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Abstract

We show that a negative relative demand shock in a sector with downwardly rigid prices, like the service sector, can generate substantial inflation. Such a shock induces an equilibrium decline in the relative price of services. If price adjustment costs are non-existent or symmetric, then this takes place through a simultaneous decline in services prices and increase in goods prices, resulting in, on net, little inflation. If prices in the services sector are downwardly rigid, however, this takes place mostly through an increase in goods prices, resulting in inflation. To illustrate the relevance of this mechanism in practice we provide evidence on the downward rigidity of person-to-person service prices during the Covid pandemic of 2020-2021. We then introduce downward price rigidities in a multisector New-Keynesian model and show how they can result in inflationary relative demand shocks.

JEL classification codes: E12, E31, E52.

Keywords: inflation, multisector models, price rigidities.

*The views expressed in this paper are those of the authors and do not necessarily reflect those of the institutions that they are affiliated with, including De Nederlandsche Bank, the Euro System, the Federal Reserve Bank of Chicago, and the Federal Reserve System.

1 Introduction

We show that the presence of Downward Price Rigidities (DPR) can amplify the inflationary effects of relative demand shocks. Especially if those shocks imply a decline in demand in the sector in which prices are downwardly rigid. Because prices in the services sector are more downwardly rigid than in the goods producing sector, this means that downturns that are associated with a disproportionate decline in the demand for services result in more inflationary pressures than those in which the relative demand for goods declines.

This insight echoes the, more informal, arguments made by Means (1935) and Schultze (1959). Their description of the type of inflationary pressures that we explore in this paper is sometimes referred to as "Demand-Shift Inflation."Ball and Mankiw (1994, 1995) make a similar point to us in a simple theoretical model but neither stress the difference in the asymmetry of goods and services price adjustments nor its general equilibrium effect on relative prices that we focus on.[1] We are the first to highlight it in the context of disaggregated micro-data evidence on inflation, analyze it in a multi-sector New Keynesian DSGE model, and discuss its potential relevance for understanding the inflationary pressures following the Covid pandemic in 2020.

DPR are much less frequently studied than the downward rigidity of nominal wages. Many studies have pointed to a "missing mass left of zero" in 12-month wage changes as indicative of the reluctance of employers to lower wages.[2] Recent studies, most notably for the Euro area (Gautier *et al.*, 2024), have shown that such a missing mass left of zero is also present for price changes of services. This is suggestive of producers of services being hesitant to reduce prices. This hesitance is also reflected in the anecdotal evidence provided by Bewley (2023) in his interview study of reasons for why producers change prices. He especially emphasizes the importance of DPR in restaurants.

We supplement the evidence from these studies with evidence from the U.K. We show that, just like in the Euro area, service price changes in the U.K. show a, be it small, missing mass below zero from 2017-2019. Then, during the pandemic (2020-2021), prices of person-to-person services in the U.K. did not decline substantially, even though demand for these services plummeted. This further supports that service prices are downwardly rigid.

The main reason that relative demand shocks are inflationary in the presence of DPR is the following. Consider a shock, like the one during the Covid pandemic, that shifts demand from services to goods. Such a shock induces an equilibrium decline in the relative price of services.

[1] Gagnon (2024) briefly discusses the potential importance of DPR for understanding the inflationary pressures after the Covid pandemic in his discussion of Guerrieri *et al.* (2023).

[2] Among these are Akerlof *et al.* (1996), Card and Hyslop (1996), Lebow *et al.* (2003), Dickens *et al.* (2007), and Grigsby *et al.* (2021).

If price adjustment costs are non-existent or symmetric, then this adjustment takes place by a simultaneous decline in services prices and increase in goods prices, resulting in, on net, little or no inflation. If prices in the services sector are downwardly rigid, however, this adjustment takes place mostly through an increase in goods prices, resulting in inflation.[3]

We introduce a two-sector New Keynesian model, similar to Cantelmo and Melina (2023), to show how this mechanism works theoretically. Our baseline model is deliberately stylized to isolate the response of the economy to relative demand shocks and to compare the case of symmetric price adjustment costs with that of DPR. For price adjustment costs. we use the functional form from Kim and Ruge-Murcia (2009), because it nests both symmetric and asymmetric adjustment costs and the asymmetry is captured by one specific parameter. The importance of asymmetry in the price adjustment cost function means that we need to solve the non-linear version of the model.[4] We use the model to make four main points.

The first is that DPR can induce inflationary pressures in response to relative demand shocks and the extent of these pressures depends on the size of the shock. We show that when price adjustment costs are symmetric, as in the commonly-used specifications of Calvo (1983) and Rotemberg (1982), relative demand shocks generate little or no inflationary pressures. Instead, under DPR relative demand shocks result in inflation when they induce a shift in demand away from the good or service with downwardly rigid prices. The inflationary impact of such a shock is more than proportionate in the size of the shock.

The second is that such relative demand shocks look like negative supply shocks in the context of the empirical Phillips curve. They result in a *negative* correlation between inflation and output and in a negatively sloped empirical Phillips curve in output-inflation space, rather than a positively sloped Phillips curve that results from aggregate demand shocks.

The third is that "inflation greases the wheels of the product market." This insight mimics Tobin (1972)'s about Downward Nominal Wage Rigidities (DNWR). He argued that, because what matters for the alignment of labor and product markets is the relative price of labor compared to output, i.e. the real wage, if nominal wages cannot adjust downward then the allocation of labor would improve as a result of elevated inflation. This is often summarized as "inflation greasing the wheels of the labor market".

The main intuition of this argument translates to DPR. In the case of multiple product markets, the relative price of one good versus another matters for the allocation of resources.[5]

[3] This mechanism is solely demand-driven and does not depend on the structure of the production function or costs of the reallocation of productive resources.

[4] The model is solved using Dynare (Adjemian *et al.*, 2022).

[5] See, for example, the models in Aoki (2001), Nakamura and Steinsson (2008), Eusepi *et al.* (2011), and Ruge-Murcia and Wolman (2022).

If a relative demand shock reduces demand in a sector where prices are downwardly rigid then higher inflation would make this downward rigidity less binding as well as speed up the adjustment of the prices of the goods whose demand has increased due to the shock. In this sense "inflation greases the wheels of the *product markets*" in case of DPR.

We show that this implies that the impact of monetary policy choices is very different in the case of relative demand shocks with DPR than when economic fluctuations are driven by aggregate demand or cost-push shocks.

The final point from our theoretical analysis is that the presence of DPR amplifies other mechanisms that generate inflationary pressures in response to relative demand shocks. To show this, we consider several extensions of our baseline model that capture these mechanisms, like real rigidities, convex (labor) adjustment and reallocation costs, and Downward Nominal Wage Rigidities (DNWR).[6]

In our model, relative demand shocks are the sole source of fluctuations. This allows us to clearly illustrate the potential relevance of DPR for inflationary pressures. We do not, however, argue that DPR are the only mechanism at play. But, there is one important difference between DPR and the other mechanisms considered. DPR help us understand why a recession associated with a large decline in the demand for services results in higher inflation than one associated with a decline in the relative demand for goods. The other mechanisms pointed to in the literature do not provide an explicit explanation for this asymmetry. This is potentially relevant for understanding the change in the slope of the empirical Phillips curve after the 2020 pandemic that occurred in a large set of countries.[7]

As for the other mechanisms, evidence on DNWR suggests that differences in the extent to which wages are downwardly rigid across industries are small. So, it is hard to explain why DNWR imply that services-centered recessions are more inflationary than others. If anything, wages are more rigid in goods-producing industries. Several studies have emphasized the importance of the cost of the reallocation of resources for the inflationary pressures resulting from relative demand shocks (e.g. Ferrante *et al.*, 2023). But, the reallocation of resources is at play during all economic downturns and thus puts upward pressures on inflation in all of them.[8] In fact, the Covid pandemic was neither an outlier in terms of the reallocation of labor (David, 2021), except for leisure and hospitality, nor in terms of skill mismatch (Barlevy *et al.*,

[6] See Ferrante *et al.* (2023), Guerrieri *et al.* (2021), and Boehm and Pandalai-Nayar (2022) for analyses of those mechanisms.

[7] See Hobijn *et al.* (2023) for evidence on the steepening of Phillips curves across countries.

[8] For an early discussion see Lilien (1982). The reallocation of resources during recessions has been central to the discussion of cleansing and sullying effects (Caballero and Hammour, 1994; Barlevy, 2002), the reason for jobless recoveries (Groshen and Potter, 2003; Jaimovich and Siu, 2020), as well as the mismatch of skills and jobs (Şahin *et al.*, 2014).

2024). Thus, though the costly reallocation of resources might have contributed to inflation from 2020-2023, it, alone, cannot explain why inflation after the Covid pandemic was much higher than after, say, the Great Recession. One indicator of reallocation that spiked in the aftermath of the Covid pandemic was the ratio of job openings to the number of unemployed persons (V/U ratio). It has been pointed to in several studies as contributing significantly to inflation.[9] However, as Blanchard and Bernanke (2023) show, even after including the V/U ratio in statistical models of inflation, the bulk of the run-up in inflation after 2020 remains unexplained.

The main point of our analysis is relevant beyond understanding the inflationary pressures during and after the Covid pandemic. It emphasizes the different nature of relative demand shocks and Demand-Shift Inflation in terms of the output-inflation trade-off that a central bank faces when prices are downwardly rigid compared to aggregate demand shocks.[10] If downward price rigidities are binding, then the distortion to relative prices in product markets and the impact this has on the allocation of real resources is a margin along which the transmission of monetary policy occurs. Thus, what is important for the assessment of these trade-offs is the real-time quantification of the mixture of shocks that are driving economic fluctuations.

2 Evidence of Downward Price Rigidities

Our argument hinges on the importance of DPR, especially in services, for the dynamics of relative prices and aggregate inflation. Since DPR are not commonly analyzed in studies of price stickiness, we review evidence from several of such studies for a large number of countries, that cover data before 2020, in the context of the downward rigidity of service prices. We supplement the evidence from these studies with an analysis of DPR in U.K. service prices. We focus on the U.K. because British data, for both individual price quotes that are used for the construction of the Consumer Price Index (CPI) as well as for quarterly time series on the prices and quantities for consumer spending on detailed expenditure categories from the national accounts, are publicly available. These data allow us to uncover additional evidence of DPR during and after the Covid pandemic (2020-2021), when the demand for many person-to-person services plummeted.

[9] See, for example, Ball *et al.* (2022) for an estimate of the Phillips curve that includes the V/U ratio and Benigno and Eggertsson (2023) for a theoretical analysis.

[10] The case of aggregate demand shocks with symmetric price adjustment costs has been studied extensively, e.g. Aoki (2001) and Eusepi *et al.* (2011). It yields that the central bank should put more weight on the prices of the most sticky goods and services when making its policy decision.

2.1 Before Covid pandemic

Analyses that point out the potential relevance of DPR for aggregate inflation go back to the Great Depression (Means, 1935) and the increases in inflation in the U.S. in the 1950's (Schultze, 1959) and 1960's (Gollop, 1969). Schultze (1959), especially, emphasizes the upward pressures on prices when some prices cannot adjust downward. The mechanism he emphasized, which is closely related to our main point in this paper, is often referred to as "Demand-Shift Inflation."[11]

These studies relied on sectoral price indices for specific goods and services, rather than on price-quote data for individual goods and services. In some form or another, all of them emphasized that fluctuations in relative prices across sectors are elevated in times of higher inflation.[12] Of course, in case of Demand-Shift Inflation these relative-price movements are distorted and smaller, and aggregate inflation higher, than what would have occurred under flexible prices.

In terms of micro-level data underlying price and wage aggregates, downward nominal rigidities have mostly been studied in the context of wages. Studies of DNWR focus on the distribution of 12-month changes in nominal wages. An extensive literature has documented a "missing mass below zero", both in the U.S. as well as in many other countries.[13] This missing mass is largely absorbed by a spike at zero wage changes that tends to be higher during economic downturns than expansions and during times with low inflation and low productivity growth.[14]

Downward price rigidities have been studied much less.[15] Micro data on price quotes suggest that service prices change much less frequently than those of goods and that price declines for services are much less common than for goods.[16] Gautier *et al.* (2024) is one of the few studies which show that micro data on price changes of services, for the Euro area for 2010-2019, exhibit a missing mass below zero, just like, but smaller than, those on nominal wage changes. This is also the case in the U.K..

[11]Though Gollop (1969) refers to it as "Structural Inflation" and emphasizes the need for movements in relative prices and factor inputs beyond those induced by relative demand shocks. Peltzman (2000) discusses how producer and consumer prices go up like rockets and come down like feathers. This is mostly analyzed in response to clear changes in input prices. DPR emphasize this is also the case in response to demand shocks.

[12]See footnote 1 in Fischer (1981) for a list of studies that document this correlation.

[13]Among the many studies that document this are Akerlof *et al.* (1996), Card and Hyslop (1996), Lebow *et al.* (2003), Dickens *et al.* (2007), and Grigsby *et al.* (2021).

[14]See Daly and Hobijn (2014) and Jo (2021).

[15]One notable study is Yates (1998), who reviews evidence related to both downward wage and price rigidities and concludes that "while the evidence is not conclusive enough to rule out these rigidities entirely, empirical results are not supportive."

[16]See Nakamura and Steinsson (2008) for the U.S., for example.

We illustrate this in Figure 1, using data on individual CPI price quotes in Britain.[17] It shows the 2017-2019 distribution of medium-run percent price changes, between January and December of the reference years, for all services as well as for person-to-person services. More than 40 percent of service prices do not change between January and December.[18] Among the prices that change, there is a small missing mass left of zero. Just like in the euro area, this missing mass is much less profound, however, than in most empirical studies of DNWR.

But it is not the only evidence. Interview studies of price-setting behavior have often emphasized the reluctance of producers, especially those of services, to lower prices. Most recently, Bewley (2023) discusses the reasons for this reluctance among his interviewees.[19] Among the reasons for why his respondents tend to shy away from lowering prices are several particularly relevant for services: (*i*) kinked demand curve, (*ii*) heterogeneneity in the price elasticity of demand across customers, and (*iii*) fixed contracts and a quasi-fixed demand.

