in equality if and only if $(1 - w_{\bar{a}}) \sqrt{\beta} = 1$ which only happens when $w_{\bar{a}} = 0$ and $\beta = 1$. \square

To analyze the effect of increasing transparency on welfare, let us focus on the case where the conditions in Proposition 10 are met so that $w_{\bar{a}} < 1$. In this case, the

welfare function is:

$$\begin{aligned}
 E[W_{AA}|\theta] &= \overbrace{\left[\frac{P_{T1} + (1-r)^2 P_{P1}}{(P_{T1} + (1-r)P_{P1})^2} + \beta \frac{(1-r)P_{\bar{a}12} + P_{T2} + (1-r)^2 P_{P2}}{(P_{\bar{a}12} + P_{T2} + (1-r)P_{P2})^2} \right]}^{W_A} \\
 &\quad \underbrace{-2\sqrt{c} [1 + \beta(1 - w_{\bar{a}})]}_{\text{Welfare due to Attention Costs} = W_B} . \tag{1.26}
 \end{aligned}$$

We focus on the affect transparency has on the portion of the welfare function due to attention costs, W_B , to study what would happen if the public authority did not acknowledge attention costs. Interestingly, Proposition 13 shows us the attention costs amplify the benefits of earlier transparency when period one transparency is relatively more precise than the private signal, but can increase the costs of earlier transparency if the private signal is relatively more precise. It also shows the costs of period two transparency are always amplified. Thus, we can find cases where transparency without acknowledging attention costs would appear beneficial but allowing for attention costs actually shows it can be costly and the reverse scenario as well.

Proposition 13 (Welfare Impact from Attention Costs: Aggregate Action). *The portion of the welfare function due to attention costs when the aggregate action acts as a signal is increasing in P_{T1} if and only if $P_{T1} > (1-r)P_{P1}$. The portion of the welfare function due to attention costs is decreasing in P_{T2} always.*

Proof. The derivative of the portion of the welfare function due to attention costs with respect to transparency in either period is:

$$\frac{\partial W_B}{\partial P_{Tn}} = 2\sqrt{c}\beta \frac{\partial w_{\bar{a}}}{\partial P_{Tn}}.$$

From Corollary 11, the weight on the average action is increasing in period one transparency if and only if $P_{T1} > (1-r)P_{P1}$. The weight on the average action is always decreasing in P_{T2} . □

This section shows we can find similar results for costly transparency in the case of attention costs whether we assume agents can learn from past aggregate actions or if we assume agents can remember information. In either case, the benefits of earlier transparency tend to be amplified whereas the benefits of delayed transparency tend to be attenuated and a central banker who does not acknowledge attention costs would inappropriately decide its transparency policy.

1.5 Conclusion

This paper studies the welfare impact of increasing public institution transparency. We are the first to explore this question in a dynamic setting with and without attention costs. Allowing for dynamics and attention costs reveals new dimensions of the benefits and costs of transparency. First, we show the overreaction to public information is not the only distortion the coordination externality creates. Agents are more likely to pay attention costs in a new period in order to use new information to help coordinate when the coordination motive is higher while under a lower coordination motive agents would prefer to reduce attention costs by ignoring the information and remembering old information. Since the coordination motive is an externality, the dynamic model with attention costs leads to another distortion for the coordination externality to matter. Second, *ceteris paribus*, agents prefer more transparency in times of greater uncertainty such as recessions and less transparency when they are already well informed. Third, attention costs amplify the benefits of earlier transparency and attenuate the benefits of delayed transparency. Therefore, a central banker who fails to acknowledge attention costs could inappropriately allocate transparency across time. For example, the central bank might determine that increasing transparency is costly in a given period while considering attention costs would indicate it is beneficial. Fourth, we verify these results hold when considering the average action as a potential signal. These results suggest determining

when transparency is costly is not as straightforward as looking at a static problem with no attention costs. Agents face constraints on how much information they can process. They also can remember information across time. These innovations taken together significantly impact the answer to this question.

Heterogenous Consumption and Fiscal Policy Shocks

2.1 Introduction

Most of the macroeconomic literature relies on the representative agent paradigm. The assumption of a representative agent is generally made for technical simplicity, since the solution of dynamic models with heterogeneous agents is computationally challenging. However, the study of aggregate data might provide the incorrect evaluation of economic theories. For example, Attanasio and Weber (1993) demonstrate that the use of microeconomic data can overturn rejections of consumer intertemporal optimization models based on aggregate data. In addition, the assumption comes at the cost of preventing the analysis of important questions such as whether economic policies equally affect individuals with different characteristics, whether they influence inequality, or what are the macroeconomic consequences of aggregate fluctuations on the welfare of individuals that differ in their consumption patterns. In other words, while the representative agent assumption allows macroeconomists to study how average values of macroeconomic variables are affected by economic

policies, it does not allow them to study how these policies affect the distribution of such variables across households.

This paper focuses on studying the effects of unexpected changes in aggregate macroeconomic policies on consumers that are allowed to differ depending on their individual characteristics. We ask the questions: “Do fiscal shocks affects individuals differently? And, if so, how?”. Fiscal policy analysis is an especially important area of macroeconomics since it has direct implications for consumers’ welfare.¹ The literature has extensively studied the effects of government spending and tax policy shocks on aggregate macroeconomic variables; one of the approaches, which we focus on, is narrative – see Ramey and Shapiro (1998), Ramey (2009, 2011a), and Romer and Romer (2010).² The narrative approach uses narrative records (such as presidential speeches and newspapers) to identify the timing and magnitude of major fiscal changes, and identifies fiscal shocks as those changes that were taken for reasons exogenous to the business cycle. However, since these analyses focus on aggregate data, by construction they only provide an estimate of the average response of aggregate macroeconomic variables to fiscal shocks (on average across individuals), while remaining uninformative regarding heterogeneity across individual responses. Realistically, fiscal shocks may affect individuals differently depending on their individual-specific characteristics, such as income, education, or age. Studying whether this is the case, and who gains and who loses from unexpected changes in government spending and tax policy is the main focus of this paper. An additional benefit of using household level data besides analyzing heterogeneity is that we can avoid the so-called “aggregation bias”, unavoidable in aggregate data where

¹ Although our paper does not directly provide a welfare analysis, it provides an analysis of the effects of fiscal policy “shocks” on one of the most important consumers’ variables, namely their consumption.

² See also Edelberg, Eichenbaum, and Fisher (1999), Burnside, Eichenbaum, and Fisher (2004), Cavallo (2005), Perotti (2005, 2007) and Rossi and Zubairy (2011) for related papers. Ramey (2011b) provides an extensive review of the literature.

researchers have no control over the aggregation process. We evaluate the empirical importance of the aggregation bias and analyze its implications for the analysis of fiscal policy shocks on aggregate behavior.

The main empirical finding of this paper is that unexpected government spending and tax policy shocks have substantially different effects on consumers depending on their age, income and education levels. Our empirical evidence is based on a narrative approach, and in particular a Vector Autoregressive (VAR) model, as in Ramey (2011a) and Romer and Romer (2010).³ By using a Structural VAR model where the shock is ordered first, we ensure that the shock series is orthogonal to past information contained in the other variables included in the VAR; at the same time, we allow variables other than the shock to contemporaneously react to the shock itself. Our main finding is that individuals whose consumption levels are most negatively affected by a government spending policy shock (i.e. an unexpected increase in government spending) are the wealthiest and younger individuals (the working and the young age groups), whereas consumption of the poorest increases the most. Thus, positive government spending policy shocks tend to decrease consumption inequality.

Regarding tax policy shocks, an unexpected increase in taxes mainly decreases consumption of the poorest, and it is mostly borne by the youngest category, whereas consumption of the wealthiest individuals increases the most.⁴ The differences among groups are strongly statistically significant. This implies that positive tax policy shocks most negatively affect consumption of the poor, more so than the rich, thus increasing consumption inequality. We also show that our main results are robust to considering different types of tax policy shocks as well as considering only unexpected tax policy shocks or the political party that implemented the tax changes.

³ See Perotti (2005, 2007) for a VAR analysis of fiscal policy shocks without a narrative approach.

⁴ The fact that an increase in government spending has a large positive effect on the oldest individuals and negative effects on the youngest individuals may signal that the government spending crowds out the younger groups consumption since the latter know they will have to pay back later.

Regarding the economic interpretation of our results, our paper is very related to Galí, López-Salido and Vallés (2006). Galí, López-Salido and Vallés (2006) show that a calibrated Keynesian model with sticky prices and rule-of-thumb consumers can generate an increase in consumption when government spending increases. Our results provide further empirical support to the analysis in Galí et al. (2006) by showing that the poorest individuals, the ones that are more likely to be credit constrained, have a positive consumption response to fiscal policy shocks; on the other hand, the richest individuals' consumption responds negatively. Overall, the response of the whole population will depend on which of the two prevails. Other related papers include Schmitt-Grohe' and Uribe (2010), who study the contribution of anticipated shocks to business cycles in US data, including government spending, and Zubairy (2011), who develops a DSGE model where deep habits generate a positive response of consumption to a positive government spending shock.

This paper's analysis is closely related to the large literature on the effects of government spending and tax shocks on macroeconomic aggregates, such as Ramey (2009, 2011a) and Romer and Romer (2010). While the latter literature focuses on the effects of shocks on aggregate data, we focus instead on effects on individual consumption by allowing individuals to be heterogeneous. Our research is also very related to Owyang and Zubairy (2009) and Nekarda and Ramey (2011); the former analyze the effects of government spending shocks on state-level personal income and employment, and find regional patterns in the way government spending policy shocks affect state-level variables. The latter study the effects of government purchases at the industry level. The difference between our paper and theirs is that we focus on heterogeneity across individual consumers, whereas Owyang and Zubairy (2009) focus on heterogeneity across states and Nekarda and Ramey (2011c) across industries.

Our paper is also related to the recent advances in the study of heterogene-

ity. Heathcote, Storesletten and Violante (2009) review the theoretical literature on quantitative macroeconomic models with household heterogeneity; our paper instead is an empirical paper that estimates whether heterogeneity in responses to policy shocks are important.⁵ Other empirical studies have also become available since the first version of our paper. Misra and Surico (2011) study tax rebates for specific events, whereas we focus on time series data since the 1980s, and hence our results cover a longer time period and more events/shocks.⁶ Giavazzi and McMahon (2012) study heterogeneity in household responses in hours worked to shifts in fiscal policy. They identify state-specific variation in military contracts driven by aggregate changes in US military spending, which is their measure of fiscal shocks. We instead analyze heterogeneity in household responses to aggregate fiscal shocks identified via a narrative approach in a VAR setting. Also, after a draft of this paper was circulated, we became aware of work by De Giorgi and Gambetti (2012), who study the effects of government spending on the distribution of consumption. Their analysis is different from ours in that it is based on an unobserved component model of consumption and considers heterogeneity measured by consumption deciles, while we measure individual heterogeneity in terms of income deciles as well as age and education levels.

The paper is organized as follows. Section 2.2 describes the data while Section 2.3 describes the VAR we estimate. Section 2.4 and 2.5 discuss results for government spending and tax policy shocks, respectively. Section 2.6 reports more results based on aggregate data, and Section 2.7 discusses robustness to the source of the tax shock, expectations as well as the political party in power. Section 2.8 concludes and

⁵ Theoretical papers on heterogeneous agents models also include Rios-Rull (1995), Krusell and Smith (1998), Heathcote (2005), among others. The latter papers have theoretically developed and calibrated heterogeneous agents models, whereas our focus is on the empirical estimation of the effects of fiscal policy shocks.

⁶ Also, Johnson, Parker and Souleles (2006) exploit the 2001 U.S. tax rebate to measure the change in consumption expenditures caused by the receipt of the rebate.

Section 2.9 contains the tables and figures.

2.2 Data Description

We collect information on consumption and income heterogeneity across individuals by using household consumption expenditure data from the interview portion of the Consumer and Expenditure Survey (CEX), conducted by the Bureau of Labor Statistics. The measure of government spending and tax policy shocks we use are the time series developed by Ramey (2011a) and Romer and Romer (2010). We use quarterly data that span 1983:Q4-2008:Q4 for our government spending shock analysis, and 1983:Q4-2007:Q4 in our tax policy shock analysis. The starting date of the sample is determined by the availability of CEX data, whereas the end date is determined by the availability of data on the government spending and tax policy shocks.⁷ Here we provide a detailed description of the data as well as preliminary data analyses that establish the usefulness of the CEX database for our purposes. In particular, we demonstrate that existing empirical results in the literature are consistent with those based on aggregate CEX data. However, CEX data have the important advantage of being suitable for more disaggregate analyses, which we undertake in the following sections.

Regarding CEX data, the interview survey follows a given household for five quarters, but gathers data on consumption for the last four interviews. Following Lusardi (1996), we focus on nondurable consumption defined as expenditures on food, alcoholic beverages, tobacco, utilities, personal care, household operations, public transportation, gas and motor oil, and miscellaneous expenses. We focus on nondurable consumption rather than durable because the latter is more similar to an investment decision. For our measure of income, we use the household's in-

⁷ Although it is possible to find CEX data back to 1980Q1, there are issues regarding the quality and the treatment of the additional data, so we decided to use data starting in 1983Q4.

come after taxes for the 12 months before the survey is taken. We drop households with missing data or non-positive consumption or income data. Also, we drop the 1986:Q1 observation due to missing data. An additional concern is the presence of measurement error in the data, in particular for income data reported in the CEX (Lusardi, 1996). Our procedure involves constructing pseudo-panels by averaging individuals belonging to groups identified by individual-specific characteristics; thus, our procedure attenuates idiosyncratic measurement error by averaging individual-level consumption data. Individual-level income data, which are subject to stronger measurement error, are used only to construct income quintiles in our main paper, thus not raising strong concerns about the effects of measurement error in income in our main results.