Kinked demand curves have been studied in economics since Hall and Hitch (1939). Anecdotal evidence from the services sector suggest they are relevant because of customer relationships and incomplete information. Customers at other restaurants are unlikely to visit a new restaurant because it has lowered its prices since they do not check the menus of other restaurants frequently. However, existing customers are more likely to look for other restaurants when prices increase. Heterogeneity of the price sensitivity of demand across customers can be a source of DPR that might reduce a firm's incentive to lower prices if the price elasticity of marginal customers in times of low demand is much lower than in other times. Finally, in case of fixed contracts, like many in health care and personal services, with agreed-upon prices and a given frequency of usage for services a reduction in prices by a provider has very limited impact on demand. Therefore making providers unlikely to lower prices, even in downturns. In addition to these reasons for DPR from interview studies, Gilchrist *et al.* (2017) show that firms that face financial constraints tend to raise prices even as demand and marginal costs decline.

Thus, empirical and interview studies of price-setting behavior from before the Covid pandemic found some, but limited, evidence of the lack of downward adjustment of services prices. This could be for two reasons. Either prices of services are not downwardly rigid or economic conditions were such that these rigidities were not very binding and had little impact on price-

[17] We describe the details of this data in section A.1 in the appendix.

[18] This is much higher than implied by evidence on monthly price changes and reflects a marked non-Markovian property of price changes in the micro data.

[19] See Bewley (2023) for a discussion of other interview studies. The most notable other one is Blinder *et al.* (1998). They do not find that DPR are important for price setting behavior. But their survey is deliberately designed to avoid questions about strategic price setting, which covers many of the reasons for DPR, to avoid non-response because respondents do not want to be on record admitting non-competitive pricing.

setting behavior and aggregate inflation dynamics. In the next subsection we use data from the pandemic to argue it is most likely the latter.

2.2 Covid pandemic

The steep decline in demand for person-to-person services during the Covid pandemic in 2020 and 2021 provides a quasi-experiment-like environment in which we can consider the response of the prices of such services to this shock. Here we show that the relative price of these services barely went down, and in some cases even increased, even though demand for them declined by more than half. This provides much stronger evidence that DPR are important for services prices than the pre-Covid evidence we reviewed above.

To make this point, we supplement evidence from the Euro Area and the United States on individual price quotes with evidence from the U.K. to show that price declines for such services were very rare and that the relative price of these services barely moved, even in the face of the drop in demand. This suggests that DPR were important for the evolution of the prices of person-to-person services during that period.

There are no studies of price setting since and after the Covid pandemic that specifically focus on DPR. But several studies provide evidence that is suggestive that downward rigidities for service prices might have been at play. Montag and Vallenas (2023) analyze the frequency, size, and direction of price changes underlying the U.S. CPI before, during, and after the pandemic. Henkel *et al.* (2023) do so for Germany, Italy, Latvia, and Slovenia. All these studies find increases in the frequency and size of price decreases during the second and third quarters of 2020. However, these increases are relatively small given the reduction in demand and put only limited downward pressures on aggregate prices. Henkel *et al.* (2023) provide disaggregated results for services and show that Germany was the only country out of the four in their sample with notably more frequent and larger price cuts of services mid 2020 than other consumption categories. But "services" covers a very broad spectrum of consumer demand.

The spread of the coronavirus specifically reduced the demand for "person-to-person" services, such as elective medical procedures, public transportation, theater and sporting events, restaurants, haircuts and personal care, and prostitution, that are likely to result in the transmission of the virus. Price and quantity indices as well as data on individual price quotes for these consumption categories in the U.K. allow us to document facts that specifically focus on DPR during and after the pandemic.[20]

[20] The availability of price and quantity data for consumer spending on "prostitution" might seem strange for a reader in the U.S., where prostitution is illegal except for a few counties in the state of Nevada. However,

The U.K. went into lockdown on March 23, 2020. The lockdown was lifted in phases starting at the beginning of June 2020. Two other lockdowns followed, in November 2020 and January and February 2021. Under lockdown or not, throughout 2020 and 2021 many measures aimed at limiting the spread of the coronavirus were in effect throughout the U.K.[21] For example, from March 2020 through September 2021, employers that were affected by the coronavirus pandemic could participate in the Coronavirus Job Retention Scheme, which covered 80 percent of furloughed employees wages. Several programs were aimed at stimulating demand for person-to-person services. For example, during August 2020 the "Eat Out to Help Out" program provided a 50 percent subsidy for orders of food and non-alcoholic drinks up to £10.

The top panel of Figure 2 shows the impact of the pandemic on the quantities of person-to-person services purchased by British consumers. It plots the relative demand for these services compared to overall consumption normalized to their level the quarter before the pandemic broke out.[22] It shows the steep drops in the purchases of these services during the shutdowns. But even between and after the shutdowns demand for most of these services was 20 percent lower than before the pandemic. Demand for transportation services was still down substantially at the end of 2023, reflecting the shift to working-from-home.

The bottom panel of Figure 2 shows the relative prices of these service categories. In spite of the dramatic decline in the consumption of them, their relative prices went up. In fact, most of them increased even more than that of overall services. These spending-category specific indices suggest that, in spite of the negative demand shock for person-to-person services, their prices did not decline during the first one and a half years after the start of the pandemic. In fact, they increased more than overall consumer prices.[23]

Data on individual price quotes for person-to-person services in the U.K. provide more evidence that is consistent with DPR being relevant for price setting after the start of the pandemic. To see this, consider Figure 3. It plots the histograms of January-December price changes for the same type of person-to-persons services at the same outlet for both 2020 (top panel) and 2021 (bottom panel). Especially in 2021 there is a clear missing mass of price cuts that, similar to the evidence on DNWR, is indicative of downward rigidities being binding.

prostitution services are legal in many countries and, to capture the economic activity associated with these services in those countries, have their own COICOP category (13.9.0.1) in the UN System of National Accounts.

[21] Institute for Government (2022) provides a brief overview of many of these measures. Some of them have remained in effect after 2021.

[22] Figure B.3 in the appendix plots demand relative to the pre-pandemic trend.

[23] The broad categories for which relative prices declined were non- and semi-durable goods (Panel (b) of Figure B.1). This pattern is not unique to the U.K. Figure B.4 shows the equivalent of Figure 2 for the United States.

3 Two-Sector Model with Downward Price Rigidities

To illustrate the importance of DPR for the inflationary impact of relative demand shocks we introduce these shocks in a two-sector New Keynesian model. The core of our model is very similar to that in Cantelmo and Melina (2023).[24] The model has two main elements. The first is that households derive utility from the consumption of two types of goods, which we, in the spirit of the data that we have shown before, label goods and services. The main difference between goods and services is that the price setting of the latter is subject to downward rigidities, which we introduce using a Linex adjustment cost function (Kim and Ruge-Murcia, 2009). The sole shock that we consider is a relative demand shock that shifts preferences from one of the two types of consumption goods to the other.

Because our main point emphasizes that DPR amplify the inflationary impact of relative demand shocks on top of other mechanisms that have been proposed, we add several aspects to our model that capture such mechanisms. Guerrieri *et al.* (2021) point out that DNWR can generate price pressures in response to the type of relative demand shock we consider and, to capture that in our model, we introduce such rigidities using household wage-setting decisions based on Erceg *et al.* (2000) in combination with a Linex wage-adjustment cost function. Another reason relative demand shocks can be inflationary is that the reallocation of factors of production across sectors is costly Ferrante *et al.* (2023) or that sectors have convex supply curves Boehm and Pandalai-Nayar (2022). Similar to Cantelmo and Melina (2023), we model such real rigidities in a very reduced-form way through the imperfect substitutability of the labor supply across sectors. Finally, we allow for pent-up demand (Beraja and Wolf, 2021), to consider its impact on the persistence of the mechanism we highlight.

3.1 Core of the model

Firms: There are two sectors in the economy, a goods and a service sector, which we denote by $j \in \{G, S\}$. Each sector consists of a unit measure of firms that each produce a particular variety ω and sell it at price $P^j_{\omega,t}$. Demand for variety ω in sector j is given by the CES demand function

$$Y^j_{\omega,t} = \left(\frac{P^j_{\omega,t}}{P^j_t}\right)^{-\epsilon} Y^j_t, \text{ where } Y^j_t = \left[\int_0^1 \left(Y^j_{\omega,t}\right)^{\frac{1+\epsilon}{\epsilon}} d\omega\right]^{\frac{\epsilon}{1+\epsilon}}, \tag{1}$$

[24] Our approach of illustrating the main mechanism we have in mind using a simple two-sector model is not unlike that taken by Guerrieri *et al.* (2021).

$\epsilon > 0$ is the elasticity of substitution between varieties within sector j, and Y_t^j is overall demand for products from sector j.

Because we consider the importance of relative demand shocks we keep our assumptions about production functions as simple as possible. We abstract from productivity shocks and assume a linear production technology in labor.[25] Firms use a composite of differentiated labor supplied by the continuum of households, indexed by i, to produce output, in that

$$Y_{\omega,t}^j = N_{\omega,t}^j, \text{ where } N_{\omega,t}^j = \left[\int \left(N_{i,\omega,t}^j \right)^{\frac{1+\eta}{\eta}} di \right]^{\frac{\eta}{1+\eta}}. \tag{2}$$

Household i supplies its labor to sector j at the nominal wage $W_{i,t}^j$. Demand for labor from household i by the producer of variety ω in sector j is given by

$$N_{i,\omega,t}^j = \left(\frac{W_{i,t}^j}{W_{\omega,t}^j} \right)^{-\eta} N_{\omega,t}^j, \tag{3}$$

where $W_{\omega,t}^j$ is the CES unit cost of $N_{\omega,t}^j$.

What differentiates the services, S, and goods, G, sectors is the type of nominal rigidities that the producers of varieties are subject to when they decide on their prices. In both sectors the price adjustment costs are given by the Linex adjustment cost function (Kim and Ruge-Murcia, 2009), which is expressed in terms of units of output and of the form

$$\Gamma_t^j \left(\pi_{\omega,t}^j \right) = \frac{\gamma_j}{\varsigma_j^2} \left\{ \exp\left[-\varsigma_j \pi_{\omega,t}^j \right] + \varsigma_j \pi_{\omega,t}^j - 1 \right\}, \text{ where } \pi_{\omega,t}^j = \frac{P_{\omega,t}^j - P_{\omega,t-1}^j}{P_{\omega,t}^j}. \tag{4}$$

Here $\gamma_j > 0$ is a scaling parameter that determines the degree of price stickiness, and ς_j determines the degree of asymmetry of the price adjustment cost. When $\varsigma_j > 0$, it is more costly to adjust prices downward than upward (and vice versa when $\varsigma_j < 0$). When $\varsigma_j \to 0$, price adjustment costs are symmetric.[26]

It is in the asymmetry of the price adjustment cost function that the services (S) and goods (G) sectors differ. In particular, our main focus is on the case where prices in the service sector are downwardly rigid due to asymmetric adjustment cost while those in the goods sector are not, i.e. $\varsigma_S > 0$ and $\varsigma_G \to 0$. The specification where both adjustment costs are symmetric, i.e.

[25] We abstract from trends in relative prices in this paper. Such trends do not affect the qualitative results of our analysis but complicate the model exposition because they imply a balanced growth path in relative prices and expenditure shares, requiring an approximation around these trends as in Ruge-Murcia and Wolman (2022).

[26] See Figure B.5 for an illustration of the Linex function for different parameters.

$\varsigma_S \to 0$ and $\varsigma_G \to 0$, is our main comparison case because symmetric price adjustment costs are what is commonly assumed in most models with nominal rigidities.[27]

The producer of each variety maximizes the expected present discounted value of profits, which equal the market value of output minus the price adjustment and labor costs, taking as given the initial price level $P^j_{\omega,t-1}$.

Households: The economy consists of a unit measure of households, indexed by $i \in [0, 1]$, that each have similar preferences but supply differentiated labor. We assume this differentiated labor to allow for households to have market power in the labor market such that each of them can set their own wages subject to a wage adjustment cost, as in Erceg *et al.* (2000). The households derive utility from the service flows of consumption of services and goods, which we denote by S_t and G_t respectively. Utility derived from these service flows is given by the following CES aggregate:

$$C_{i,t} = \left[(1-\alpha_t)^{\frac{1}{\theta}} S_{i,t}^{\frac{\theta-1}{\theta}} + \alpha_t^{\frac{1}{\theta}} G_{i,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}. \tag{5}$$

This specification is uncommon in two respects. First of all, the utility parameter α_t is time varying around a mean α. Deviations of α_t from this mean are the relative demand shocks that are the sole source of fluctuations we consider. If $\alpha_t > \alpha$ then demand shifts away from services towards goods, i.e. the type of shock that happened during the Covid pandemic, and vice versa.

Secondly, to allow for pent-up demand, S_t and G_t are service flows in that they depend not only the current level of consumption of services and goods but also on past levels. In particular, following Beraja and Wolf (2021), we assume that

$$S_{i,t} = (1-\delta_j)\, S_{i,t-1} + C^S_{i,t}, \tag{6}$$

$$G_{i,t} = (1-\delta_j)\, G_{i,t-1} + C^G_{i,t}, \tag{7}$$

where $\delta_j \in [0, 1]$ captures how quickly the importance of past consumption for current utility depreciates. Our baseline is the case in which only current consumption matters for current utility and there is no pent-up demand effect, i.e. $\delta_S = \delta_G = 1$. The prices of the consumption goods, C^S_t and C^G_t, are given by P^S_t and P^G_t respectively.

Households derive disutility from working from a combined labor supply composite, N_t, that

[27] Both the adjustment-cost specifications from Rotemberg (1982) and Calvo (1983) fall into this category.

is a CES aggregate of the time worked in the service, N_t^S, and goods, N_t^G, producing sectors:

$$N_{i,t} = \left[\left(\chi^S\right)^{-\frac{1}{\lambda}} \left(N_{i,t}^S\right)^{\frac{1+\lambda}{\lambda}} + \left(1-\chi^S\right)^{-\frac{1}{\lambda}} \left(N_{i,t}^G\right)^{\frac{1+\lambda}{\lambda}} \right]^{\frac{\lambda}{\lambda+1}}, \tag{8}$$

where χ^S represents the preference for labor supply in sector S. The parameter $\lambda > 0$ controls the intratemporal elasticity of substitution of labor across sectors.

When $\lambda \to \infty$, sectoral labor services are perfect substitutes. When $\lambda \to 0$, labor becomes virtually non-substitutable across sectors. Following Cantelmo and Melina (2023), we use this degree of substitutability of labor across sectors in terms of the labor supply to capture the costs of reallocating labor across sectors in response to a shock.

Because the labor each household supplies to the producers of varieties of goods and services is slightly differentiated from that supplied by other households, households have market power in the labor market and can set their own wages, subject to the following labor demand functions:

$$N_{i,t}^j = \int_0^1 \left(\frac{W_{i,t}^j}{W_{\omega,t}^j} \right)^{-\eta} N_{\omega,t}^j d\omega, \text{ where } j \in \{G, S\}. \tag{9}$$

As in Erceg *et al.* (2000), we assume that households are expected to supply all the labor demanded at the wages they set.

Several papers have argued that downward nominal wage rigidities bend the Phillips curve (Daly and Hobijn, 2014) and can be the source of upward pressures on prices in the case of relative demand shocks (Guerrieri *et al.*, 2021). With that in mind, we allow for wage rigidities in that it is costly for households to change the nominal wages they charge for their labor services in the two sectors. Just like for prices, we assume that the wage-adjustment cost function, as a fraction of output, is of the Linex form. In particular,

$$\Gamma_{i,t}^{w,j} = \frac{\gamma_j^w}{\left(\varsigma_j^w\right)^2} \left\{ \exp\left[-\varsigma_j^w \left(\frac{W_{i,t}^j}{W_{i,t-1}^j} - 1 \right) \right] + \varsigma_j^w \left(\frac{W_{i,t}^j}{W_{i,t-1}^j} - 1 \right) - 1 \right\}. \tag{10}$$

Following Kim and Ruge-Murcia (2009), we assume that this adjustment cost is expressed in terms of units of goods and services, depending on j.

In terms of these consumption and labor-supply aggregates, household i maximizes

$$\mathbb{E}_t \sum_{k=0}^{\infty} \beta^k U\left(C_{i,t+k}, N_{i,t+k}\right) = \mathbb{E}_t \sum_{k=0}^{\infty} \beta^k \left(\frac{C_{i,t+k}^{1-\sigma}}{1-\sigma} - \nu \frac{N_{i,t+k}^{1+\varphi}}{1+\varphi} \right), \tag{11}$$

with $\beta \in (0,1)$ the discount factor, $\sigma > 0$ the inverse intertemporal elasticity of substitution, and $\varphi > 0$ the inverse Frisch elasticity. It has access to one-period nominal bonds, $B_{i,t}$, that pay a risk-free gross nominal interest rate equal to R_t and earns profits Ω_t from its ownership of the firms in goods and service sectors.

Household i makes its consumption, savings, labor supply, and wage-setting choices to maximize its utility subject to the budget constraint

$$B_{i,t} \quad = \quad R_{t-1}B_{i,t-1} + \Omega_t - \sum_{j\in\{S,G\}} \left(P_t^j C_{i,t}^j - \left(1 - \Gamma_{i,t}^{w,j}\right) W_{i,t}^j N_{i,t}^j \right), \tag{12}$$

the labor demand functions, (9), and the wage adjustment cost functions, (10). It takes as given the initial levels of the stocks of consumption services flows, i.e. $S_{i,t-1}$ and $G_{i,t-1}$, its initial level of asset holdings, $B_{i,t-1}$, as well as the initial level of their nominal wages, $W_{i,t-1}^S$ and $W_{i,t-1}^G$.

Equilibrium and measurement: We consider the symmetric equilibrium in which all households, i, and producers of varieties in the same market, ω, make the same decisions, including on their prices, P_t^j, and wages, W_t^j, for $j \in \{G, S\}$. In that case the aggregate levels of gross output and labor inputs by sector j can be expressed as

$$Y_t^j = Y_{\omega,t}^j = N_t^j = N_{\omega,t}^j = N_{i,t}^j, \text{ where } j \in \{G, S\}. \tag{13}$$

But, because of the price- and wage-adjustment costs, not all output produced in each sector is consumed. Consumption of j equals

$$C_t^j = Y_t^j - \Gamma_t^j Y_t^j - \Gamma_t^{w,j} \left(\frac{W_t^j}{P_t^j} \right) N_t^j = C_{i,t}^j, \text{ where } j \in \{G, S\}. \tag{14}$$

Nominal Gross Domestic Product (GDP), $P_t Y_t$, in this economy is the market value of sales to final demand. It equals consumption expenditures on goods and service, i.e.

$$P_t Y_t = P_t^G C_t^G + P_t^S C_t^S. \tag{15}$$

Because of the time-varying preferences, i.e. α_t, and the fact that we allow for pent-up demand, i.e. $\delta \in [0, 1]$, there is no specific well-defined theoretical price associated with the consumption composite (5). Instead, what we assume is that the statistical agency in this economy publishes macroeconomic aggregates as fixed-weighted Laspeyres indices, with the weights determined by the steady-state consumption shares of goods and services. This yields a price index for

P_t and associated gross and net inflation rates, i.e. $\Pi_t = \frac{P_t}{P_{t-1}} = (1+\pi_t)$, as well as an associated quantity index for Y_t. We call these fixed-weighted CPI and fixed-weighted GDP respectively. These are the main aggregate equilibrium variables that we track when we analyze the equilibrium dynamics of the model.[28]

Central bank: Finally, the central bank pursues price stability by setting the risk-free one-period nominal interest rate according to a Taylor rule of the form:

$$R_t = \left(\frac{1}{\beta}\right)^{(1-\rho_R)} (R_{t-1})^{\rho_R} (1+\pi_t)^{\phi_\pi(1-\rho_R)}, \tag{16}$$

where $\rho_R \in [0,1]$ is the interest rate smoothing parameter and $\phi_\pi > 1$ is the Taylor-rule parameter for the monetary policy response to inflation. This rule reflects that, throughout, we assume a zero percent inflation target and that the natural real rate of interest is equal to β^{-1}.[29]

3.2 Choice of parameter values

We use our model to illustrate the main mechanism behind Demand-Shift Inflation in a stylized general equilibrium framework, not for a detailed empirical quantification of the mechanism in the data. This means that we calibrate the model parameters and provide some expositional numerical comparative statics results to highlight the margins that are important.

With this in mind, our choice of parameters is not meant to match empirical moments. Instead, we start off with a set of "stripped" baseline values and then turn model features on and off to analyze their impact on the inflationary effect of relative demand shocks. These baseline parameter values are listed in Table 1. We chose these values because they have the following properties and implications.

Symmetric adjustment costs to prices: We set ς_G and ς_S close to zero such that price adjustment costs are symmetric in our baseline case, as they are in the specifications based on Calvo (1983) and Rotemberg (1982) that are most commonly used in macroeconomic models with price

[28]We also calculate an aggregate wage index in a similar manner.

[29]There is an extensive number of studies that discuss the optimal level of the inflation rate in the presence of downward nominal rigidities, especially of wages. See, for example, Akerlof *et al.* (1996). In this model, positive steady-state inflation implies incurring price and wage adjustment costs through (4) and (10). The potential benefit, which depends a lot on the structure and variance of the different shocks in the model, would be that inflation could accommodate a faster adjustment of the relative prices and real wages in this economy. We discuss this, for the transitional dynamics, in the context of our model in Subsection 4.3. We abstract from longer-run steady-state considerations along this line, since it requires making detailed assumptions about the mixture of shocks that drive fluctuations in the economy.

stickiness. As we discussed above, our main alternative to this is the case in which price adjustment costs in the services sector are asymmetric, such that $\varsigma_S > 0$. Steady-state markups are 20 percent, as determined by the elasticity of substitution between varieties, i.e. $\varepsilon = 6$.

Flexible wages: The baseline is that households can costlessly adjust their wages, i.e. $\gamma_j^w = 0$. They only have very limited market power in the labor market, because the elasticity of substitution between labor provided by the households to each sector is very high, i.e. $\eta = 21$ (as in Cantelmo and Melina (2023)). This elasticity implies that households charge a 5 percent markup on their wage relative to a competitive equilibrium in which their marginal rate of substitution equals the marginal revenue product of labor.

No pent-up demand: In the baseline, the service flows of goods and services that the household derives utility from only depend on the current levels of consumption, i.e. $\delta_j = 1$. In our baseline, the household has Cobb-Douglas preferences over these service flows, i.e. $\theta = 1$, and goods and services have equal steady-state expenditure shares, i.e. $\alpha = 1/2$.

Real rigidities: We assume that the elasticity of substitution between the labor supply across sectors, i.e. λ, is one. This means that, in our baseline, the shares of labor income earned from services and goods are constant and that there is only limited substitutability between the households' labor supplied to the two different sectors. That is, our baseline does include a degree of real rigidities. We think this is a useful benchmark because it captures that sector-specific skills make it hard for households to shift their labor supply across broad occupational categories or, in the stylized context of our model, sectors. We provide results for different degrees of these rigidities in the results section below.

Throughout, we use common values for the preference parameters in that we consider the case of log utility and set both the intertemporal elasticity of substitution and Frisch elasticity of labor supply to equal one.

4 Inflationary Relative Demand Shocks

We use our model to illustrate the inflationary impact of relative demand shocks. The shock that we consider is a shift in demand from services to goods. In particular, we look at the response of the model economy to

$$(\alpha_t - 0.5) = 0.9 \times (\alpha_{t-1} - 0.5), \text{ where } \alpha_1 = 0.58. \tag{17}$$

At the baseline level of the elasticity of demand between goods and services (which is one, see Table 1), this implies that the consumption expenditure share on services drops from 50% to 42% and then recovers back to 50%.

We first show that, in the baseline case in which price rigidities are symmetric, as is assumed in most analyses of New Keynesian models, such a relative demand shock is not very inflationary. But when prices in the services sector are downwardly rigid, then this type of shock results in substantial positive inflation.

4.1 DPR and Demand-Shift Inflation

The impulse responses in Figure 4 illustrate this point. For brevity, we limit ourselves to presenting the responses of the variables that are most relevant for the point we make. In this case these are inflation, π_t, output, Y_t, and inflation in the services and goods sectors, π_t^S and π_t^G. Each of the panels in the figure shows four impulse responses, varying in the degree of asymmetry of the price adjustment cost function in the service sector. From symmetry, $\varsigma_S = 0$, to very high asymmetry, $\varsigma_S = 1000$, making it exorbitantly expensive to lower service prices.

The blue lines in the panels depict the response of the economy in case of symmetric price adjustment costs. In that case the relative demand shock results in almost offsetting price declines and price increases in services and goods respectively (panels (c) and (d)). The net result is only a very small response of overall inflation to the shock (panel (a)).

This increase in inflation is accompanied by a small decline in measured GDP. This decline can be attributed to two main effects. The first is the loss of output due to the adjustment costs incurred to accommodate the relative price change. The price rigidities also cause a deviation of relative prices from the flexible price outcome and this nominal distortion affects the allocation of real resources, i.e. labor, across the two sectors. The second is that the fixed-weighted quantity index for GDP puts a disproportionate weight on the decline in output in the service sector, resulting in a drag on measured GDP.

As can be seen from the line for $\varsigma_S = 1000$ in panel (a) of the figure, contrary to the case of symmetric price adjustment costs, the relative demand shock that we consider has a substantial inflationary effect when price declines in the service sector are costly. In that case, service prices barely decline in response to the shock (panel (c)) and goods price inflation is elevated compared to the symmetric benchmark. The result is a 2.5 percentage point spike in annualized inflation.

Under DPR the shock does not only have an outsized impact on inflation, it also results in a much larger decline in GDP than under symmetric price adjustment. This is because the

DPR slow down the equilibrium adjustment of the relative price of services compared to goods, resulting in larger nominal distortions that translate into bigger allocative effects on the use of production factors across the two sectors. In addition, the Taylor rule that the central bank follows, (16), implies a contractionary policy response to the elevated level of inflation, further contributing to a slowdown on the real side of the economy.

Thus, under DPR a relative demand shock can have a substantial inflationary impact. Important to note is that this result occurs in our model in the *absence* of wage rigidities or productivity shocks and, even though our labor supply specification allows for a degree of real rigidities, these rigidities do not result in inflation in response to a relative demand shock in the absence of DPR. It is solely the asymmetry of the price adjustment costs in the service that generates the price pressures after a relative demand shock away from services in our model.

Because the mechanism we point out relies on the asymmetry of the price adjustment cost function, it is inherently non-linear in the size of the relative demand shock that hits the economy. We illustrate this in Figure 5 in which we plot the response of the model economy to a 2.5, 5.0, 7.5, and 10.0 percentage point decline in the expenditure share of services. The figure shows that the magnitude of the impact of the largest shock on inflation is about 7 times larger than the smallest, even though the largest shock is only four times the size of the smallest.

4.2 DPR and the slope of the empirical Phillips curve

Even though all fluctuations in the economy in Figures 4 and 5 are due to changes in preferences, those who analyze output and inflation in Phillips-curve space (e.g. Samuelson and Solow, 1960) would interpret it as a stagflationary "supply shock". This is because it results in a contemporaneous decline in output and increase in inflation. To illustrate this, we plot the inflation and output responses from Figures 4 and 5 in this space in Figure 6. The empirical Phillips curve traced out by the equilibrium dynamics is negatively, rather than positively, sloped, even though all the dynamics are demand induced.

Our observation that downward rigidities or asymmetries can shift or bend the Phillips curve is not new. For example, Ball and Mankiw (1994, 1995) consider models in which steady-state inflation with symmetric menu costs and asymmetric cost shocks can possibly generate inflation and look like supply shocks. Daly and Hobijn (2014) show how DNWR can bend the Phillips curve in a one-sector economy in response to a negative demand shock. Guerrieri *et al.* (2021) make a similar point in the context of a two-sector model. Our model illustrates how the insights from those papers are applicable to the case of relative demand shocks with DPR and, thus, why this might be particularly relevant in periods during which demand shifts away from services, like the Covid pandemic.