Our measure of consumption is the log of real per capita consumption expenditures. To construct this measure, we first transform CEX consumption in real terms using non-seasonally adjusted CPI data (since the CEX data are initially non-seasonally adjusted) from the St. Louis Federal Reserve's FRED database. Then, we seasonally adjust the data by taking a centered moving average of 5 quarters. Finally, we divide CEX household data by the number of family members for each household to get a measure of per capita consumption.

We study the effects of government spending and tax policy shocks identified via a narrative approach. The main advantage of using the narrative approach relative to identifying shocks via a Structural VAR is that the shock is directly identified by using information outside the VAR estimation, and hence does not depend on which variables are included in the VAR or which identifying assumptions are made. The disadvantage of the narrative approach is that it requires judgment calls when creating the shock variable. To mitigate the latter concern, we use already established measures and we include the shocks measures in a Structural VAR to ensure that the shock we use in the empirical analysis is uncorrelated with past values of the other

macroeconomic variables we consider.

The measure of government spending policy shocks we use is developed by Ramey (2011a). Typically, when studying government spending policy researchers use defense news shocks since they are the least likely to crowd out private consumption and be affected by demographic changes or the state of the economy. Ramey (2011a) does provide a narrative time series of defense spending news shocks based on studying articles in news sources such as *Business Week* magazine. Unfortunately, Ramey (2011a) shows that the defense news shock does not have good explanatory power for real government spending in the sample period we are working with, which is constrained by the availability of data in the CEX. Ramey (2011a) develops an alternative narrative measure of government defense spending shocks based on the Survey of Professional Forecasters (SPF). The SPF shock is the difference between actual real government spending growth and the SPF's forecasted growth. She shows that this measure does have good explanatory power for government spending in the time period that we consider, so we focus on this measure in our paper.

We also use the tax policy shock measure developed by Romer and Romer (2010). The measure is constructed by using records of presidential speeches and Congressional reports. Using the latter sources, Romer and Romer (2010) identified the size, timing and principal motivations behind all major post-war tax policy innovations. By identifying the motivations for the tax change based on the legislation, they derive an exogenous tax shock that only contains tax changes affecting the long run state of the economy, instead of short term fluctuations. An example of an exogenous tax change is one that is motivated by the need to improve output growth in the long run, rather than to return output to its trend level when fighting a recession. The tax shock we focus on is the exogenous tax series measured as the change in tax liabilities as a percentage of GDP, labeled "EXOGENRRATIO" in Romer and Romer (2010), which is the same measure that they use in their empirical analysis. If the

shocks were truly exogenous to short term fluctuations of output, one could proceed with a simple univariate regression. However, Romer and Romer (2010) recognize that identifying the motivation behind the legislated tax changes can be difficult, so they estimate a Structural VAR (SVAR) model, and we follow the same approach.

It is important to verify that the CEX data are appropriate for our analysis, and that using aggregate CEX data does not invalidate fundamental empirical findings in the existing literature. It is also important to verify that our VAR specification is suitable for the analysis even though it includes fewer variables than in Ramey (2011a) and Romer and Romer (2010), due to concerns about parameter proliferation and its negative effects in small samples on VAR estimation with a large number of endogenous variables. We demonstrate that this is the case by comparing aggregate CEX data results with those in Ramey (2011a) and Romer and Romer (2010), which are based on the National Income and Product Accounts (NIPA) data.⁸ Although Slesnick (1992, 1998) offers some empirical evidence that the CEX data and the personal consumption expenditure data from the NIPA do not necessarily measure the same quantities, their correlation is substantial (Attanasio, 1998). Furthermore, we are concerned mainly about responses to policy shocks, which might be less affected by differences in the levels of the variables.

We start by replicating Ramey's (2011a) and Romer and Romer's (2010) results with their databases.⁹ For aggregate consumption data we use several components of personal consumption expenditure (PCE) from the NIPA database including: non-durable, durables, and services consumption. In order to ensure that a similar seasonal adjustment procedure is applied to both CEX and NIPA data, and since NIPA

⁸ Ramey's (2010) sample period is 1969-2008, while ours is 1983-2008. Romer and Romer's (2010) sample period is 1950-2007. We cannot extend our sample further back due to shorter sample of data available for CEX data.

⁹ Note that Romer and Romer (2010) use monthly industrial production and PPI while we use GDP and CPI in order to keep the empirical analysis consistent across specifications.

data are already seasonally adjusted, we do not make any other seasonal adjustment, and use the seasonally adjusted CPI series from FRED (instead of the non-seasonally adjusted series we used for the seasonally unadjusted CEX data). To transform aggregate consumption and government spending data in per capita terms, we use population data from the United States Census.¹⁰

In a first exercise, we consider a basic Structural VAR (SVAR) specification inspired by Ramey (2011a):

$$A(L)Z_t = K + D_1t + D_2t^2 + U_t \quad (2.1)$$

where Z_t is a vector containing the SPF shock, the log of real per capita total government spending and the log of real per capita aggregate consumption, $A(L) = A_0 + A_1L + \dots + A_4L^4$, L is the lag operator, K is a vector of constants and U_t is a vector of shocks identified via the recursive ordering procedure, where the SPF shock is ordered first, and consumption last. This VAR is similar to Ramey (2011a) except that she also includes an average tax rate variable and an interest rate variable (we do not include the latter in order to keep our VAR parsimonious, due to small sample concerns).¹¹ By using a Structural VAR model where the shock is ordered first, we ensure that the shock series is orthogonal to past information contained in the other variables included in the VAR; at the same time, we allow variables other than the shock to contemporaneously react to the shock itself. We replicate the analysis in Ramey (2011a) by using exactly her aggregate variables, time periods

¹⁰ The NIPA defines the population as the total population of the United States including the Armed Forces overseas and the institutionalized population. See page 14 in the *A Guide to the National Income and Product Accounts of the United States* located at <http://www.bea.gov/national/pdf/nipaguid.pdf>.

¹¹ The objective of this exercise is to verify that, even in parsimonious VARs, we obtain results similar to Ramey (2011a). In particular, Ramey (2011a) includes taxes in her VAR; however, the disaggregate data that we will consider in the main part of our paper are available only for a shorter sample than Ramey's, which will require a more parsimonious VAR. For the same reasons we do not include a measure of monetary policy even though it might be important in principle – see Rossi and Zubairy (2011) and Davig and Leeper (2011).

and number of lags (four). The main difference is that we replace her measures of aggregate nondurable consumption from NIPA with our measure of CEX aggregate nondurable consumption. Figure 2.1 reports impulse responses of nondurables consumption (Panel A) to a government spending shock estimated from Equation (2.1) using aggregate NIPA data. The impulse response for nondurables has a very similar shape to Ramey (2011a, Fig. XII). Both responses are negative on impact as well as a few quarters after the shock. Thus, our results match Ramey’s (2011a) results fairly well.¹² Panel B in Figure 2.1 considers instead Ramey’s specification using aggregate CEX consumption data in place of consumption from NIPA. CEX aggregate consumption is constructed the same way as the NIPA consumption aggregate, that is:

$$C_t \equiv \ln \left(\frac{1}{H_t} \sum_{i=1}^{H_t} c_{i,t} \right) \quad (2.2)$$

where $c_{i,t}$ is consumption attributed to individual i at time t in the CEX survey, and H_t is the number of individuals in the survey at time t . It is clear that the responses are both negative and significant, and very similar in magnitude.

Furthermore, we report multipliers. The multipliers are calculated as follows. The peak multiplier is $\max_h \left| \frac{\partial \ln C_{t+h}}{\partial \ln G_t} \frac{\bar{G}}{\bar{C}} \right| \text{sign} \left(\frac{\partial \ln C_{t+h}}{\partial \ln G_t} \right)$, where C_t is aggregate consumption at time t , G_t is government spending and \bar{G} and \bar{C} are the average government spending and consumption values over the entire time series. The cumulative multiplier is instead calculated as $\sum_{h=0}^{20} \left(\frac{\partial \ln C_{t+h}}{\partial \ln G_t} \frac{\bar{G}}{\bar{C}} \right)$. The multiplier definition is similar to that commonly used in the literature. Furthermore, we normalize the im-

¹² Unreported results show that the response of durables is instead quite different from Ramey’s (2011a), who finds an (insignificant) negative impact response while we have a positive impact response. We also find a significant positive response one quarter after the shock whereas Ramey (2011a) instead finds a negative significant response in quarters 2-8. For nondurables and services, our response has a shape similar to Ramey (2011a, Fig. XII), except for the fact that we find a short positive response on impact. Services consumption shows a negative (although insignificant) impact response similar to Ramey’s (2011a), except that ours is smaller in magnitude.

pact response of G_t to the fiscal policy shock to be unity, so we can interpret the impulse-responses of consumption at horizon h (reported in the figures) to be h -period multiplier (although not rescaled by the long-run values of G_t and C_t). Panel A in Table 2.1 reports both peak and cumulative impulse responses (multipliers) for the various measures of consumption, including the CEX (first column) as well as Nondurables and Services (column labeled “ND and Services”), Nondurables (labeled “ND”), Services (labeled “Services”), and Durables (labeled “Durables”).¹³ In all cases, the cumulative responses are negative. Panel B reports statistical tests on the pairwise differences between the groups; asterisks denote significantly different cumulative responses: one asterisk denotes significance at the 68% level, two asterisks denote significance at the 90% level, and three asterisks denote significance at the 95% level.¹⁴ Although the tests do find quantitatively different cumulative and peak responses for the various measures, the responses are qualitatively very similar and, overall, their shapes are also very similar, which increases our confidence in using CEX consumption data in our analysis.

In a second exercise, we consider the SVAR in Romer and Romer (2010):

$$A(L)Z_t = C + U_t, \tag{2.3}$$

where Z_t is a vector containing the Romer and Romer’s (2010) tax policy shock and the log of real per capita consumption. The VAR is identified with a recursive ordering procedure, where the shock is ordered first and consumption last. The number of lags is 4. Figure 2.2 reports impulse responses of nondurables consumption to a tax policy shock using aggregate NIPA data (Panel A); Panel B in Figure 2.2 reports instead the response to a tax policy shock using CEX aggregate consumption data

¹³ Note that the peak and cumulative multipliers for nondurables and services are not simply obtained as the sum of their respective multipliers.

¹⁴ Note that we also report 68% confidence intervals as they have been widely used in the literature on fiscal policy, so that we can compare our results with those in the existing literature.

in place of NIPA consumption data. The medium to long-run responses are negative and similar in magnitude, although the CEX response is (not-significantly) positive on impact and the NIPA response is larger in magnitude, and more significant. Panel A in Table 2.2 reports both peak and cumulative impulse responses for the various measures of consumption that we consider. All are negative and very similar in magnitude. Panel B shows that they are also not statistically significantly different from each other.

To summarize our results, we conclude that empirical results based on aggregate CEX data are very similar to those currently reported in the literature, even in our simple VARs with fewer variables than in the literature (driven by the small sample constraints in CEX data). Thus, we can use CEX data in our analysis and focus on small VAR without being too concerned about the potential misspecification induced by the parsimonious number of variables that we consider. However, CEX data have an important advantage relative to NIPA data: They can be disaggregated across individuals, and used to evaluate the extent of heterogeneity in individual consumption responses to policy shocks. The next two sections provide such analysis.

2.3 Our Approach

Our disaggregate analysis focuses on CEX data. The CEX is not really a genuine panel, where the same individual is followed over time, but a rotating panel, where individuals remain in the sample only for a limited number of quarters. Deaton (1985) discusses methodologies for adapting the analysis of time series of cross section data to panel data using pseudo-panels identified by defining groups of individuals. For our main analysis, we construct a pseudo panel dataset from the CEX by grouping households according to either age, income, or education.¹⁵ The challenge when

¹⁵ In unreported results, we also consider groups based on age cohorts. In particular, we construct five cohorts with twenty years of data (e.g. the first cohort contains individuals born between 1895

picking the group definitions is to not aggregate the individuals too much, otherwise we would not observe heterogeneity. On the other hand, we cannot study individuals since each household is only in the survey for four quarters. Thus, we choose group sizes that maintain the heterogeneity while keeping enough households in each group. Households fall into one of five possible age groups, defined as: 15-24, 25-34, 35-44, 45-70, and 71-90 year-old individuals. Sometimes, researchers drop students and retired households to study consumption inequality over the workforce portion of the life cycle: see for instance Attanasio (1998) and Attanasio and Weber (1993). We do not follow this convention since our goal is to study differences in consumption responses across groups, where students and retirees could be potentially interesting groups. Income groups are based on income quintiles. Finally, education groups are broken into four categories: “no high school degree”, “high school degree”, “some college”, and “college degree or more”. Table 2.3 contains the average cell size for each group category. In general, we have cell sizes similar to Attanasio and Weber (1993, 1995).¹⁶

In order to examine the consequences of a government spending policy shock, we consider a three variable VAR inspired by Ramey (2011a) and Equation (2.1), with SPF fiscal shock, government spending, and consumption. As previously discussed, the VAR is identified with a recursive ordering procedure where the shock is ordered first and consumption last. We estimate the VAR separately for individuals belonging to each group j , $j = 1, \dots, J$, where J is the total number of groups. The household groups are identified based on the individual characteristics previously discussed (income, age and education). We also include a constant and a quadratic time

and 1914, the second contains individuals born between 1915 and 1934, and so forth). We again find significant differences in the effects of fiscal shocks on individuals depending on their age cohort.