4.3 Inflation greases the wheels of the product market

For our results, so far, we assumed that the central bank implements its goal of price stability by following the inertial Taylor rule with a zero inflation target, i.e. (16). But, an extensive number of papers have argued that, in case of DNWR, inflation might actually be benefitial in that it "greases the wheels of the labor market." This argument goes back at least to Tobin (1972), who argued that, because what matters for the alignment of labor and product markets is the relative price of labor compared to output, i.e the real wage, if nominal wages cannot adjust downward then the allocation of labor would improve as a result of elevated inflation.

The main intuition of this argument translates to DPR. In the case of multiple product markets, the relative price of one good versus another matters for the allocation of resources.[30] If a relative demand shock reduces demand in a sector where prices are downwardly rigid then higher inflation would make this downward rigidity less binding as well as speed up the adjustment of the prices of the goods whose demand has increased due to the shock. In this sense "inflation greases the wheels of the *product markets*" in case of DPR.

If DNWR have significant allocative consequences, then there exists a long-run trade off between the average level of inflation and the steady-state level of unemployment and output. This is known as a long-run Phillips curve and it has been studied in, arguably, highly stylized models (e.g. Akerlof *et al.*, 1996; Benigno and Ricci, 2011; Daly and Hobijn, 2014). But there is no broad consensus about how binding DNWR are (Elsby and Solon, 2019) and the optimal level of inflation with DNWR depends on the distribution of shocks that hit the economy and many other considerations. In fact, several studies that tried to fully account for these shocks and considerations have found that DNWR play no, or only a limited role, in the practical considerations about the optimal inflation target (e.g. Coibion *et al.*, 2012). With this in mind and the observation that, before the Covid pandemic, the evidence pointed to DPR being less binding than DNWR (e.g. Yates, 1998), we ignore the implications of DPR for the optimal inflation target in our analysis.

Instead, we consider the argument in Schmitt-Grohé and Uribe (2013) who make the point that, at a given credible inflation target and when DNWR are binding and prevent real wages from declining, it might be beneficial for a central bank to temporarily allow for higher inflation. This insight also applies for DPR. If DPR slow down adjustments in relative prices in product

[30] See, for example, the models in Aoki (2001), Nakamura and Steinsson (2008), Eusepi *et al.* (2011), and Ruge-Murcia and Wolman (2022).

markets, then temporarily higher inflation might act as a "lubricant" and be beneficial for the allocation of real resources along the transition path in the economy.

We illustrate this in Figure 7. It shows the response of the economy to the relative demand shock under two policy responses. The first, shown as the blue line, is the one in which the central bank implements the Taylor rule as specified in equation (16). The second is one in which the central bank realizes the nature of the shock and delays its response to the spike in inflation by four quarters. As the figure shows, the delayed monetary policy response (panel(c)) allows for a 2 percentage point higher run up in annualized inflation (panel (a)) that accommodates an accelerated adjustment of the relative price of goods (panel (d)) which results in a much more favorable real impact of the shock, captured by an increase in the fixed-weighted GDP index (panel (b)).

This type of "patience" in the monetary policy response is not unlike the one advocated by Guerrieri *et al.* (2023) in response to the relative price shock in Europe induced by the spike in energy prices after the start of the war in Ukraine in February 2022. What is important to realize, however, is that this simulation assumes that the central bank realizes that it is dealing with an inflationary relative demand shock and that the simulation does not take into account the potential impact of letting inflation rise substantially on the credibility of the central bank.[31]

4.4 DPR amplify other inflationary relative demand pressures

Besides DPR, there are of course other features in the economy that affect the adjustment of relative prices across sectors following a relative demand shock, and which may render such shocks inflationary. For example, Guerrieri *et al.* (2021) point out how DNWR can generate non-linear Phillips curves at the sectoral level, which in turn may give rise to inflation once demand shifts away from one sector to another. Ferrante *et al.* (2023) show in a multi-sector model that labor reallocation costs can cause inflationary pressures following relative demand shocks as these hamper the expansion of supply in those sectors that face an increase in demand relative to other sectors. Beraja and Wolf (2021) argue that pent-up demand can speed up the recovery from demand-driven recessions, and show that this is more likely the case when recessions are caused by a decline in demand for durable goods than for services.

In this section, we move away from our baseline model and consider DNWR, costly reallocation of labor across sectors and pent-up demand separately, and how they interact with DPR. Our main point is that if we add DPR on top of these other mechanism then this tends

[31]We derived the model under the assumption that the central bank maintains its credibility on its inflation target.

to increase their inflationary impact.

4.4.1 Downward Nominal Wage Rigidities (DNWR)

Related to DNWR, we use our model to illustrate two main things. First of all, DNWR can cause inflationary pressures in response to relative demand shocks. This result is not new. For example, Guerrieri *et al.* (2021) have made this as well. Secondly, the addition DPR on top of DNWR renders their impact more inflationary as well as more contractionary.

This is illustrated in Figure 8. It compares the impulse responses of our model economy for four cases. The first, plotted as the blue solid line, is the baseline case from Figure 4. The second, the yellow dashed line, is the baseline case with DPR added, also replicated from Figure 4. The third and fourth cases correspond to these two cases with DNWR added.

We add DNWR by recalibrating the parameters of the wage adjustment cost function faced by the household, ((10)). In particular, we set γ_j^w, which controls the degree of wage rigidity, to 50 (baseline of 0 implies flexible wages), and ς_j^w, which governs the degree of asymmetry in the wage adjustment cost, to $1,000$.[32]

The green dotted line shows the model response in the case in which wages are downwardly rigid but prices are not. It reveals that the main result from Guerrieri *et al.* (2021) also holds in our model. Under DNWR relative demand shocks can be inflationary because they hamper the downward adjustment of factor costs in the sector with declines in demand. In particular they impede the downward adjustment of real wages (panel (c)). This means that marginal costs in the service sector decline much less than without the rigidities and that puts upward pressures on services prices.

Introducing DPR on top of DNWR amplifies these inflationary pressures, albeit only slightly.[33] With services prices not adjusting sufficiently downwards, the response to the relative demand shock of aggregate inflation is more persistent than in the case of symmetric price adjustments.

4.4.2 Real rigidities

Another reason why inflationary pressures might emerge after relative demand shocks is because real rigidities prevent the reallocation of factors of production needed to accommodate the shift in demand. For example, Ferrante *et al.* (2023) argue that labor reallocation costs raise marginal

[32]Note that we allow the degree of DNWR to be the same across sectors. Having wages be downwardly rigid in only one of the two sectors does not qualitatively alter the results.

[33]The difference between the cases with DNWR alone and with both DPR and DNWR are small because we assume that the labor cost share is one. Which is, of course, much lower than in the data (e.g Valentinyi and Herrendorf, 2008).

costs of production after a relative demand shock and thus result in upward pressures on prices.

In our model, real rigidities are captured in a similar way as in Cantelmo and Melina (2023), i.e. through the limited substitutability of hours supplied by households across the sectors in the economy. This substitutability is captured by the intratemporal labor supply elasticity, λ. In our baseline case we included some degree of real rigidities in the sense that λ was not infinite but, instead, equal to one. To show the impact real rigidities have on the build-up inflationary pressures after relative demand shocks, we compare that case with one in which labor is less substitutable, i.e. $\lambda = 0.5$. The results are plotted in Figure 9. The first two lines plotted are the same two from Figure 4 that we plotted for DNWR above.

The last two lines are those associated with a higher degree of real rigidities. Even with more real rigidities, without DPR the response of aggregate inflation is muted, as firms in the service sector respond by aggressively lowering their prices, thereby offsetting the rise in goods prices. Thus, in our model, impediments to the sectoral reallocation of factor inputs by themselves do not generate inflationary pressures after relative demand shocks. However, once we add DPR to the higher degree of real rigidities both the inflationary and real impact of the relative demand shock ends up being substantially larger than with a lower degree of real rigidities. So, it is the interaction of real rigidities with DPR that is essential for the price pressures to occur after a shift in demand.

4.4.3 Pent-up demand

Finally, we allow for pent-up demand towards both goods and services by lowering the rate at which the utility gain from past consumption depreciates, δ, from its baseline value of 1 to 0.5.[34] As shown by Figure 10, in the absence of DPR, the response of aggregate inflation to the relative demand shock is virtually zero, due to the offsetting responses of services and goods prices. With pent-up demand, the initial decline in services consumption implies that the household is temporarily left with a lower stock of services, which the household aims to undo in subsequent periods. Conversely, the initial rise in goods consumption leaves the household with an abundance of goods that the household aims to run down. As a consequence, service prices recover more strongly upwards, whereas the downward adjustment of goods prices, following their initial jump, becomes more pronounced.

When introducing DPR on top of the pent-up demand mechanism, inflationary pressures arise at the aggregate level for the same reasons as discussed before. Compared to our baseline

[34] This δ applies to both goods and services. One might find this unusual for services, but one can think of pent-up demand in services as the utility depending on the number of visits to the dentist in the past year, the number of meals consumed in restaurants over the past month, etc..

results, however, we find that inflation returns to steady state more abruptly as pent-up demand causes the initial change in relative demand to revert more quickly.

5 Conclusion

Relative demand shocks alone, even in the absence of convex supply curves, factor reallocation costs, or downward wage rigidities, can cause upward pressures on prices when they result in a decline in demand for goods or services whose prices exhibit Downward Price Rigidities (DPR). This is because such shocks require an equilibrium adjustment of relative prices that disproportionately occurs through price increases of goods and services whose demand increases. This mechanism is reminiscent of "Demand-Shift Inflation."

We argued that this mechanism might be particularly relevant to understand the inflationary pressures during and after the Covid pandemic. The outbreak of Covid in 2020 caused an unprecedented shift in demand away from person-to-person services. In spite of this drop in demand, the prices of these services barely declined. Instead, goods prices, especially those of durables, went up and inflation emerged.

The inclusion of DPR in a stylized two-sector New Keynesian model provides four main insights. The first is that the inflationary pressures that build up as a result of a relative demand shock with DPR are highly non-linear in the size of the shock. The second is that such inflationary relative demand shocks look like "supply shocks" when interpreted through the lens of a simple Phillips curve framework, because they result in a simultaneous increase in inflation and decline in measured output. The third is that the real-side impact of the inflationary relative demand shock is alleviated by the central bank temporarily allowing for more inflation. This is because inflation lubricates the adjustment of relative prices that is slowed down by the nominal rigidities along the equilibrium path. Finally, "Demand-Shift Inflation" is not a competing explanation of why price pressures can build up after relative demand shocks. Instead, it complements other theories in that it amplifies the inflationary impact of other channels proposed.

Our stylized model is useful because it allows us to isolate the impact of large relative demand shocks. Such shocks are not very common. The Covid pandemic was a highly unusual economic downturn. This is important, because it means that one has to be careful to generalize our conclusions, especially about monetary policy, to other business cycles as well as to default policy rules. What our results point out is that it is essential for policymakers to have an accurate real-time assessment of the sources of fluctuations they aim to stabilize and to understand the different implications of these sources for the output-inflation trade off that they face.

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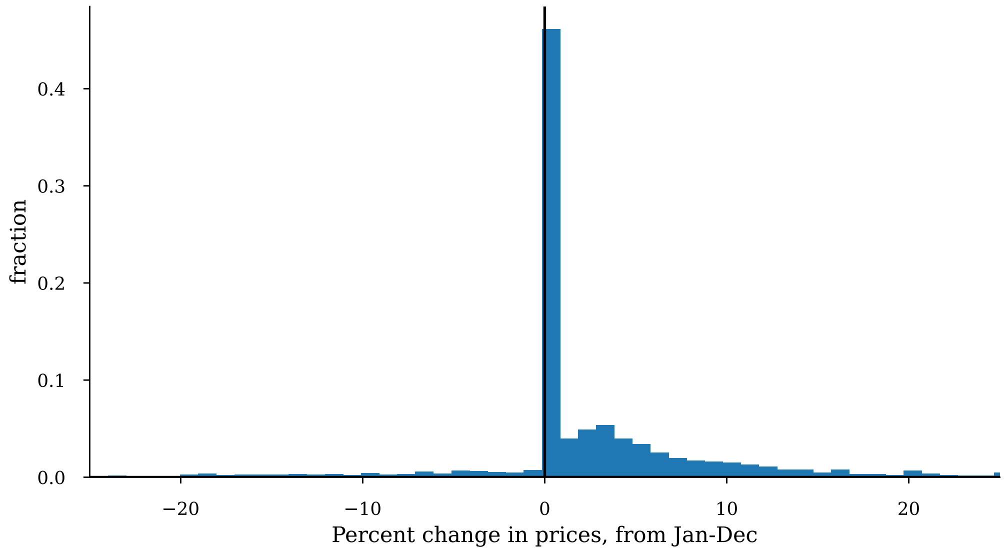
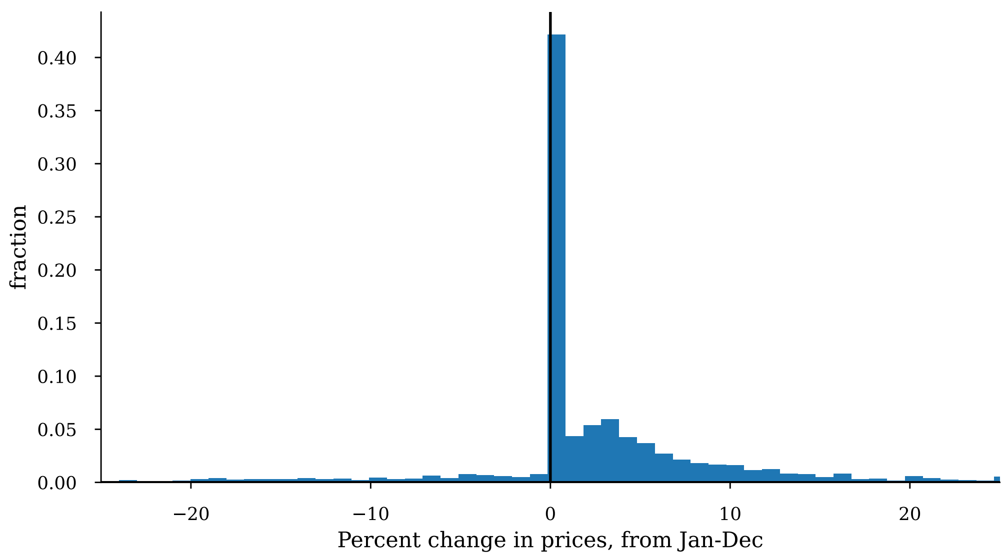
Figures and tables



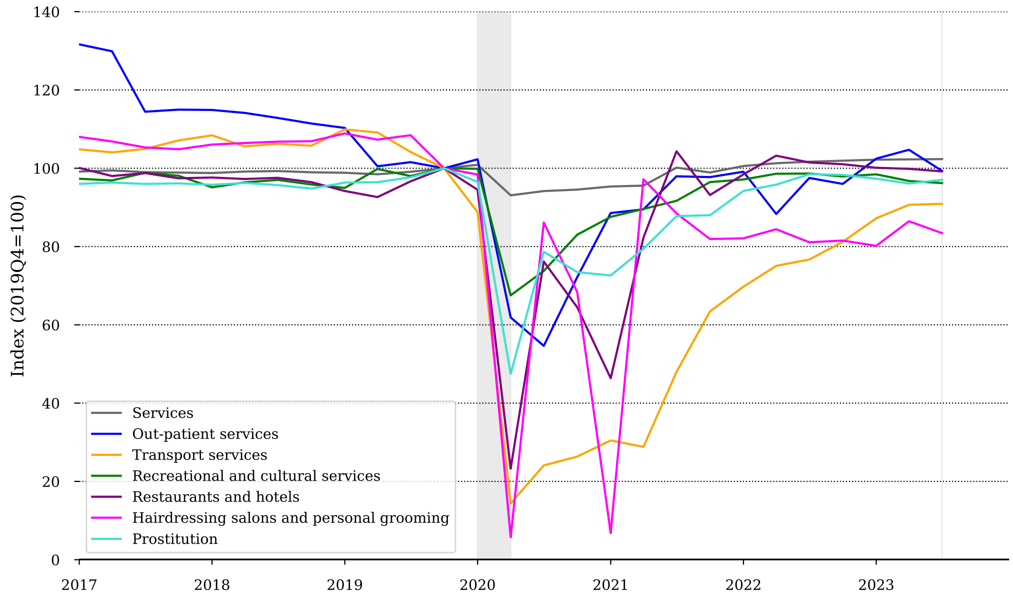
(a) Services



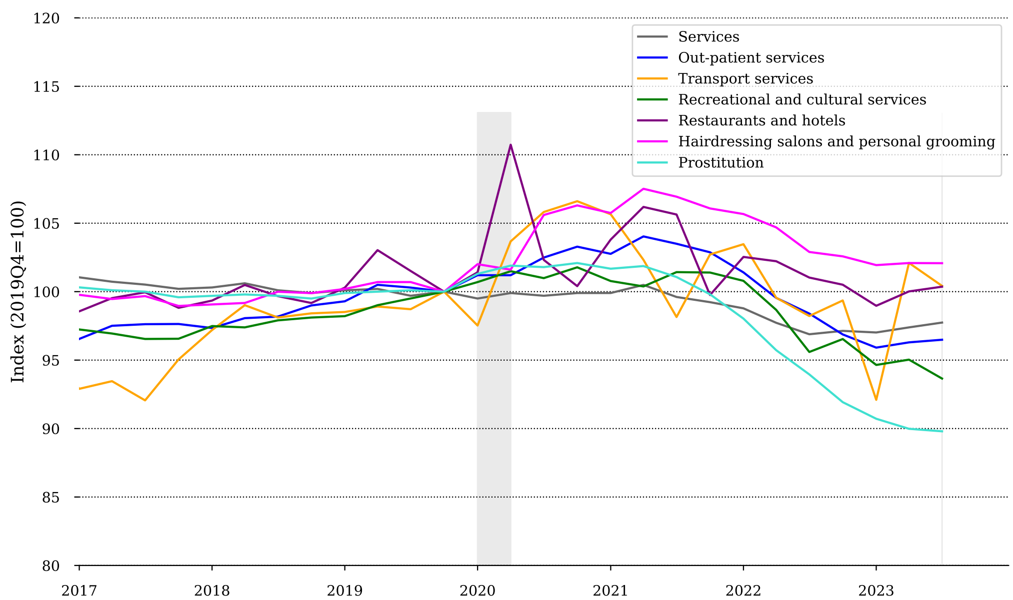
(b) Person-to-person services

Figure 1: Price changes for total and person-to-person services before pandemic (2017-2019)

Source: Office for National Statistics (U.K.) (ONS) and authors' calculations. 11-month price changes from January through December for 2017-2019. Person-to-person services are 'Out-patient health services', 'Transport services', 'Recreational and cultural services', 'Restaurants and hotels', 'Hairdressing salons and personal grooming', and 'Prostitution'.



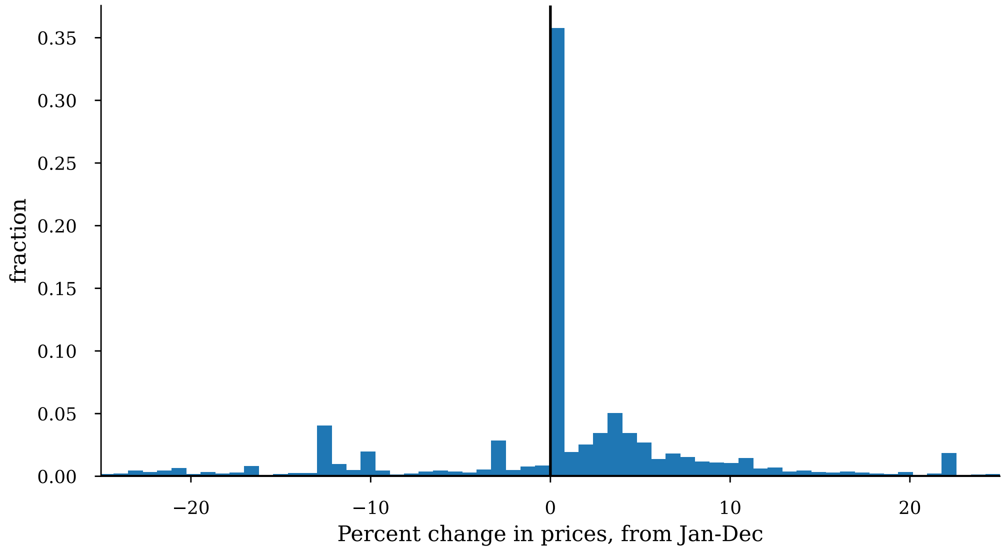
(a) Relative quantities



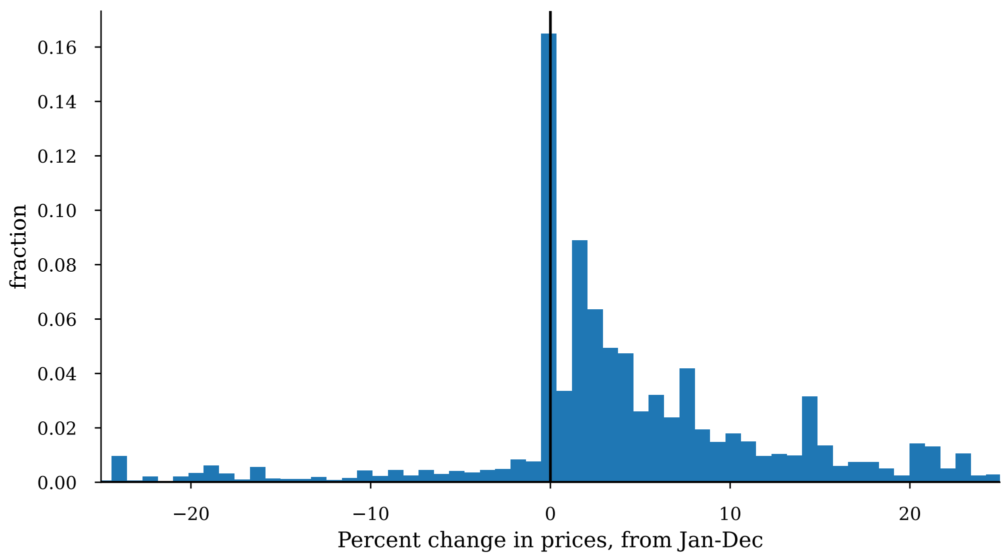
(b) Relative prices

Figure 2: Relative quantities and prices for total and person-to-person services, 2017-2023

Source: ONS Consumer Trends (National Accounts) and authors' calculations. Quantites relative to total consumer spending. Relative prices compared price of total consumer spending. Index (2019Q4=100). Person-to-person services are 'Out-patient health services', 'Transport services', 'Recreational and cultural services', 'Restaurants and hotels', 'Hairdressing salons and personal grooming', and 'Prostitution'.



(a) 2020



(b) 2021

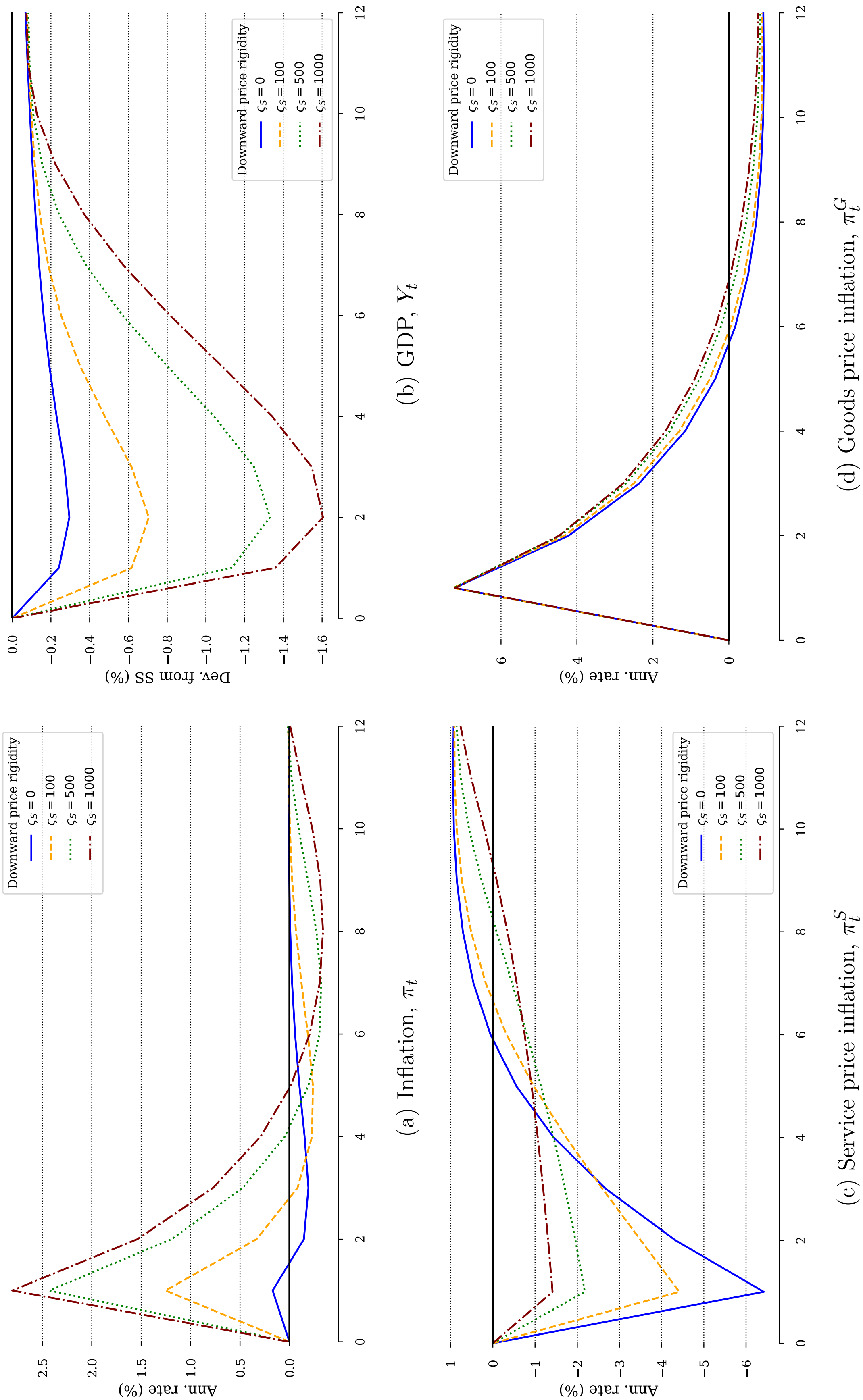
Figure 3: Price changes for person-to-person services during pandemic (2020 and 2021)

Source: ONS and authors' calculations. 11-month price changes from January through December for 2017-2019. Person-to-person services are 'Out-patient health services', 'Transport services', 'Recreational and cultural services', 'Restaurants and hotels', 'Hairdressing salons and personal grooming', and 'Prostitution'.

Table 1: Baseline parameter values

Parameter	**Description**	**Value**
α	Steady-state share of good G in consumption basket	0.5
χ^S	Steady-state share of hours worked in sector S	1/2
β	Discount factor	0.9925
ϵ	Elasticity of substitution between good varieties	6
λ	Elasticity of substitution of labor across sectors	1
σ	Inverse of intertemporal elasticity of substitution	1
φ	Inverse of Frisch elasticity of labor supply	1
γ_j	Degree of price stickiness in sector j	100
ς_j	Degree of price adjustment cost asymmetry in sector j	0
ρ_R	Interest rate smoothing parameter	0.8
ϕ_π	Monetary policy response to inflation	1.5
ρ_α	Persistence of relative demand shock	0.9
γ^w	Degree of wage stickiness in sector j	0
ς^w	Degree of wage adjustment cost asymmetry in sector j	500
η	Elasticity of substitution of labor varieties within sector j	21
θ	Elasticity of substitution between final goods	1
δ	Depreciation rate of good j	1

Note: Time period t is a quarter.