¹⁶ Note that the 45-70 age group contains more households, on average, than other age groups. While we could potentially split this group further, we are interested in this age group because it contains working-age individuals.

trend. Specifically, our VAR is:

$$A^j(L) Z_t^j = K^j + D_1^j t + D_2^j t^2 + U_t^j \quad (2.4)$$

where Z_t^j is a vector containing the SPF shock, the log of real per capita government spending and the log of real per capita consumption for individuals belonging to group j , $A^j(L) = A_0^j + A_1^j L + \dots + A_4^j L^4$, K^j, D_1^j, D_2^j are vectors of parameters, and U_t^j is a vector of residuals. Our choice of lag length, time trend, and per capita consumption is based on Ramey (2011a). We estimate Equation (2.4) separately for each of the J groups of households.

In order to examine the consequences of a tax policy shock, we consider a bivariate SVAR similar to Romer and Romer (2010), with the tax policy shock and consumption. Our measure of tax policy shock is Romer and Romer's (2010) exogenous tax shock, EXOGENRRATIO.¹⁷ We estimate the VAR separately for individuals belonging to each group j , $j = 1, \dots, J$. Specifically, our equation is:

$$B^j(L) Z_t^j = K^j + \xi_t^j \quad (2.5)$$

where Z_t^j is a vector containing the Romer and Romer's (2010) shock and the log of real per capita consumption for individuals belonging to group j , $B^j(L) = B_0^j + B_1^j L + \dots + B_4^j L^4$, K^j is a vector of constants, and ξ_t^j is a vector of residuals.¹⁸ The SVAR is identified with a recursive ordering procedure, with the shock ordered first and consumption ordered last.¹⁹

The next two sections report estimated impulse responses (IRFs) to either a positive government spending policy shock or a positive tax policy shock, as well as

¹⁷ The empirical results reported in the paper are robust to using EXOGENR instead of EXOGENRRATIO.

¹⁸ Romer and Romer (2010) use 3 years of lags in their model, but our more limited sample period prevents using that many lags.

¹⁹ Note that we do not include government spending shocks in Equation (2.5) and we do not include tax shocks in Equation (2.4) due to the fact that our sample is too short to include many variables in the VAR. We also do not include a deterministic trend following Romer and Romer (2010).

standard error bands calculated using a parametric bootstrap (Berkowitz and Kilian, 2000). The standard error bands have 68% coverage rate, as is common practice in the fiscal policy literature (see Ramey, 2011a, and Romer and Romer, 2010). We also calculate peak and cumulative responses that measure the cumulative effect of the policy shock and can be interpreted as a multiplier measure – see Spilimbergo et al. (2009). We report statistical tests on the pairwise differences between peak responses among the various groups; asterisks denote statistical significance: one asterisk denotes significance at the 68% level, two asterisks denote significance at the 90% level, and three asterisks denote significance at the 95% level. We also consider significance for cumulative responses, denoted by daggers: one dagger denotes significance at the 68% level, two daggers denote significance at the 90% level, and three daggers denote significance at the 95% level.

2.4 Heterogeneity in Individuals’ Responses to Government Spending Policy Shocks

This section presents the main empirical results for the responses to a government spending shock. We discuss results for groups of individuals sorted by either income levels or age. Additional results for individuals sorted by education level are reported in Appendix A.

To preview our results, in general we find substantial empirical evidence in favor of heterogeneity across consumers’ responses to an aggregate positive government spending policy shock. In particular, we find that the poorest and the oldest individuals’ consumption levels are the most positively affected by the shock. Consumption of the middle-age, the youngest and the wealthiest groups is the most negatively affected by the government spending policy shock.²⁰

²⁰ Note that it is unlikely that our results are driven by a homogeneous response to a heterogeneous fiscal policy shock rather than being heterogeneous responses to a homogeneous fiscal policy shock (as we argue) since CEX is a random sample and since the fiscal shock measure we use is an

2.4.1 IRFs and Multipliers by Income Groups

Impulse responses for consumption of individuals grouped by income quintiles are displayed in Figure 2.3. The figure also reports the aggregate response calculated as the response of the average individual's log consumption.²¹ That is, the aggregate consumption response is defined to be the response of $\frac{1}{H_t} \sum_{i=1}^{H_t} \ln(c_{i,t})$. Note that aggregate consumption (last panel) overall significantly increases on impact by about 0.5%, then increases even more for about two additional quarters, and finally reverts back to zero, with a peak response of about 0.7% two years after the shock; the cumulative multiplier is about 0.05 in the five years following the shock. Most of the individual responses have a positive and significant response with the exception of the richest quintile, whose response is significantly negative. It is noteworthy that the richest quintiles are hurt the most in terms of consumption by the increase in government spending. Table 2.4 reports multipliers (Panel A) and tests of statistical significance (Panel B) for pairwise groups of consumers, as well as relative to aggregate consumption. Interestingly, the richest group is statistically significantly different from the third, fourth and fifth poorest quantiles. Note that the poorest quantile's responses are statistically significantly different from those of the richest groups as well. These results point to the existence of substantial heterogeneity in the responses to government spending shocks of consumers that differ by income.

Our results have important implications for the existing debate of the effects of government spending shocks – see Engemann, Owyang and Zubairy (2008) for a survey of the debate. In fact, theoretical models have very different implications regarding the effects of government spending shocks on consumption. According

aggregate measure.

²¹ Note that this is different from the aggregate response calculated as the response of the log of average consumption reported in Figure 2.1. We provide more discussion on the differences between the two in Section .

to standard RBC models, consumption should decrease after a permanent positive government spending shock, whereas consumption should increase in the textbook IS-LM model. In fact, according to the standard RBC model, households anticipate the higher taxes that are necessary to repay the (non-productive) government spending, which lowers the net present value of after tax income, and thus would be affected by a negative wealth effect. Therefore, they react to the increase in government spending by lowering their consumption and their leisure. On the other hand, in the IS-LM model, consumers behave in a non-Ricardian fashion and real disposable income is the most important variable affecting consumption. This is because individuals' consumption is a function of their current income and not of their life-time resources. For example, in the presence of credit constraints, we should observe that the increase in government spending causes consumption to increase. Gali et al. (2007) show that in a New Keynesian model where a fraction of households consume all their income in every period can explain how consumption increases after a government spending shock.²² In our analysis, we are able to disentangle the consequences of government spending shocks on consumers with different levels of income, and therefore, facing different levels of credit constraints.²³ Consumers in the poorest income quantiles, which are more likely to be credit constrained, end up increasing consumption. On the other hand, consumers in the richest income quantiles, which are less likely to be credit constrained, end up decreasing consumption, as the theory predicts.

The reason why we can claim that poorest individuals are more likely to be credit constrained is the empirical evidence discussed in Attanasio et al. (2008), according to which low income consumers are substantially more credit constrained than high

²² Gali et al. (2007) show that another necessary condition for consumption to rise in response to a fiscal expansion is price stickiness in goods markets as well as, in one version of their model, imperfectly competitive labor markets.

²³ While income may not necessarily reflect the degree of liquidity constraints faced by an individual, in the next paragraph we discuss the empirical evidence that supports the interpretation that individuals with low income levels may face liquidity constraints.

income consumers. Interestingly, we find that approximately 20% of consumers (the wealthiest) increase their consumption after a government spending shock, and hence are estimated not to be credit constrained. This estimate is very similar to that reported in Attanasio et al. (2008) for CEX data, according to which approximately 15% of the population with the highest income is not liquidity constrained.²⁴

We also verify in Appendix B that income of the poorer individuals does significantly increase, following an unexpected increase in government spending. We do so by including income as an additional variable in the SVAR. This is important to verify because the mechanism that leads to the increase in consumption for rule-of-thumb consumers is exactly an increase in income. Indeed, income of all groups increases following a positive government spending shock, including that of the poorer individuals, as the theory would predict.

Finally, note that, typically, the richest individuals would have higher consumption levels than poorer individuals. Fiscal shocks, by increasing consumption of the poorest and decreasing consumption of the richest, overall tend to decrease consumption heterogeneity.

2.4.2 IRFs and Multipliers by Age Groups

Panel A in Figure 2.4 shows the impulse response of consumption to a positive government spending shock for individuals grouped by age. Most of the youngest groups experience a negative and statistically significant response at some point over the three years following the shock. The oldest category, instead, has a significantly positive increase in consumption for a few quarters after the shock.

Panel A in Table 2.5 provides additional results by reporting the peak and cumulative multiplier of consumption for each group. The middle age groups have

²⁴ In their paper, Attanasio et al. (2008) identify consumers as being credit constrained if they are responsive to interest rates and loan maturity changes, since a longer debt maturity decreases the size of the monthly payment and allows consumers to sign up for a larger debt.

the most negative peak multiplier, equal to -0.1 approximately,²⁵ closely followed by the youngest category, 15-24 years-old, with a consumption multiplier of -0.05. The oldest category is the only group with a positive peak response, about 0.15, which is statistically significantly different from the negative responses of the 45-70 year-old group.²⁶

Overall, these results provide empirical evidence that age also matters in the response to a government spending shock, and that age groups have substantially heterogeneous multipliers.

2.5 Heterogeneity in Individuals' Responses to Tax Policy Shocks

This section presents the main empirical results for the tax policy shock. We focus on the SVAR model, Equation (2.5). We estimate both the impulse responses and the cumulative impulse responses of consumption to an increase in tax liabilities as a ratio of GDP. This section reports results for individuals sorted according to either income levels or age; Appendix A discusses results when the source of heterogeneity is education.

To preview our results, we find that, after an unexpected increase in taxes, the wealthiest groups experience a significant increase in consumption, whereas the poorest quintiles have a significantly negative response. When looking at individual heterogeneity by age group, the youngest group experiences the most dramatic decrease in consumption, whereas the response of consumption of all the other groups is significantly positive on impact. The response of the youngest is significantly different

²⁵ The multipliers are in unit terms. That is, a 1 dollar increase in government spending leads to a 0.10 dollars decrease in consumption for the middle-age group.

²⁶ Note that these results seem at odd with the finding in Attanasio et al. (2008) that there is no evidence that the younger groups are more credit constrained than the older groups. However, note that their oldest group includes individuals that are 55 year-old or older. If we group together individuals that are 45 to 70 year-old and individuals that are 71 or older, we also do not find empirical evidence that consumption increases.

from that of the other age groups. These results again highlight the importance of allowing for heterogeneity in the individuals' responses, which aggregate data would not be able to uncover.

2.5.1 IRFs and Multipliers by Income Quintiles

Figure 2.5, Panel A, shows the effect that increasing tax liabilities by 1% of GDP has on consumption when we group individuals by income quintiles. First, note that aggregate consumption significantly increases on impact, then decreases in a hump shape fashion, with a peak response of about -0.02 approximately one year after the shock; the cumulative response is about -0.03 in the five years following the shock.²⁷ When looking at individual responses, however, results are quite different from the aggregate. The wealthiest groups experience a significant increase in consumption (of about 0.02 at its peak response, on impact), then the effects decrease non-monotonically across income quintiles towards the significantly negative response of the second poorest quintile (which peaks at -0.04% approximately a year after the shock). It might be surprising that the income of the poorest quintile is negatively affected by the tax shock as these individuals may pay little or no federal taxes. We speculate that this effect may be caused by general equilibrium effects such as the lay-off of workers in the poorest categories.

It is very interesting to compare the group's responses with those of the aggregate, which is mostly negative. It is again clear that studies that focus on the aggregate response will fail to notice the significant differences in the responses of the poorest and the wealthiest groups. Some of the differences among the groups' cumulative responses are statistically significant, as Table 2.6, Panel A, shows. In particular, the responses of the richest groups (whose consumption cumulatively increases by 0.02%

²⁷ Note that the increase in consumption on impact is different from Romer and Romer's (2010) results and might be due to the difference in the sample period we consider.

in the 5 years after the shock) are statistically significantly different from those of the other quintiles (whose consumption decreases by -0.07%, approximately) at the 68% significance level.

Overall, unexpected increases in taxes tend to hurt the poor and especially increase consumption of the wealthiest. Thus, tax shocks tend to increase consumption inequality. It is worthwhile to stress again how using only aggregate data would miss the heterogeneous effects that unexpected tax increases would have on consumption for the various categories.

2.5.2 IRFs and Multipliers by Age Groups

It is also interesting to analyze the effects of tax shocks on individuals sorted by age to evaluate whether the younger or older categories are mostly affected by tax shocks. This analysis provides further evidence on the redistributive effects of taxes, in particular relative to age. Panel A in Figure 2.6 reports impulse responses of consumption for individuals sorted according to their age. While aggregate consumption decreases, the figure shows that the decrease is mostly born by the youngest category (15-24 years-old): the response of consumption of all the other groups is insignificantly different from zero, except on impact, when it is significantly positive. Looking at the comparisons across groups, reported in Panel B of Table 2.7, the cumulative consumption response of the youngest category, whose consumption decreases by -0.05% over the five years following the shock, is statistically significantly different from that of all of the other groups as well as the aggregate. The results demonstrate that the heterogeneity in individuals' responses across age groups is not only confined to government spending shocks, but also holds for tax policy shocks.