(a) Inflation, π_t

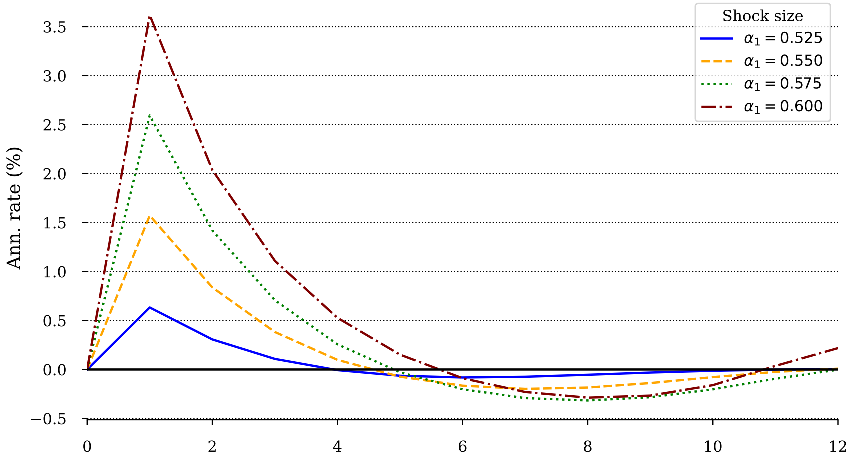
(b) GDP, Y_t

(c) Service price inflation, π_t^S

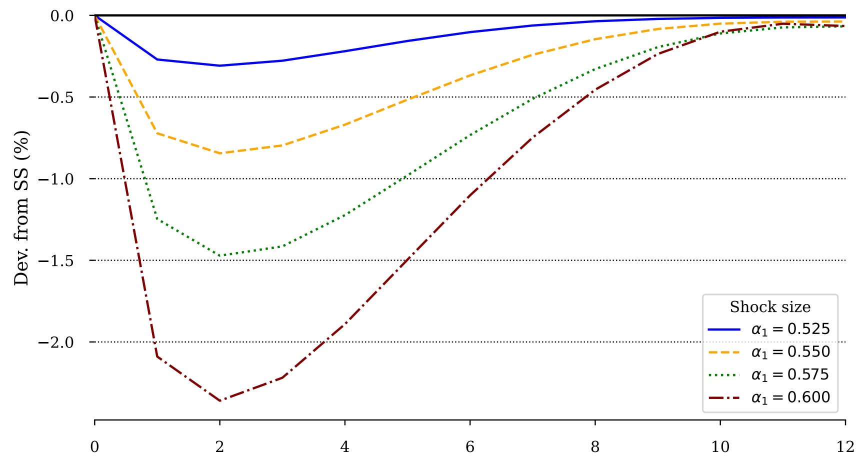
(d) Goods price inflation, π_t^G

Figure 4: Impact of degree of DPR in services, ς_S, on path of inflation and output.

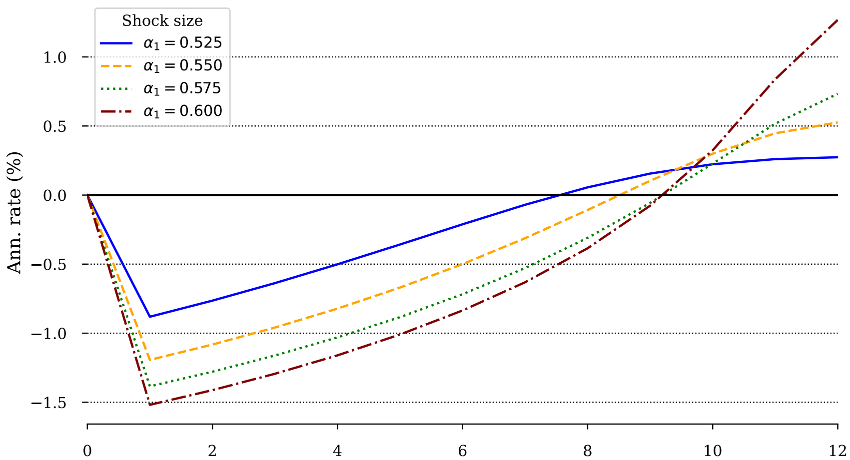
Note: Time period is a quarter. Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 = 0.58$.



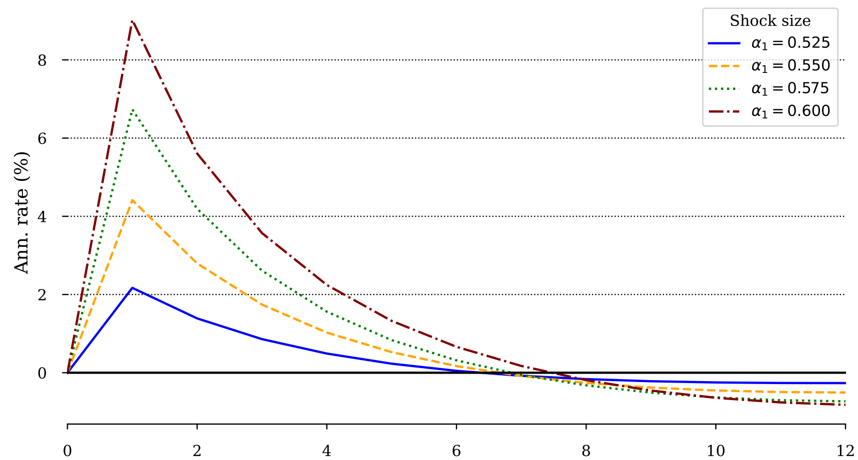
(a) Inflation, π_t



(b) GDP, Y_t



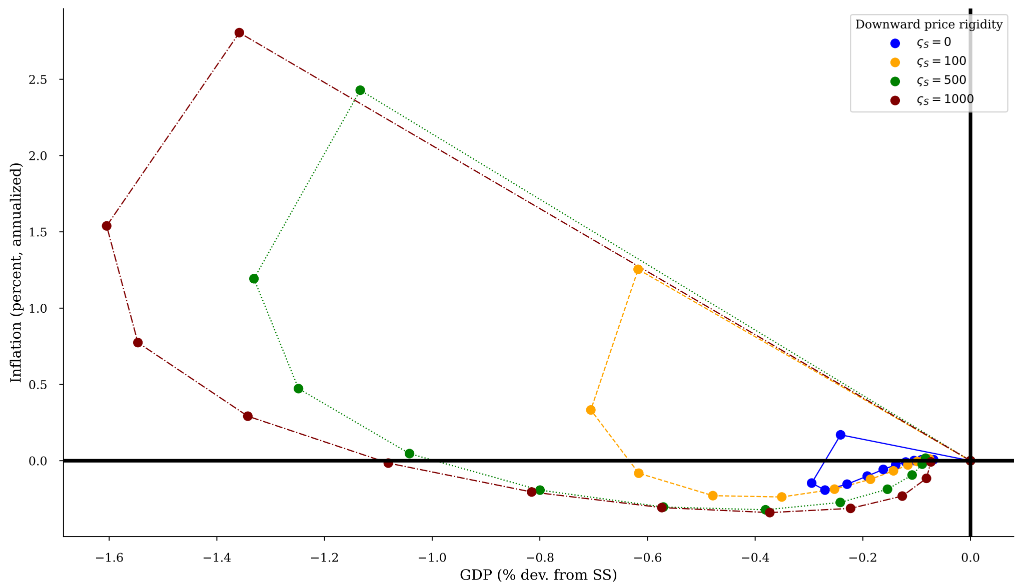
(c) Service price inflation, π_t^S



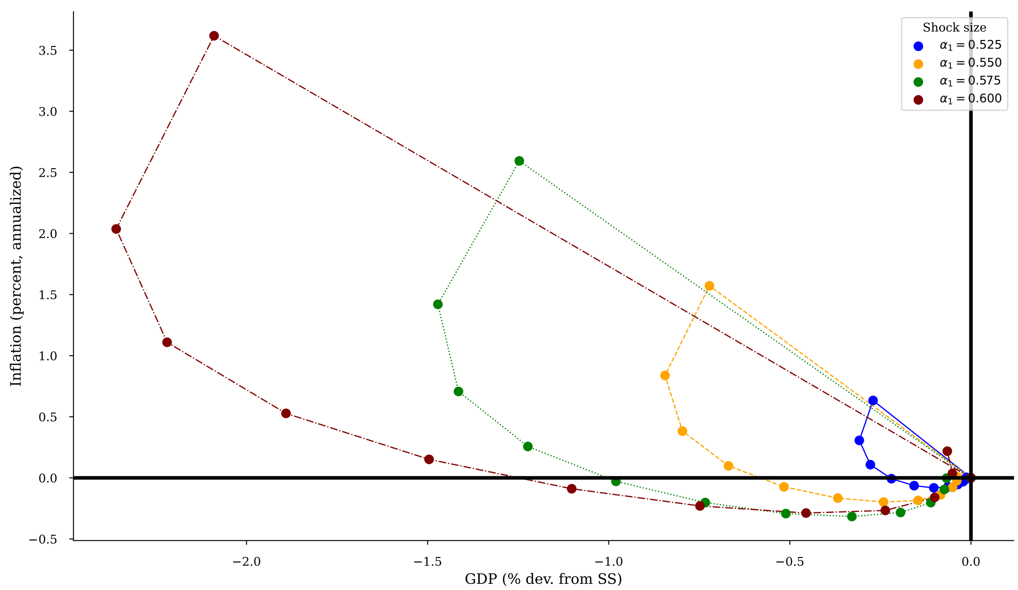
(d) Goods price inflation, π_t^G

Figure 5: Impact of shock size on path of inflation and output under DPR in services.

Note: Time period is a quarter. Prices in services are downwardly rigid, i.e. $\varsigma_S = 1000$ Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 \in \{0.525, 0.550, 0.575, 0.600\}$.



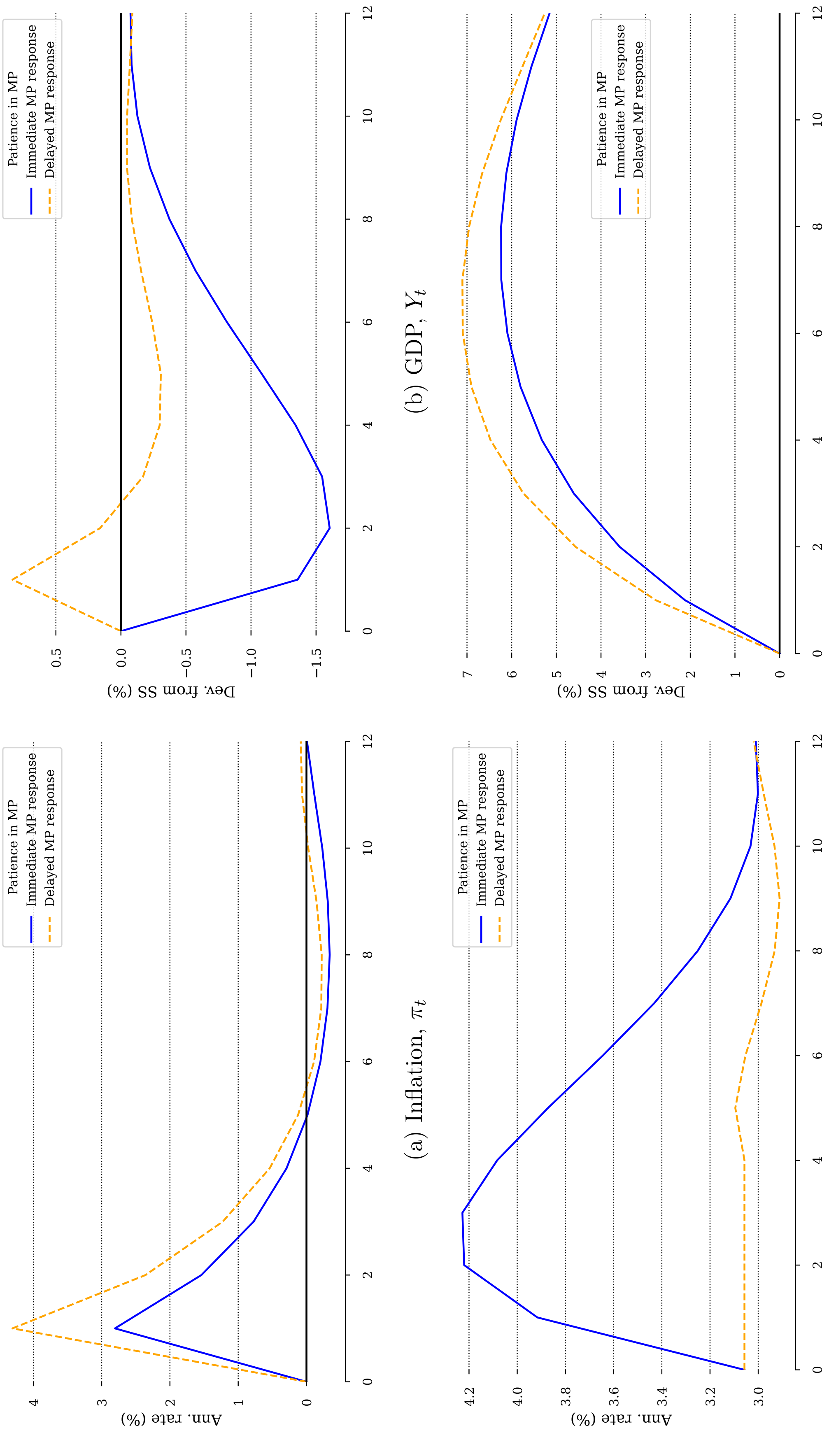
(a) For different degrees of DPR in service sector



(b) For different shock sizes

Figure 6: Inflationary relative demand shocks in Output-Inflation space (Phillips curve)

Note: Time period is a quarter. Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 = 0.58$ in panel (a) and $\alpha_1 \in \{0.525, 0.550, 0.575, 0.600\}$ in panel (b)



(a) Inflation, π_t

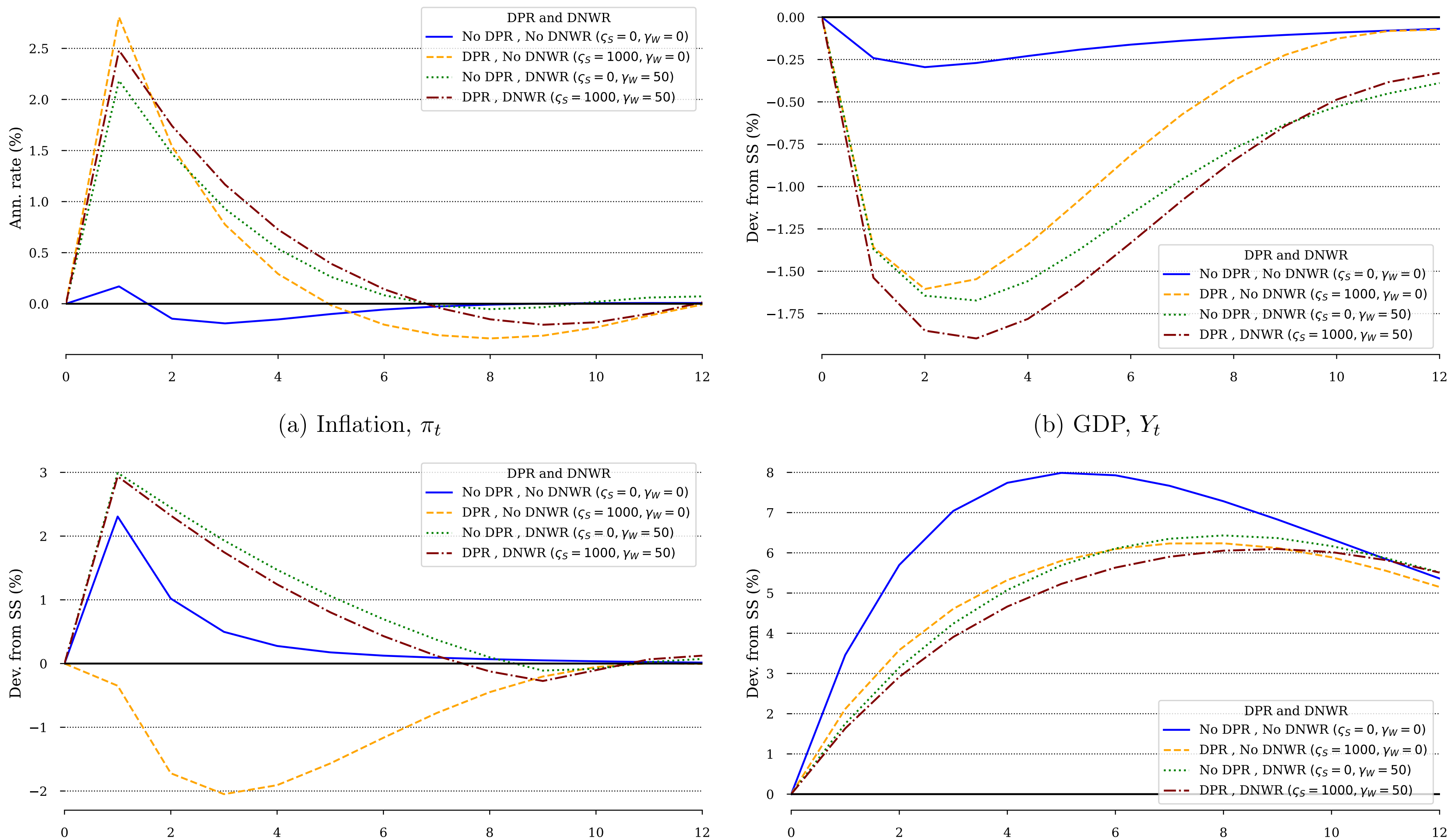
(b) GDP, Y_t

(c) Policy rate, R_t

(d) Relative price of goods, P_t^G/P_t^S

Figure 7: Impact of delaying monetary policy response after inflationary relative demand shock.

Note: Time period is a quarter. Prices in services are downwardly rigid, i.e. $\varsigma_S = 1000$. Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 = 0.58$.



(a) Inflation, π_t

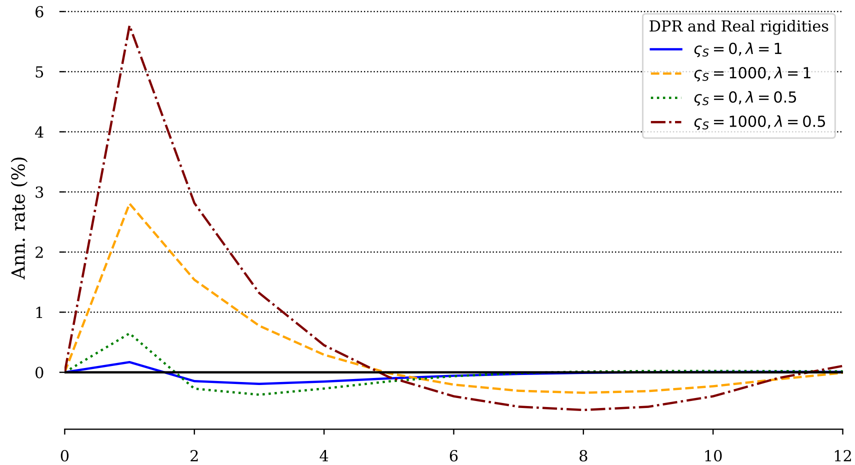
(b) GDP, Y_t

(c) Real wage, W_t/P_t

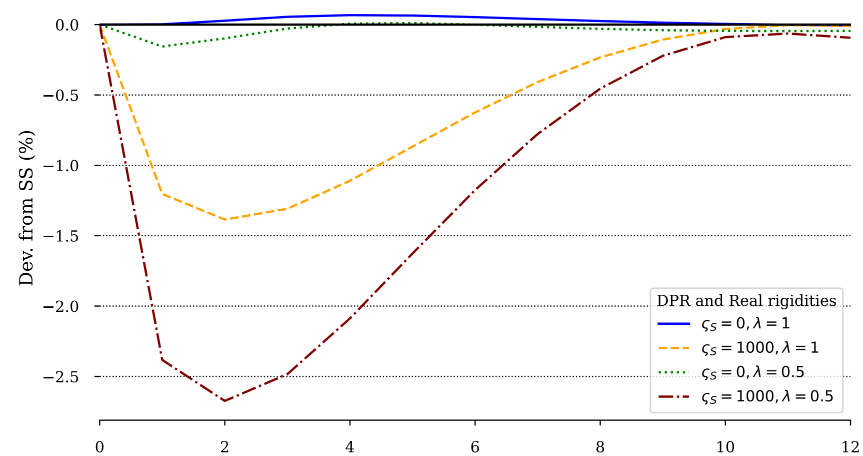
(d) Relative price of goods, P_t^G/P_t^S

Figure 8: Interaction of DPR and DNWR for inflationary and real impact of relative demand shock.

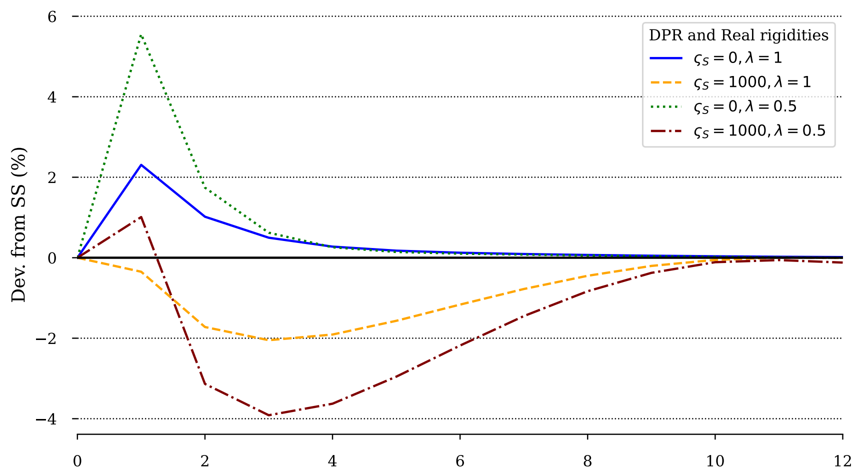
Note: Time period is a quarter. Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 = 0.58$. No DNWR is case of $\gamma^w = 0$ and "DNWR" is case where $\gamma^w = 50$ and $\varsigma^w = 1000$.



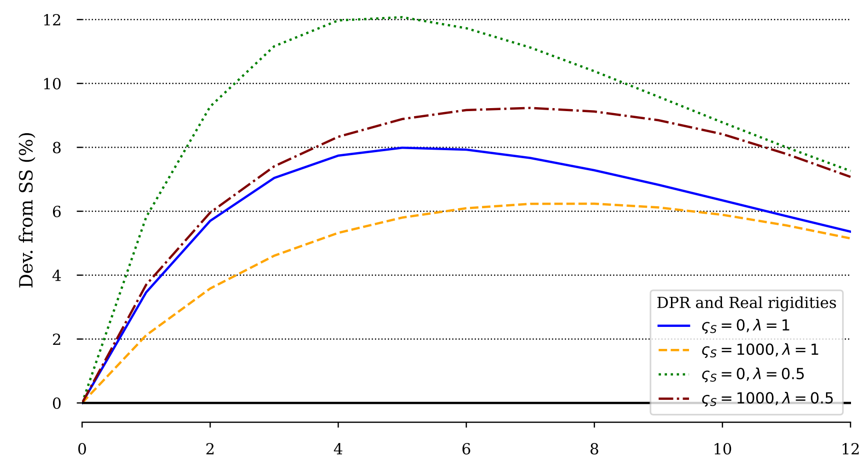
(a) Inflation, π_t



(b) GDP, Y_t



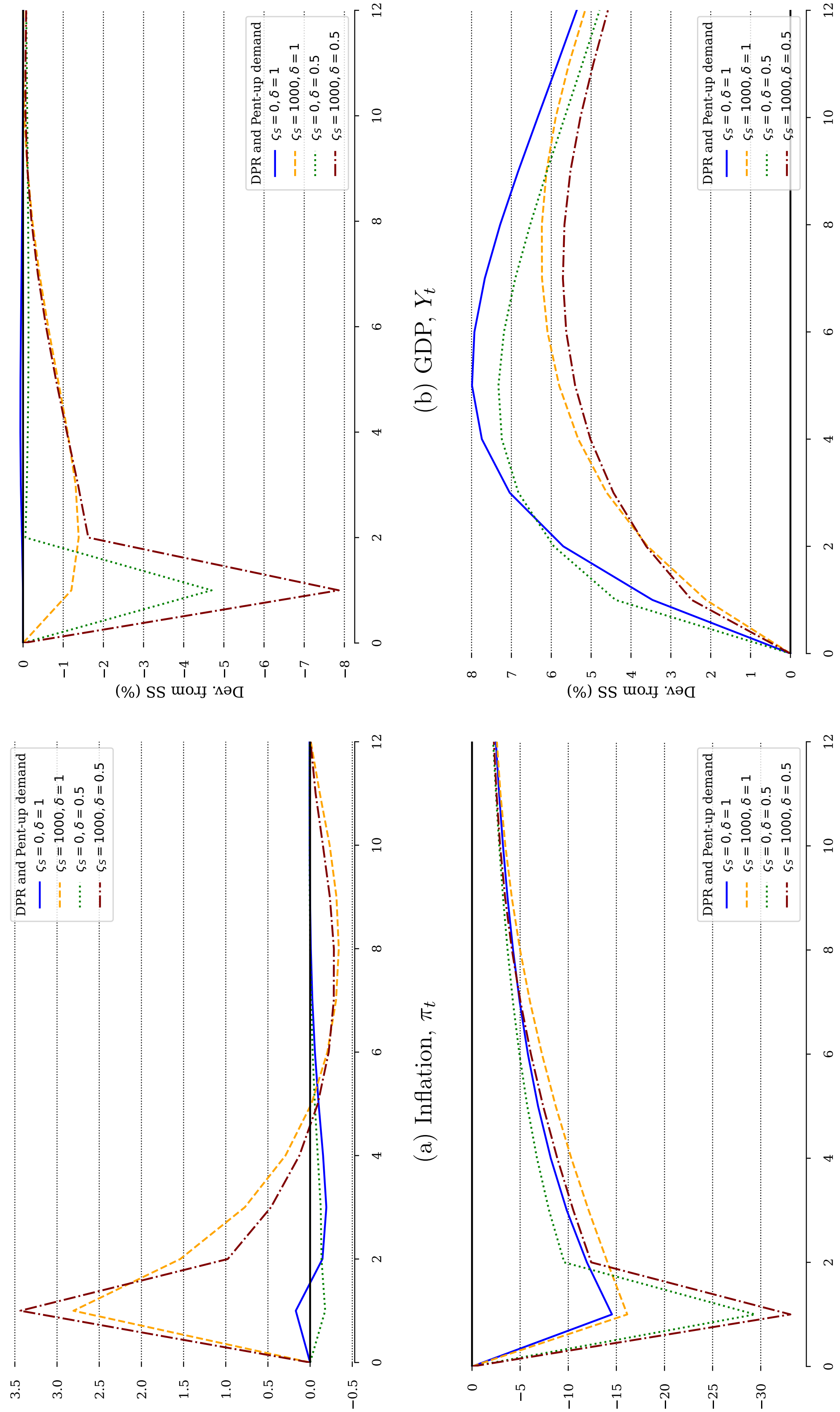
(c) Real wage, W_t/P_t



(d) Relative price of goods, P_t^G/P_t^S

Figure 9: Real rigidities (substitutability of labor supply) and inflationary impact of relative demand shocks.

Note: Time period is a quarter. Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 = 0.58$.



(a) Inflation, π_t

(b) GDP, Y_t

(c) Consumption of services, C_t^S

(d) Relative price of goods, P_t^G/P_t^S

Figure 10: Pent-up demand and inflationary relative demand shock.

Note: Time period is a quarter. Prices in services are downwardly rigid, i.e. $\varsigma_S = 1000$. Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 = 0.58$.