2.6 Aggregate Responses

An additional benefit of using household level data besides analyzing heterogeneity is that we can control the aggregation process. This enables us to avoid the aggregation bias that might be present when working with aggregate data. Specifically, Attanasio and Weber (1993, 1995) point out that an aggregation bias will be introduced if researchers use aggregate data by taking the logarithm of the mean (the common procedure used when working with aggregate data) instead of the mean of the logarithm. In order to construct our aggregate pseudo panel dataset we calculate:

$$\frac{1}{H_t} \sum_{i=1}^{H_t} \ln(c_{i,t}), \quad (2.6)$$

where $c_{i,t}$ represents individual i 's consumption level, H_t is the total number of households at time t , and t is time. When only aggregate data is available, one would instead calculate:

$$\ln \left(\frac{1}{H_t} \sum_{i=1}^{H_t} c_t^i \right). \quad (2.7)$$

Note that the latter is the measure we discussed in Section 2.2. By comparing (2.6) and (2.7) we can compare average multipliers calculated across individual responses with the multiplier based on aggregate consumption data. Note that neither Equation (2.6) nor Equation (2.7) are a better measure of consumption than the other: which is best depends on the scope of the analysis. Equation (2.7) is useful to understand how (log) consumption responds on average (across individuals) to a shock; however, this does not necessarily provide a measure of how the average individual (log) consumption responds to the shock, which is instead what Equation (2.6) reports.

Another interesting exercise we perform is to compare our results based on the two alternative measures of CEX data, either (2.6) or (2.7), with those based on NIPA

data for three different measures of Personal Consumption Expenditures (PCE): nondurables, services, and durables consumption.²⁸

Figures 2.7 and 2.8 depict impulse responses using aggregate CEX consumption data (Equation (2.6), labeled “CEX”), CEX with aggregate data only (Equation (2.7), labeled “CEX biased”), nondurables and services consumption (labeled “ND and services”), services consumption (labeled “Services”), and durables consumption (labeled “Durables”). Figure 2.7 reports results for the response to a government spending shock in the SVAR model (2.4) and Figure 2.8 reports results for the tax policy shock in the SVAR model (2.3).

Panel A in Figure 2.7 shows that the responses of aggregate CEX consumption, eqs. (2.6) or (2.7), are very different from each other. The response of aggregate consumption calculated according to Equation (2.6) are positive on impact, reaching a peak one quarter after the shock, then slowly disappear over time. The response of aggregate consumption calculated according to Equation (2.7) are instead negative on impact, and they reach their peak after about a year. The latter are much more similar to the pattern found in the data by Ramey (2011a), among others. In fact, Panel B in Figure 2.7 shows that for both nondurables and services consumption as well as durables, the pattern of the response in NIPA data is very similar to that of Equation (2.7). Note that the response of services consumption (middle figure in panel B) is negative but mostly insignificant, while the response of durables and nondurables and services is negative *and* significant. The implication is that by using aggregate data that do not control for the aggregation bias, researchers might overestimate the negative effects of government spending shocks.²⁹

²⁸ Note that, in order to be consistent with the literature, the CEX aggregate measure reported in Table 2.2 is Equation (2.7).

²⁹ Unreported results show that both the peak and the cumulative multipliers of the CEX measure in Equation (2.6) are significantly different from those of Equation (2.7), as well as those of Nondurables and Services, Nondurables and Durables.

On the other hand, Panel A in Figure 2.8 shows that the responses to a tax policy shock are very similar: positive on impact, and then negative after a few quarters until they reach a peak around a year after the shock. The increase in consumption that we observe in CEX data (Panel A) on impact is not present in NIPA data (Panel B).³⁰

2.7 Robustness Analyses

While the government spending analysis relies on unanticipated shocks, the tax policy analysis relies on shocks that are a mixture of anticipated and unanticipated shocks; it is therefore important to consider the case of unanticipated shocks only. Furthermore, it might matter which types of tax shocks are implemented (whether, for example, they concern individual income, corporate income or employment) or which political party was in power at the time of the implementation. We consider each of these concerns, and show that our main results are robust to considering unanticipated tax policy shocks, income or corporate income tax shocks. While some of the results might be different if one considers employment tax shocks, our main results for the wealthiest and the poorest quintiles are the same, and for the rest of the quintiles there is too much uncertainty in our sample to conclude that the responses in the employment tax case are different from those we discuss in the main part of the paper. Finally, the party in power may matter: The qualitative results are unaffected by focusing tax shocks implemented by Republicans, but the responses under the Democratic party are different although, again, there is too much uncertainty and the responses are not statistically different. A more detailed analysis follows.

First, we focus on unanticipated tax policy shocks. We replace the Romer and Romer's (2010) shock in Equation (2.5) with the unanticipated shock constructed by

³⁰ Unreported results show that both the peak and the cumulative multipliers of the CEX measure in Equation (2.6) are not significantly different from those of Equation (2.7), as well as those of Nondurables and Services, Nondurables and Durables.

Mertens and Ravn (2011); otherwise, the VAR remains as in Equation (2.5). Figure 2.9 reports the results for the individual responses by income quintiles whereas Figure 2.10 reports the results for the aggregate responses. Since Figure 2.9 is similar to Figure 2.5, and since Figure 2.10 is similar to Figure 2.8, we conclude that our main results are robust to using only unanticipated tax shocks.

Second, we separately classify tax shocks into corporate income tax liabilities, individual income liabilities and employment taxes following Mertens and Ravn (2012).³¹ Our main conclusions would be invalid should the responses be different across groups only because the nature of the tax shocks is different. Figures 2.11 and 2.12 report results for individual income liabilities (results are similar for corporate income tax liabilities, unreported), whereas Figure 2.13 reports results for employment taxes. The figures show that the main results in the paper are robust to focusing only on individual income; in the case of employment taxes only, the main message of the paper is qualitatively similar (i.e. the response of the wealthiest group is positive and the response of the poorest group is negative) although the responses are slightly quantitatively different. The latter typically induce an increase in consumption for a few income groups (the richest and the second richest quintiles as well as the second poorest quintile) and a negative response of the third richest quintile as well as the poorest quintile (except on impact). However, all responses are measured very imprecisely and are never significantly different from zero since there are only two episodes of employment tax shocks in our sample.

Finally, we consider whether the political party in power affects the responses. This is an interesting question because the redistributive effects of tax shocks may differ depending on the philosophy of the party in power.³² Figure 2.14 reports

³¹ See Mertens and Ravn (2012) for details on the construction of their measure.

³² Which political party is in power is determined by the date in which the president of that political party is elected until the date he/she resigns.

results for Equation (2.5) where we replace the Romer and Romer's (2010) shock with the shock interacted with a dummy variable that equals one if the Republican party is in power; similarly, Figure 2.15 reports results for Equation (2.5) where we replace the Romer and Romer's (2010) shock with the shock interacted with a dummy variable that equals one if the Democratic party is in power. The figures show that the results conditional on a Republican party regime are very similar to our main results, whereas those conditional on a Democratic party regime are not, however the latter are again very imprecisely estimated and never significantly different from zero. The reason is that we have many more episodes of tax shocks under Republican regimes (both positive and negative) than under the Democratic one, which help us identify the effects more precisely in the former case.

Overall, when the empirical findings differ from our main results, typically they are associated with insignificant differences. We therefore conclude that our main findings are robust to the political parties in power as well as the type of tax shock being implemented, at least based on our limited sample.

2.8 Conclusion

Our empirical results uncover significant differences in disaggregate individuals' consumption responses to government spending and tax policy shocks, which would not be possible to uncover with traditional analyses based on aggregate data.

In particular, unexpected increases in government spending policy hurt the young and the wealthiest the most in terms of consumption. The wealthiest experience the highest cumulative drop in consumption whereas consumption of the poorest categories increases significantly. On the other hand, unexpected increases in taxes hurt especially the youngest and the poorer groups in terms of consumption, whereas the wealthiest experience a significant increase in consumption. Government spending policy shocks tend to decrease consumption inequality, whereas tax policy shocks

tend to increase consumption inequality.

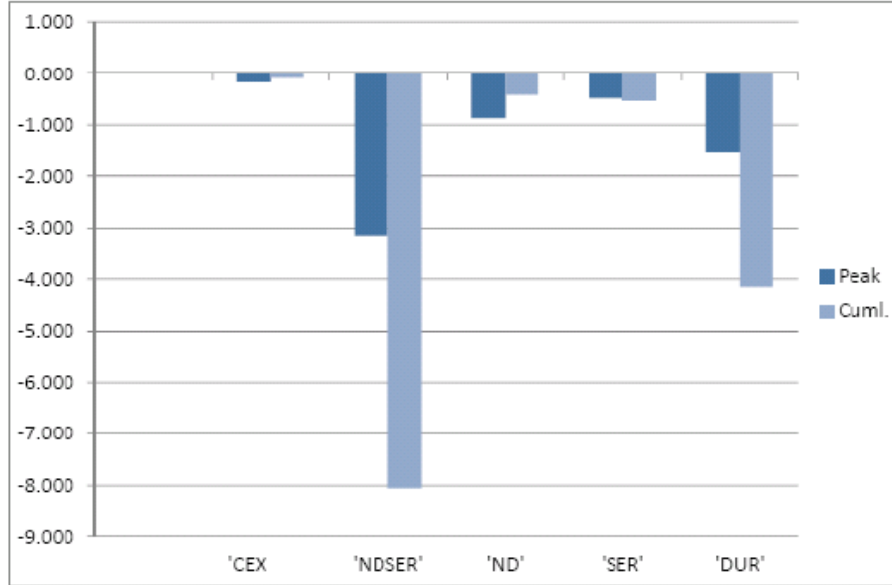
Another advantage of using disaggregate data is that it is possible to create aggregate data that are more suitable for economic analyses. We find that aggregation does not matter much when studying the effects of tax policy shocks. However, properly aggregated CEX data behave differently from traditional aggregate data in response to a government spending shock. In particular, traditionally aggregated CEX data show a delayed and significant decrease in aggregate consumption after a government spending shock, which is instead significantly positive for about a year after the initial shock according to our aggregate CEX measure.

These results suggest that it is important to allow for heterogeneity in individuals' behavior when studying the effects of fiscal policy shocks. Existing theoretical models suggest that fiscal shocks may have very different effects on consumption depending on whether consumers are credit constrained. Our empirical results show that indeed individuals respond to shocks differently depending on their wealth, education and age, highlighting the fact that, indeed, consumers who are most likely credit constrained do increase their consumption after an unexpected increase in government spending. As we show, these interesting results are in line with theoretical macroeconomic models that allow for a fraction of consumers to be credit constrained.

2.9 Tables and Figures

Table 2.1: Cumulative Impulse Response of Aggregate Consumption to a Government Spending Policy Shock

Panel A. Multipliers Size



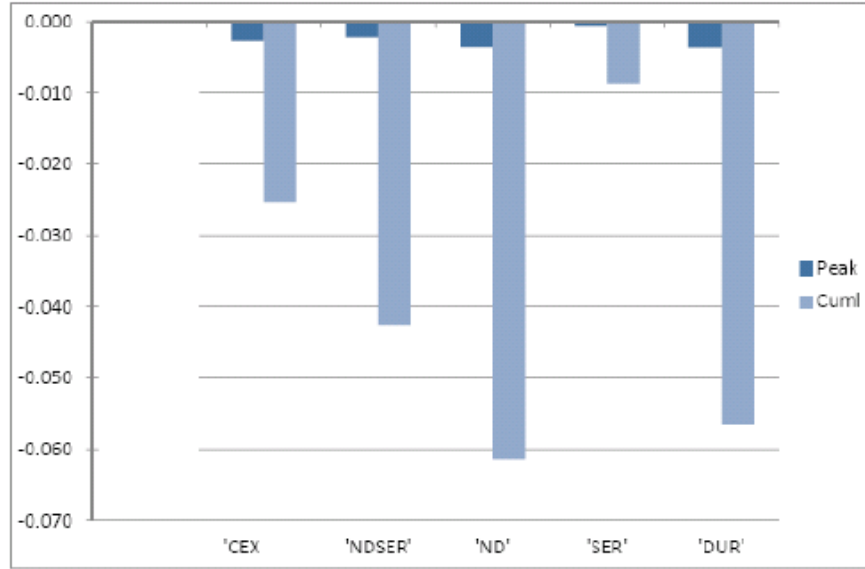
Panel B. Comparisons

	CEX	ND and Services	ND	Services	Durables
CEX	—	***, †††	**		***, †††
ND and Services	—	—	** , †††	***, †††	*
ND	—	—	—		††
Services	—	—	—	—	*, †

Notes: The table reports the cumulative Impulse Response (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption to a government spending policy shock for several measures of consumption: the CEX (Equation 2.2) and NIPA aggregates: nondurables and services (labeled “ND and Services”), Non Durables (labeled “ND”), services, and durables. It also reports the statistical significance of comparing the multipliers across groups. Statistical significance of the peak multiplier is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively.

Table 2.2: Cumulative Impulse Response of Aggregate Consumption to a Tax Policy Shock

Panel A. Multipliers Size



Panel B. Comparisons

	CEX	ND and Services	ND	Services	Durables
CEX	—				
ND and Services	—	—			
ND	—	—	—		
Services	—	—	—	—	

Notes: The table reports the cumulative Impulse Response (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption to a tax policy shock for several measures of consumption: the CEX (Equation 2.2) and NIPA aggregates: nondurables and services (labeled “ND and Services”), Non Durables (labeled “ND”), services, and durables. It also reports the statistical significance of comparing the multipliers across groups. Statistical significance of the peak multiplier is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively.

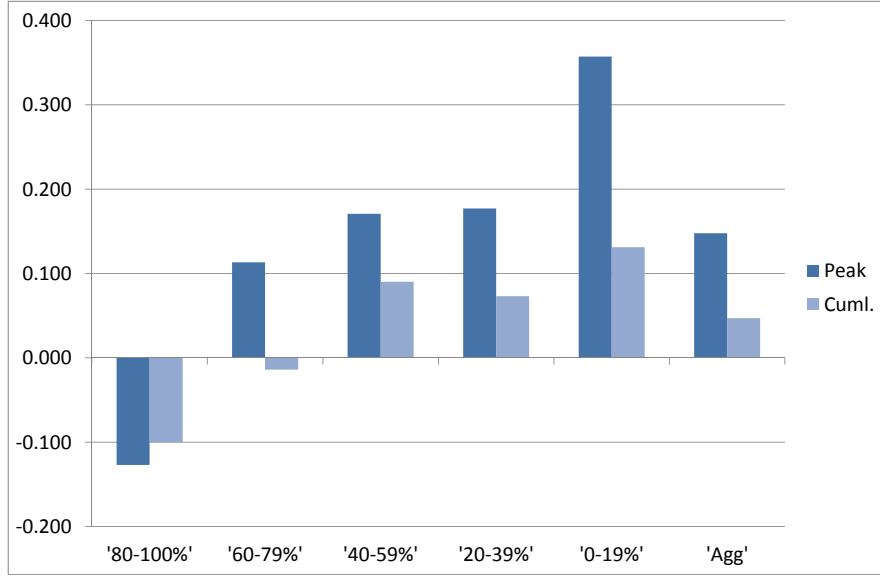
Table 2.3: Average Cell Size by Groups

Age Groups	15-24	25-34	35-44	45-70	71-90
Cell Size	121.97	404.89	469.17	845.83	285.82
Income Groups	80-100%	60-79%	40-59%	20-39%	0-19%
Cell Size	268.91	434.45	474.84	495.11	454.36
Education	<12 years	HS Grad	13-15 years	≥ 16 years	
Cell Size	429.69	632.96	550.43	533.45	

Notes: This table reports the average cell size for each group category where the cell size is how many households are used to make one quarterly observation.

Table 2.4: Cumulative Impulse Responses to a Government Spending Policy Shock, by Income

Panel A. Multipliers Size



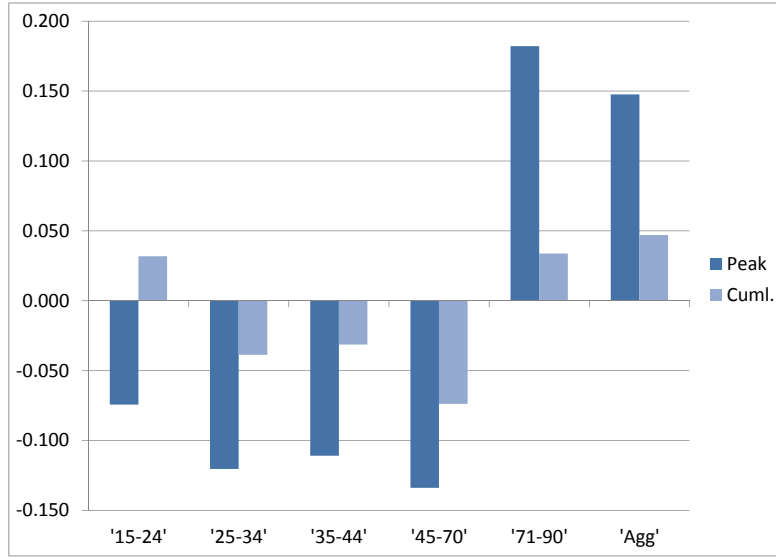
Panel B. Comparisons

Income Groups	80-100%	60-79%	40-59%	20-39%	0-19%	Agg.
80-100%	—		*, †	*, †	*, †	*, †
60-79%	—	—			*	
40-59%	—	—	—			*
20-39%	—	—	—	—		*
0-19%	—	—	—	—	—	

Notes: The table reports the cumulative Impulse Responses (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption (Panel A) to a government spending policy shock for individuals sorted according to their income. It also reports the statistical significance of comparing the peak multipliers across groups. Statistical significance for peak multipliers is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively. The multipliers for aggregate CEX are listed under “Agg.”.

Table 2.5: Cumulative Impulse Responses to a Government Spending Policy Shock by Age

Panel A. Multipliers Size



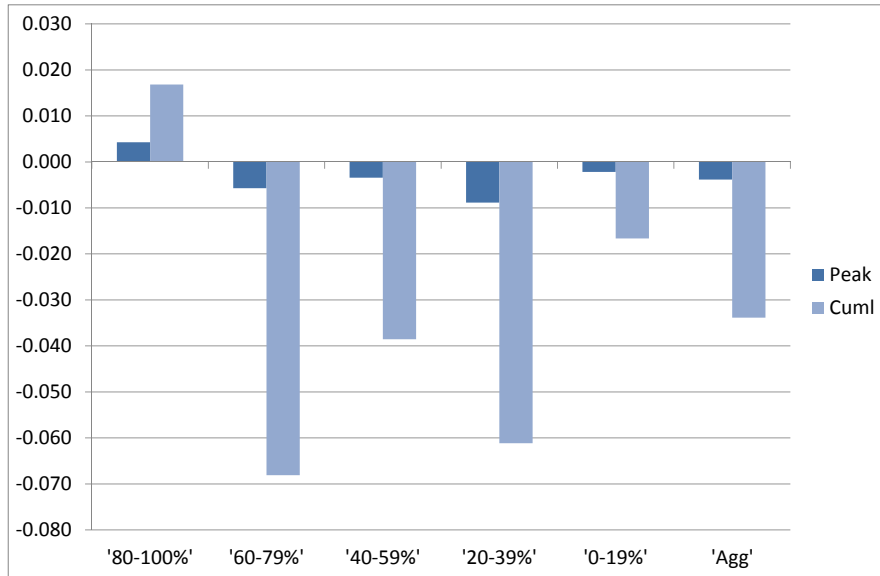
Panel B. Comparisons

Age Groups	15-24	25-34	35-44	45-70	71-90	Agg.
15-24	—					
25-34	—	—				
35-44	—	—	—			
45-70	—	—	—	—	†	*, †
71-90	—	—	—	—	—	

Notes. The table reports the cumulative Impulse Responses (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption (Panel A) to a government spending policy shock for individuals sorted according to their age. Statistical significance of the peak multiplier is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. The multipliers for aggregate CEX are listed under “Agg.” Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively.

Table 2.6: Cumulative Impulse Responses to a Tax Policy Shock By Income

Panel A. Multipliers Size



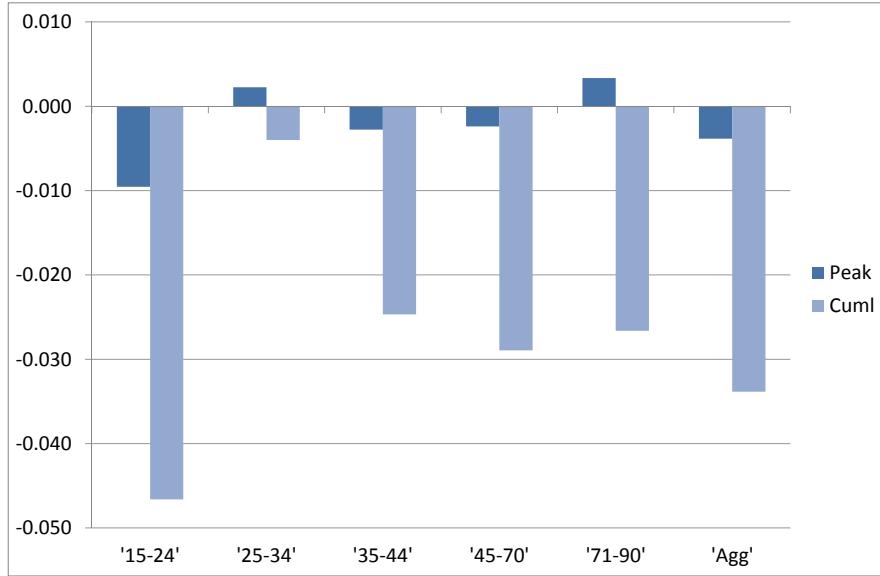
Panel B. Comparisons

Income Groups	80-100%	60-79%	40-59%	20-39%	0-19%	Agg.
80-100%	—	*, †		*, †		
60-79%	—	—				
40-59%	—	—	—			
20-39%	—	—	—	—		
0-19%	—	—	—	—	—	

Notes: The table reports the cumulative Impulse Responses (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption (Panel A) to a tax policy shock for individuals sorted according to their income. It also reports the statistical significance of comparing the multipliers across groups. Statistical significance of the peak multiplier is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. The multipliers for aggregate CEX are listed under “Agg.”. Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively.

Table 2.7: Cumulative Impulse Responses to a Tax Policy Shock By Age

Panel A. Multipliers Size



Panel B. Comparisons

Age Groups	15-24	25-34	35-44	45-70	71-90	Agg.
15-24	—	*	*	*	*	*
25-34	—	—	—	—	—	—
35-44	—	—	—	—	—	—
45-70	—	—	—	—	—	—
71-90	—	—	—	—	—	—

Notes: The table reports the cumulative Impulse Responses (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption (Panel A) to a tax policy shock for individuals sorted according to their age. Statistical significance of the peak multiplier is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. The multipliers for aggregate CEX are listed under “Agg.” Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively.

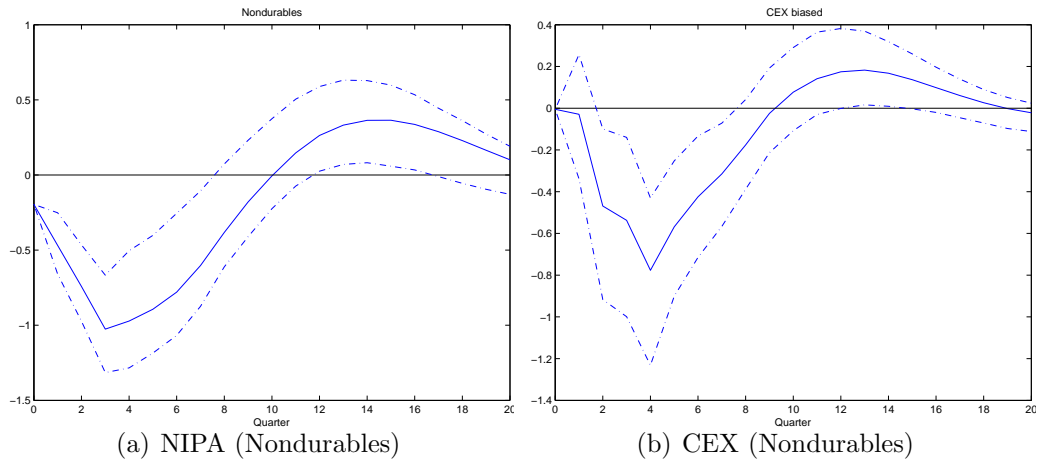


FIGURE 2.1: Impulse Responses to a Government Spending Shock in Aggregate Consumption Data

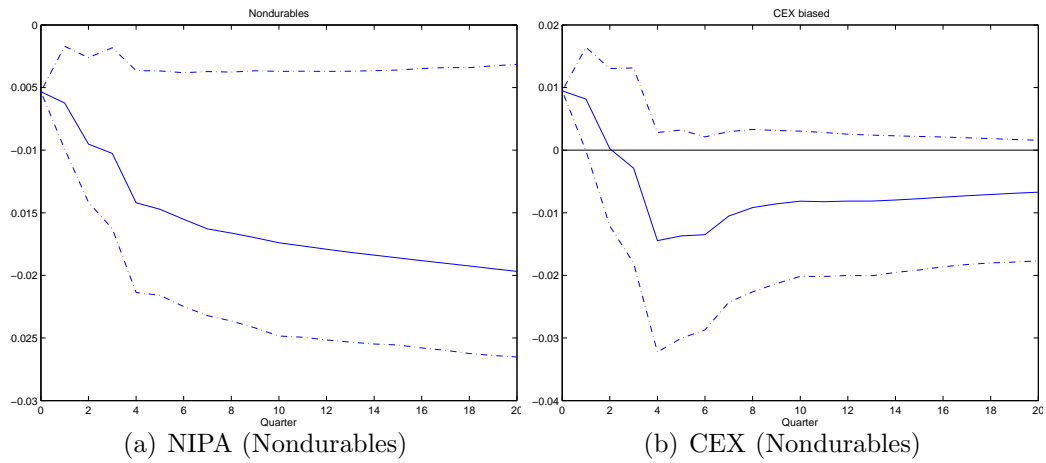


FIGURE 2.2: Impulse Responses to a Tax Shock in Aggregate Consumption Data

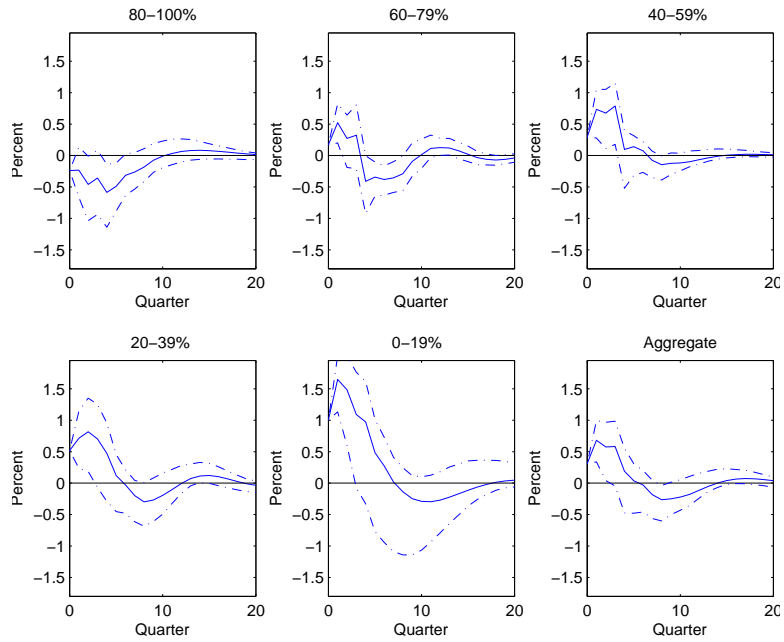


FIGURE 2.3: Impulse Responses of Consumption to a Government Spending Shock by Income Group (68% Standard Error Bands)

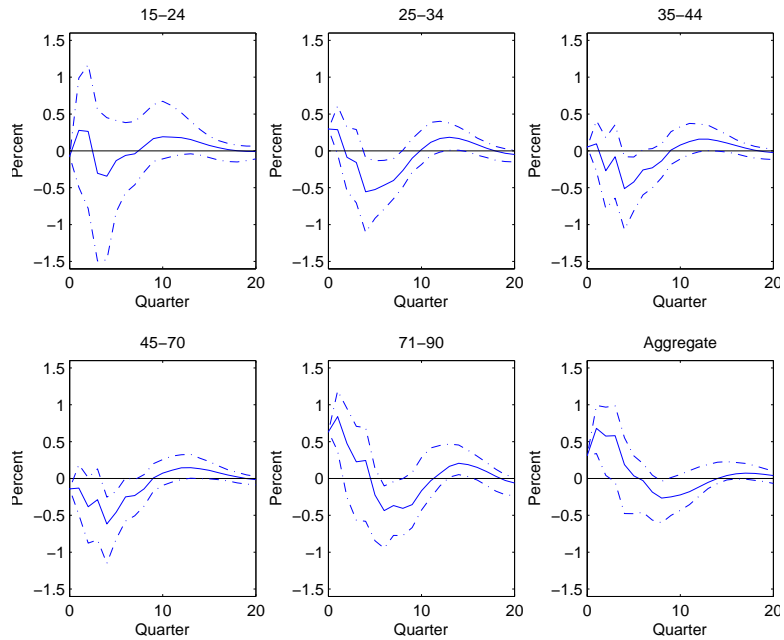


FIGURE 2.4: Impulse Responses of Consumption to a Government Spending Shock by Age Group (68% Standard Error Bands)

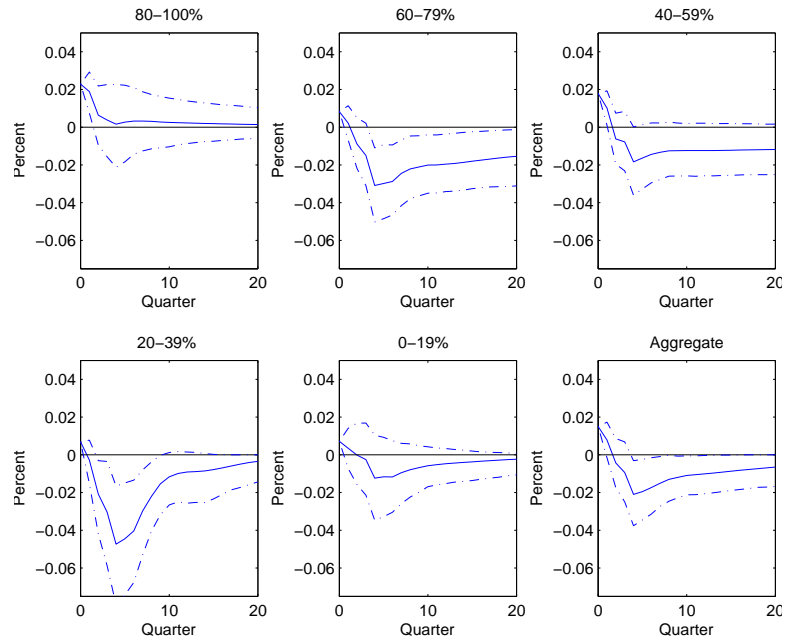


FIGURE 2.5: Impulse Responses of Consumption to a Tax Shock by Income Group (68% Standard Error Bands)

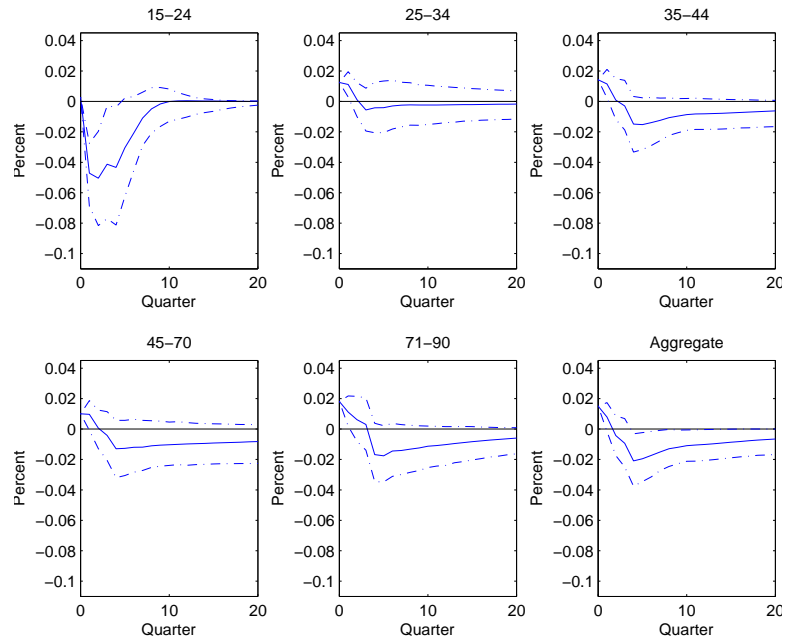


FIGURE 2.6: Impulse Responses of Consumption to a Tax Shock by Age Group (68% Standard Error Bands)

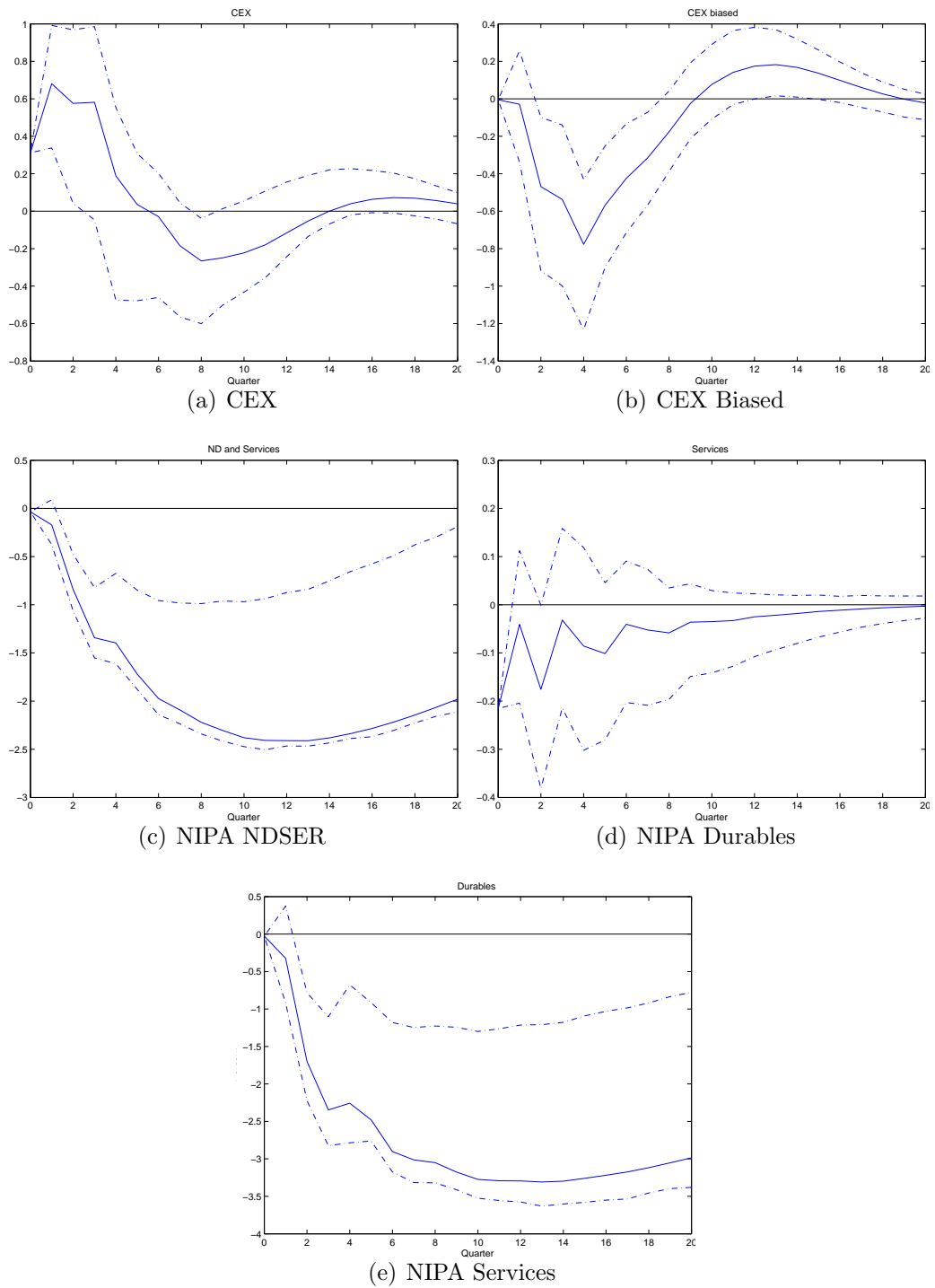


FIGURE 2.7: Impulse Responses to a Government Spending Shock in Aggregate Consumption Component Data (68% Bands)

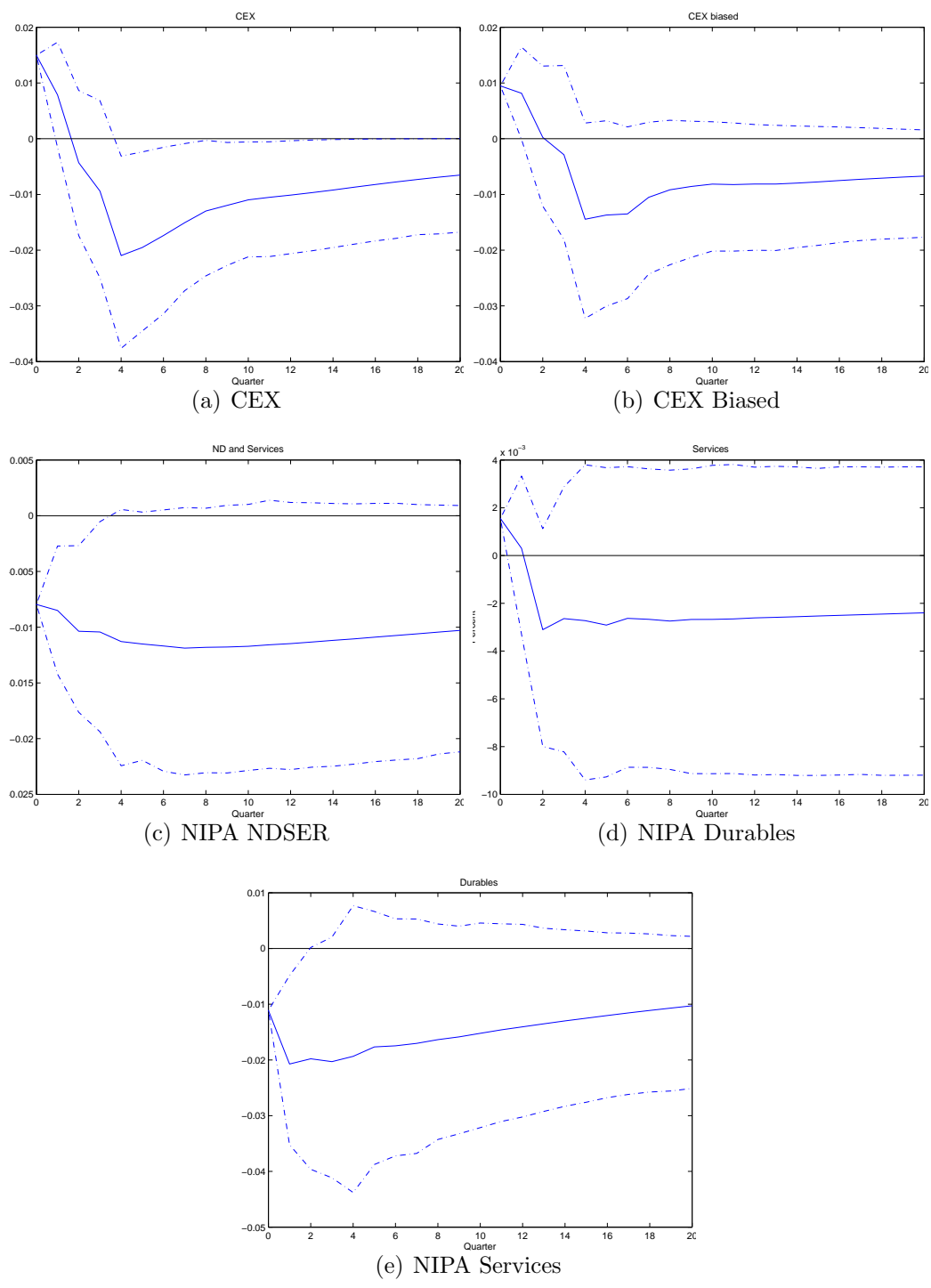


FIGURE 2.8: Impulse Responses to a Tax Shock in Aggregate Consumption Component Data (68% Bands)

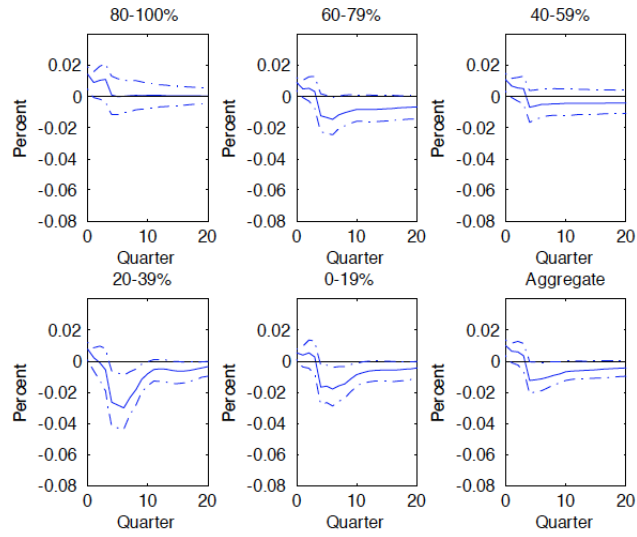
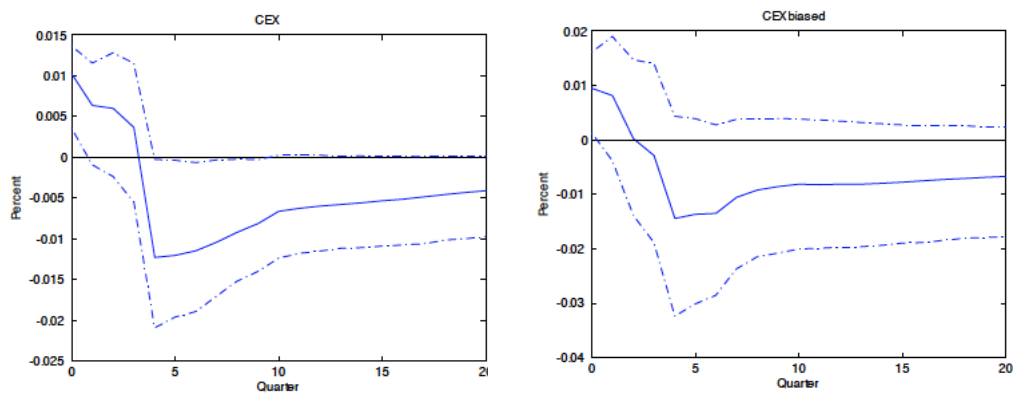
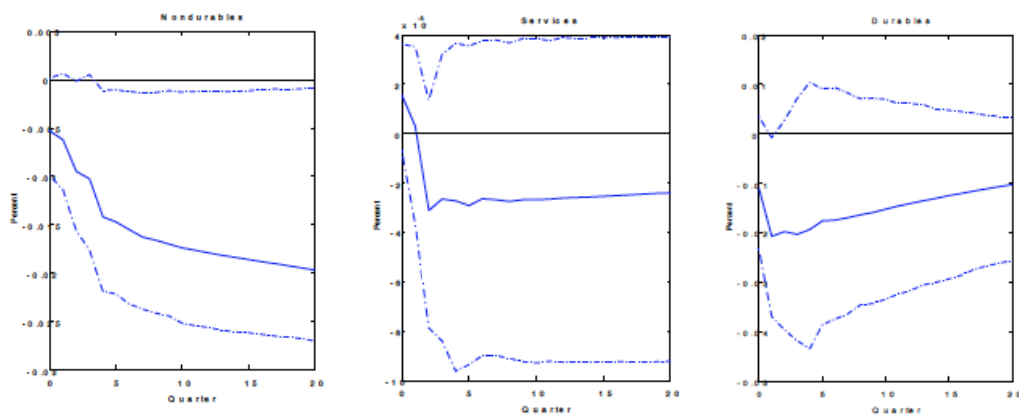


FIGURE 2.9: Impulse Responses of Consumption to an Unanticipated Tax Shock by Income Group (68% Standard Error Bands)



(a) CEX

(b) CEX Biased



(c) Nondurables

(d) Services

(e) Durables

FIGURE 2.10: Aggregate Consumption Responses to an Unanticipated Tax Shock

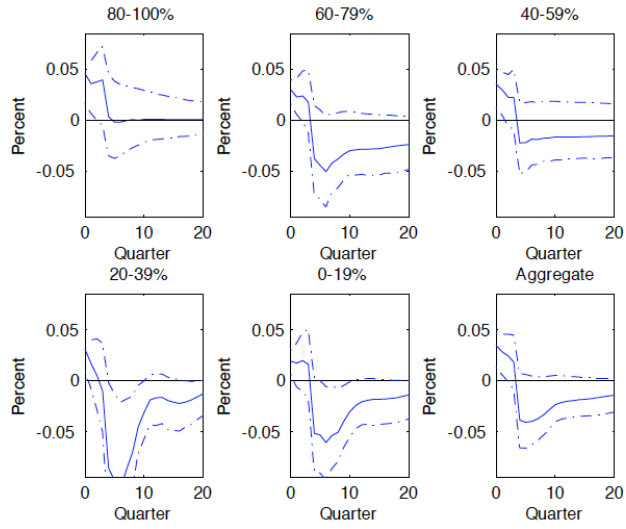
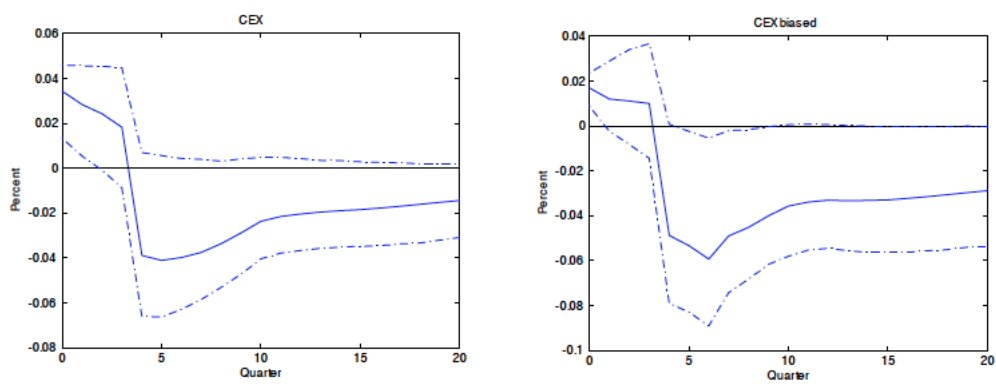
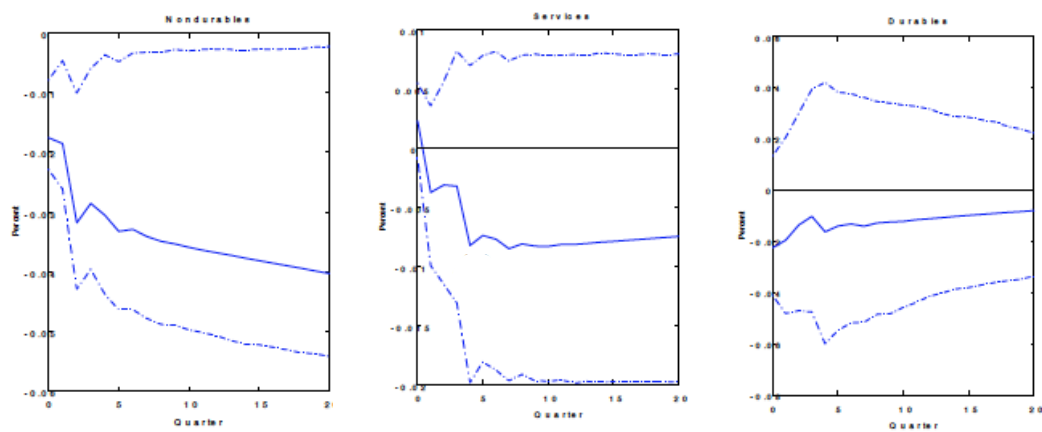


FIGURE 2.11: Impulse Responses of Consumption to an Individual Liabilities Tax Shock by Income Group (68% standard error bands)



(a) CEX

(b) CEX Biased



(c) Nondurables

(d) Services

(e) Durables

FIGURE 2.12: Aggregate Consumption Responses to an Individual Income Tax Shock

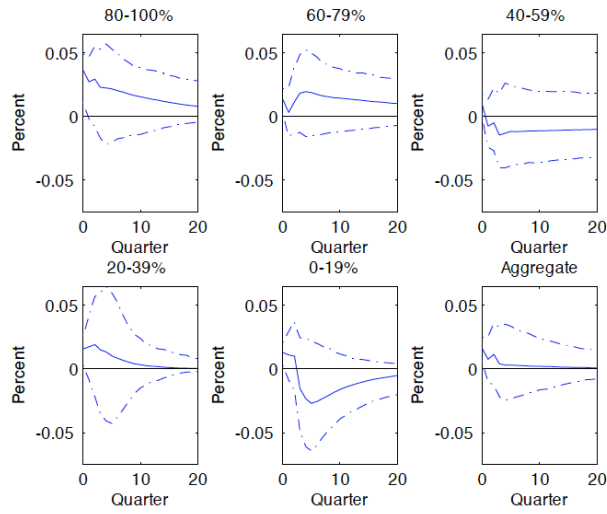


FIGURE 2.13: Impulse Responses of Consumption to an Employment Tax Policy Shock by Income Group (68% standard error bands)

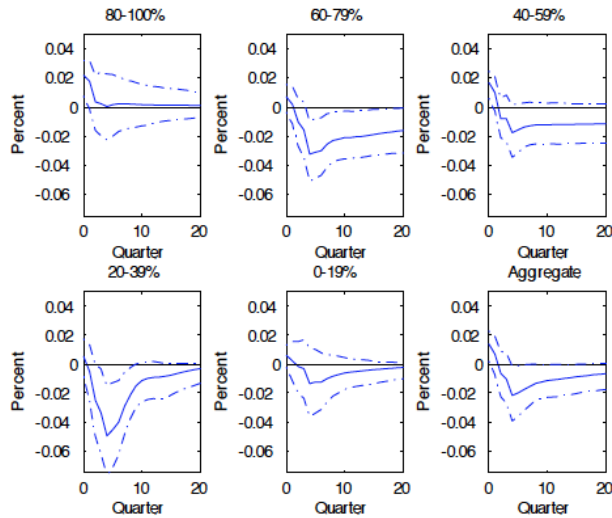


FIGURE 2.14: Impulse Responses of Consumption to a Tax Shock under Republican Government by Income Group (68% standard error bands)

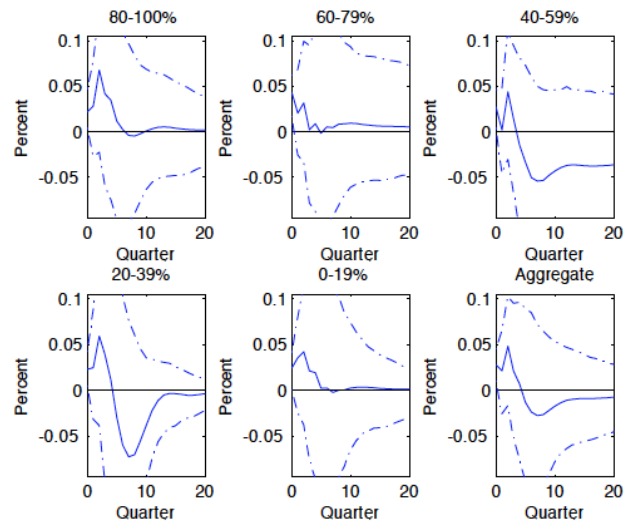


FIGURE 2.15: Impulse Responses of Consumption to a Tax Shock under Democratic Government by Income Group (68% standard error bands)

Appendix A

Heterogenous Consumers and Fiscal Policy Shocks

This Appendix empirically analyzes the effects of government spending and tax shocks on individuals sorted according to their education level. Figures A.1-A.2 report the empirical results. Individuals are sorted in groups with either no high school degree (“<12 years”), high school graduates (“HS Grad”), individuals exposed to some college (“13-15 years”), and those with at least a college degree (“ \geq 16 years”).

Figure A.1 reports the response of consumption to a government spending policy shock with individuals grouped by education levels. The figures show that the effects do again differ depending on the level of education: consumption of the lowest education groups are generally positively affected on impact and for a few quarters after the shock hits; on the other hand, the consumption of individuals with the highest education levels is negatively affected on impact and for a few quarters afterwards. Table A.1 reports the cumulative impulse response functions. Both the peak and the cumulative multipliers are negative for highly educated individuals and positive for individuals with low levels of education. The cumulative multipliers for the highly

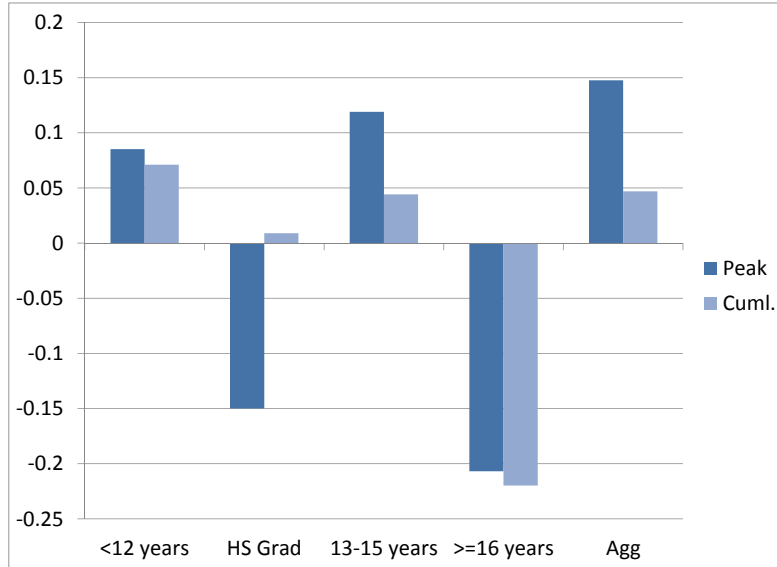
educated individuals are statistically significantly different from those of any of the other groups. Thus, these results indicate that an increase in government spending helps the least educated and hurts the college graduates in terms of consumption levels. They also indicate that college graduates behave according to New Keynesian models, whereas individuals with low education levels behave like rule-of-thumb consumers.¹

Figure A.2 reports the response of consumption to a tax policy shock. The figures show that the tax shock significantly increases consumption on impact for all education groups; however the effects become negative in the medium run for low education groups, whereas they are always positive for highly educated individuals. Table A.2 shows that most of the groups experience an overall increase in consumption and that there are only few statistically significant differences among education groups as well as relative to the aggregate.

¹ This is not surprising given the high correlation between income and education levels.

Table A.1: Cumulative Impulse Responses to a Government Spending Shock by Education

Panel A. Multiplier Size



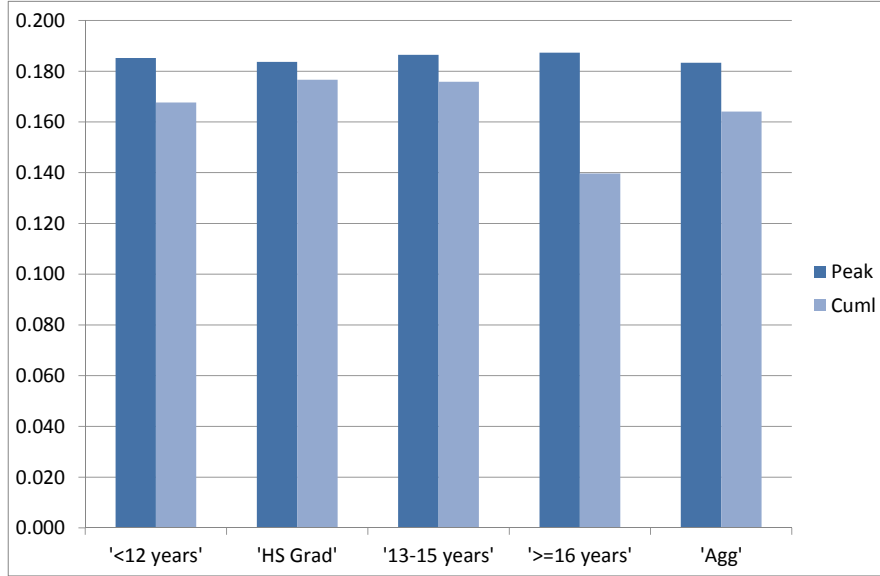
Panel B. Comparisons

Education Groups	<12 yrs	HS Grad	13-15 yrs	≥16 yrs	Agg.
<12 yrs	—			††	
HS Grad	—	—		†††	
13-15 yrs	—	—	—	*, ††	
≥16 yrs	—	—	—	—	***, †††

Notes: The table reports the cumulative Impulse Responses (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption (Panel A) to a government spending policy shock for individuals sorted according to their education level. Individuals are sorted in groups with either no high school degree (“12 years”), high school graduates “HS Grad”), individuals exposed to some college (“13-15 years”), or those with at least a college degree (“16 years”). Statistical significance of the peak multiplier is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively.

Table A.2: Cumulative Impulse Responses to a Tax Policy Shock by Education

Panel A. Multipliers Size



Panel B. Comparisons

Education Groups	<12 yrs	HS Grad	13-15 yrs	≥16 yrs	Agg.
<12 yrs	—				
HS Grad	—	—		†	
13-15 yrs	—	—	—	*, †	
≥16 yrs	—	—	—	—	

Notes: The table reports the cumulative Impulse Responses (that is, the sum of the responses at horizons from 1 to 20 quarters) of consumption (Panel A) to a tax policy shock for individuals sorted according to their education level. Individuals are sorted in groups with either no high school degree (“12 years”), high school graduates (“HS Grad”), individuals exposed to some college (“13-15 years”), or those with at least a college degree (“16 years”). Statistical significance of the peak multiplier is indicated by asterisks: *, **, and *** denote 68%, 90%, and 95% significance, respectively. Statistical significance of the cumulative multiplier is indicated by daggers: †, ††, and ††† denote 68%, 90%, and 95% significance, respectively.

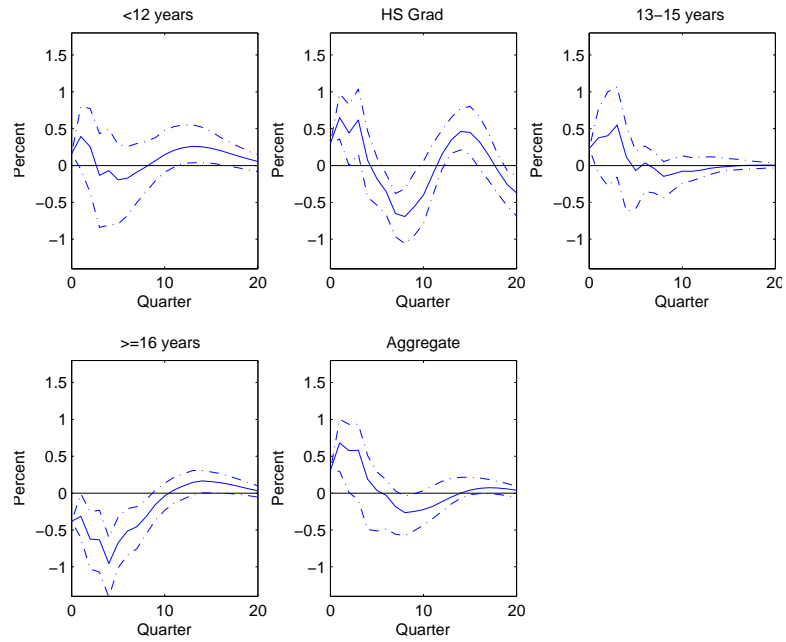


FIGURE A.1: Impulse Responses of Consumption to a Government Spending Shock by Education Group (68% Standard Error Bands)

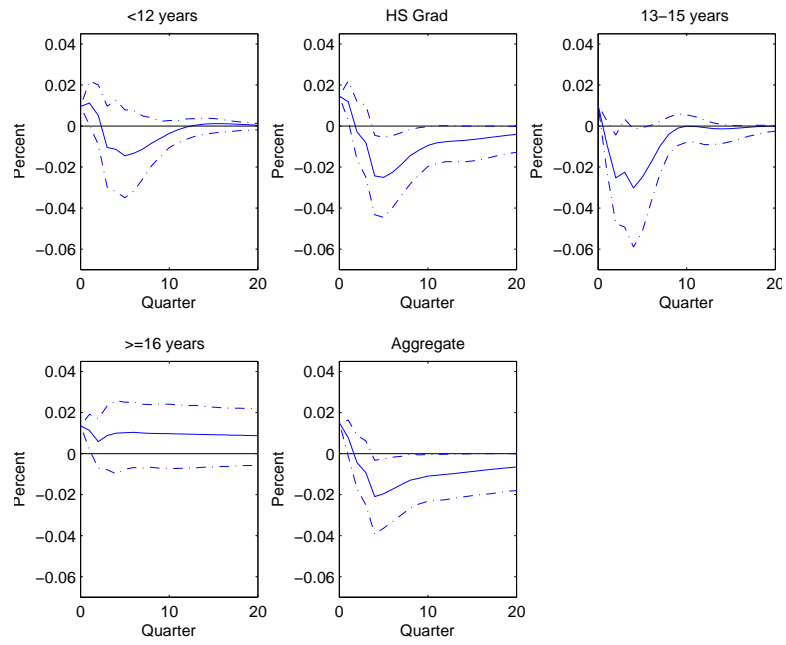


FIGURE A.2: Impulse Responses of Consumption to a Tax Shock by Education Group (68% Standard Error Bands)

Appendix B

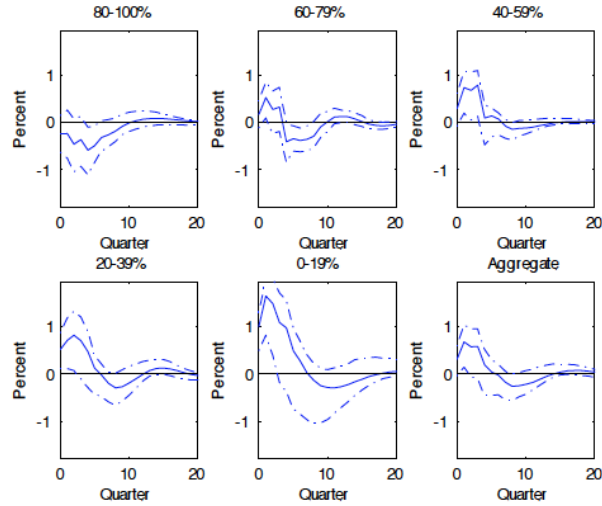
Heterogenous Consumers and Fiscal Policy Shocks

We study more in detail the transmission mechanism of government spending shocks by including income in our SVAR. In particular, the theory predicts that rule-of-thumb consumers increase their consumption after an unexpected increase in government spending because the latter increases their income. In other words, since these individuals are not forward looking and instead decide their consumption as a fixed fraction of their income, their consumption should increase whenever their income increases. We verify the theory by including income as an additional variable in the SVAR, and modifying the identification accordingly, with the shock ordered first, then government spending, income and consumption. Although income reported in the CEX is subject to measurement error (see Lusardi, 1996), we nevertheless use it as a first approximation for our analysis.¹

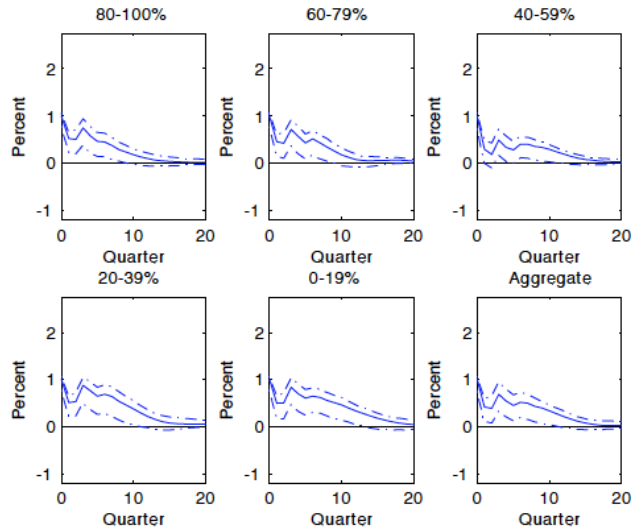
Figure B.1 reports responses of consumption (Panel A) and income (Panel B)

¹ Alternative income measures that could be used are based on the Current Population Survey (CPS) data from the CBO. The advantage of using CPS data is that it is less subject to measurement error. The disadvantage is that it needs to be merged with the CEX data using the assumption that the poorest quintile in the CPS dataset is comparable to that in the CEX data. As it is not clear whether the advantages would overcome the disadvantages, we focus on CEX data.

to an unexpected increase in government spending. Recall that we identify rule-of-thumb consumers with the poorest individuals in the survey. Indeed, the Figure shows that income of all groups increases, following the shock, and verifies that the mechanism that leads to the increase in consumption for rule-of-thumb consumers is exactly through an increase in income.



(a) Responses of Consumption



(b) Responses of Income

FIGURE B.1: Impulse Responses of Consumption to a Government Spending Policy Shock by Income Group (68% standard error bands)

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Biography

My name is Emily Bridget Lynch Anderson, and I was born on March 7th, 1986 in Saint Charles, MO, USA. I earned my Bachelor of Science degree in Business Economics from Miami University in 2008. While at Miami, I was awarded the Junior Economic Scholar Award for Excellence in Economics and the William J. McKinstry Award for Excellence in Business Economics. I graduated with University, Business, and Economic Honors.

After graduation, I enrolled in the Economics Ph.D. Program at Duke University where I specialized in macroeconomics and econometrics. In 2009, I earned a Master of Arts degree in economics from Duke. While at Duke, I was awarded the Duke University Graduate School Summer Fellowship and the Duke University Graduate School Conference Travel Fellowship two years in a row. I used the travel fellowships to present my research at the Canadian Economic Association Annual Meeting in 2011 and 2012. In the summer of 2011, I completed the Dissertation Internship at the Federal Reserve Bank of St. Louis where I participated in seminars and presented my research. I expect to earn my Ph.D. in economics in the spring of 2013. Afterwards, I will be starting my career as a data scientist at CoreCompete in Raleigh, NC.