A Mathematical and data details

A.1 ONS CPI Price Quotes and Consumer Trends data

We use two types of data from the Office for National Statistics (U.K.) (ONS). The first is from the national accounts and consists of quarterly price and quantity indices for detailed personal consumption expenditure categories. These data are published as a bulletin on Consumer Trends. The underlying source data are mainly from the are the Living Costs and Food Survey (LCF) and the Retail Sales Index (RSI) that are used to construct quarterly GDP statistics for the United Kingdom.

The second source is data on shop-region-item-level price quotes underlying the British CPI, published as consumer price inflation item indices and price quotes by the ONS. Other studies that use these data Kryvtsov and Vincent (2014) and Dixon and Tian (2017) and Hobijn *et al.* (2021). The data are monthly price quotes for specific items in specific shops in a specific region. In principle, one can construct month-to-month changes in these prices. But the matching between price quotes across months is not unique because shops with multiple outlets in the same region can have multiple price quotes and matching them perfectly across months is not possible.

But there is a way to consider price changes for the same item in the same shop and region. For each price quote the data also provides the percent increase in the price since January of the year. Because we are not specifically interested in month-to-month changes in prices but in the medium adjustment of prices after the outbreak of the pandemic, we use this measure of price change. In particular, for all the items with price quotes in December we consider the percent change in their price since January of that year. This is what is plotted in the histograms of price changes.

A.2 Detailed derivation of model equations

The model is that of a closed economy populated by an infinite number of households and firms, and a central bank that conducts monetary policy. The production side of the economy consists of two sectors that produce either services or goods, which are consumed by the household. Households supply differentiated labor to both sectors and set their wage at a markup over the marginal rate of substitution. Producers of differentiated services and goods set their price at a markup over marginal costs. Households and firms incur a cost when adjusting their wages and prices, respectively. Wage and price cuts may be more costly than wage and price increases.

The central bank influences aggregate demand by setting the nominal interest rate.

A.2.1 Households

In each period, t, an infinitely-lived household, indexed by $i \in [0,1]$, chooses how much services, $S_{i,t}$, and goods, $G_{i,t}$, to consume, how many hours to work, $N_{i,t}$, and how many one-period nominal bonds to hold, $B_{i,t}$, in order to maximize its expected lifetime utility, which is given by:

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{C_{i,t+k}^{1-\sigma}}{1-\sigma} - \nu \frac{N_{i,t+k}^{1+\varphi}}{1+\varphi} \right), \tag{18}$$

with $\beta \in (0,1)$ the discount factor, $\sigma > 0$ the relative risk aversion coefficient and $\varphi > 0$ the inverse Frisch elasticity.

Total consumption, $C_{i,t}$, is a CES aggregator of services and goods:

$$C_{i,t} = \left[(1-\alpha_t)^{\frac{1}{\theta}} S_{i,t}^{\frac{\theta-1}{\theta}} + \alpha_t^{\frac{1}{\theta}} G_{i,t}^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \tag{19}$$

with $\theta > 1$ the elasticity of substitution between services and goods, and where $\alpha_t \in [0,1]$ measures the consumption share of goods, which may be time varying. $S_{i,t}$ and $G_{i,t}$ evolve according to:

$$S_{i,t} = (1-\delta_S) S_{i,t-1} + C_{i,t}^S, G_{i,t} = (1-\delta_G) G_{i,t-1} + C_{i,t}^G, \tag{20}$$

with $\delta_j \in [0,1]$ the rate at which the utility gain arising from past consumption depreciates, and where $C_{i,t}^j$ denotes the service flow of good $j = \{S, G\}$. The price indices of goods and services are denoted by P_t^G and P_t^S, respectively.

The household supplies differentiated labor to the services sector, $N_{i,t}^S$, and goods sector, $N_{i,t}^G$, with the optimal demand for labor variety i supplied to sector j given by

$$N_{i,t}^j = \left(\frac{W_{i,t}^j}{W_t^j} \right)^{-\eta} N_t^j, \tag{21}$$

where W_t^j denotes the nominal wage in sector j, N_t^j total labor supply in sector j, and $\eta > 0$ the elasticity of substitution across labor varieties within each sector. The household is able to set its wage in each sector, $W_{i,t}^j$, at a markup over the marginal rate of substitution, and incurs a cost, $\Gamma_{i,t}^{w,j}$, whenever it adjusts its wage. This wage adjustment cost is given by the following

Linex function:

$$\Gamma_{i,t}^{w,j} = \frac{\gamma_j^w}{\left(\varsigma_j^w\right)^2}\left\{\exp\left[-\varsigma_j^w\left(\frac{W_{i,t}^j}{W_{i,t-1}^j}-1\right)\right]+\varsigma_j^w\left(\frac{W_{i,t}^j}{W_{i,t-1}^j}-1\right)-1\right\}, \tag{22}$$

where $\gamma_j^w > 0$ is a scaling parameter that determines the degree of wage rigidity, and ς_j^w determines the degree of (a)symmetry of the wage adjustment cost. Total hours worked by household i is given by:

$$N_{i,t} = \left[\left(\chi^S\right)^{-\frac{1}{\lambda}}\left(N_{i,t}^S\right)^{\frac{1+\lambda}{\lambda}} + \left(1-\chi^S\right)^{-\frac{1}{\lambda}}\left(N_{i,t}^G\right)^{\frac{1+\lambda}{\lambda}}\right]^{\frac{\lambda}{\lambda+1}}, \tag{23}$$

where χ^S represents the preference for labor supply in sector S and $\lambda > 0$ the intratemporal elasticity of substitution of labor across sectors.

The household's period budget constraint, deflated by P_t^S, is given by:

$$S_{i,t}-(1-\delta_S)\,S_{i,t-1}+Q_t\,(G_{i,t}-(1-\delta_G)\,G_{i,t-1})+\frac{B_{i,t}}{P_{S,t}} = \sum_{j=\{S,G\}}\left(1-\Gamma_{i,t}^{w,j}\right)\frac{W_{i,t}^j}{P_t^S}N_{i,t}^j+R_{t-1}\frac{B_{i,t-1}}{P_t^S}+\frac{\Omega_t}{P_t^S}, \tag{24}$$

where R_t denotes the risk-free gross nominal return on bonds and Ω_t profits received from the firms which the households own. Perfect risk sharing ensures that consumption levels are the same across households. We can therefore ignore the i subscript. The household aims to maximize (18), subject to (19)-(24), taking as given aggregate prices, P_t^j, aggregate wages, W_t^j, the gross nominal interest rate, R_t, the depreciation rate, δ_j, initial bond holdings, B_{t-1}, and initial nominal wages, W_{t-1}^j.

The first-order conditions with respect to the consumption of services and goods are given by:

$$\Lambda_t = C_t^{\frac{1}{\theta}-\sigma}\left(1-\alpha_t\right)^{\frac{1}{\theta}}S_t^{-\frac{1}{\theta}}+\beta E_t\left[\Lambda_{t+1}\left(1-\delta_S\right)\right], \tag{25}$$

$$\Lambda_t Q_t = C_t^{\frac{1}{\theta}-\sigma}\alpha_t^{\frac{1}{\theta}}G_t^{-\frac{1}{\theta}}+\beta E_t\left[\Lambda_{t+1}Q_{t+1}\left(1-\delta_G\right)\right], \tag{26}$$

where Λ_t is the Lagrange multiplier on (24), and Q_t is the sectoral relative price, defined as

$$Q_t \equiv \frac{P_t^G}{P_t^S}. \tag{27}$$

Let $w_t^j \equiv W_t^j/P_t^S$ denote the real wage in sector j and $\Pi_t^{w,j} \equiv W_t^j/W_{t-1}^j$ the gross nominal wage growth in sector j. The first-order condition with respect to the nominal wage is then given by

$$0 = (1-\eta) - \frac{\eta}{w_t^j}\frac{U_{N^j,t}}{\Lambda_t} - \Pi_t^{w,j}\Theta_t^{w,j} - (1-\eta)\,\Gamma_t^{w,j} + \beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\Pi_{t+1}^{w,j}\Theta_{t+1}^{w,j}\frac{w_{t+1}^j}{w_t^j}\frac{N_{t+1}^j}{N_t^j}\right], \tag{28}$$

where

$$\Theta_{i,t}^{w,j} = \frac{\gamma_j^w}{\varsigma_j^w}\left\{1 - \exp\left[-\varsigma_j^w\left(\frac{W_{i,t}^j}{W_{i,t-1}^j} - 1\right)\right]\right\}, \tag{29}$$

$$U_{N^j,t} = -\nu\left(\frac{N_t^j}{\chi^j N_t^{\varphi}}\right)^{\frac{1}{\lambda}}. \tag{30}$$

Finally, the first-order condition with respect to nominal bond holdings is given by:

$$\Lambda_t = \beta E_t\left[\Lambda_{t+1}\frac{P_t^S}{P_{t+1}^S}R_t\right]. \tag{31}$$

We obtain the consumer price index, CPI, by rewriting the expenditure constraint, $P_tC_t = P_t^S S_t + P_t^G G_t$, using the marginal utilities with respect to S_t and G_t:

$$P_t^{CPI} = \Psi_t^{-1}\left[P_t^S U_{S,t}^{-\theta}(1-\alpha_t) + P_t^G U_{G,t}^{-\theta}\alpha_t\right], \tag{32}$$

with $\Psi_t \equiv \left[(1-\alpha_t)\,U_{S,t}^{1-\theta} + \alpha_t U_{G,t}^{1-\theta}\right]^{\frac{\theta}{\theta-1}}$. In the main text, we focus on the fixed-weighted CPI:

$$\overline{P}_t^{CPI} = \overline{\Psi}_t^{-1}\left[P_t^S U_{S,t}^{-\theta}(1-\alpha) + P_t^G U_{G,t}^{-\theta}\alpha\right], \tag{33}$$

with $\overline{\Psi}_t \equiv \left[(1-\alpha)\,U_{S,t}^{1-\theta} + \alpha U_{G,t}^{1-\theta}\right]^{\frac{\theta}{\theta-1}}$.

A.2.2 Firms

In each sector $j = \{S, G\}$, a monopolistically competitive firm, indexed by $\omega \in [0,1]$, faces the following optimal demand for its output, $Y_{\omega,t}^j$:

$$Y_{\omega,t}^j = \left(\frac{P_{\omega,t}^j}{P_t^j}\right)^{-\epsilon} Y_t^j, \tag{34}$$

where $\epsilon > 0$ governs the elasticity of substitution between varieties within sector j, $P_{\omega,t}^j$ denotes the price set by firm ω and Y_t^j is aggregate sectoral output. The firm uses one type of input, labor, $N^j_{\omega,t}$, to produce its output:

$$Y^j_{\omega,t} = N^j_{\omega,t}. \tag{35}$$

It is able to set its price at a markup over marginal costs, and incurs a cost, $\Gamma^j_{\omega,t}$, whenever it adjusts its price. This price adjustment cost is given by the following Linex function:

$$\Gamma^j_{\omega,t} = \frac{\gamma_j}{\varsigma_j^2}\left\{\exp\left[-\varsigma_j\left(\frac{P^j_{\omega,t}}{P^j_{\omega,t-1}}-1\right)\right]+\varsigma_j\left(\frac{P^j_{\omega,t}}{P^j_{\omega,t-1}}-1\right)-1\right\}, \tag{36}$$

where $\gamma_j > 0$ a scaling parameter that determines the degree of price rigidity, and ς_j determines the degree of (a)symmetry of the price adjustment cost.

The firm aims to maximize the expected discounted sum of current and future profits:

$$E_t\sum_{k=0}^{\infty}\beta^k\frac{\Lambda_{t+k}}{\Lambda_t}\left[\left(1-\Gamma^j_{\omega,t+k}\right)\frac{P^j_{\omega,t+k}}{P^j_{t+k}}Y^j_{\omega,t+k}-\frac{W^j_{t+k}}{P^j_{t+k}}N^j_{\omega,t+k}\right],$$

subject to (34)-(36), and taking as given aggregate prices, P^j_t, aggregate wages, W^j_t, and initial prices, $P^j_{\omega,t-1}$. Let $\Pi^j_t \equiv P^j_t/P^j_{t-1}$ denote the gross inflation rate in sector j. The first-order conditions with respect to $P^j_{\omega,t}$ for each sector j are then given by

$$(1-\epsilon_S)+\epsilon_S w^S_t = \Pi^S_t\Theta^S_t+(1-\epsilon_S)\Gamma^S_t-\beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\Pi^S_{t+1}\Theta^S_{t+1}\frac{Y^S_{t+1}}{Y^S_t}\right], \tag{37}$$

$$(1-\epsilon_G)+\epsilon_G\frac{w^G_t}{Q_t} = \Pi^G_t\Theta^G_t+(1-\epsilon_G)\Gamma^G_t-\beta E_t\left[\frac{\Lambda_{t+1}}{\Lambda_t}\Pi^G_{t+1}\Theta^G_{t+1}\frac{Y^G_{t+1}}{Y^G_t}\frac{Q_{t+1}}{Q_t}\right], \tag{38}$$

where

$$\Theta^j_t \equiv \frac{\gamma_j}{\varsigma_j}\left\{1-\exp\left[-\varsigma_j\left(\Pi^j_t-1\right)\right]\right\}. \tag{39}$$

A.2.3 Monetary policy

Monetary policy is conducted by the central bank and characterized by the following Taylor-type rule:

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{\rho_R}\left(\frac{\overline{\Pi}^{CPI}_t}{\overline{\Pi}^{CPI}}\right)^{\phi_\pi(1-\rho_R)}, \tag{40}$$

where $\rho_R \in [0,1]$ measures the degree of interest rate smoothing by the central bank, $\phi_\pi > 1$ the monetary policy response to inflation, and where $\overline{\Pi}^{CPI}_t$ denotes the gross growth rate of the fixed-weighted CPI:

$$\overline{\Pi}_t^{CPI} \equiv \frac{\overline{P}_t^{CPI}}{\overline{P}_{t-1}^{CPI}}. \tag{41}$$

A.2.4 Market clearing

Goods market clearing in each sector $j = \{S, G\}$ implies the following:

$$Y_t^j = C_t^j + \Gamma_t^j Y_t^j + \Gamma_t^{w,j} w_t^j N_t^j, \tag{42}$$

while total output is given by

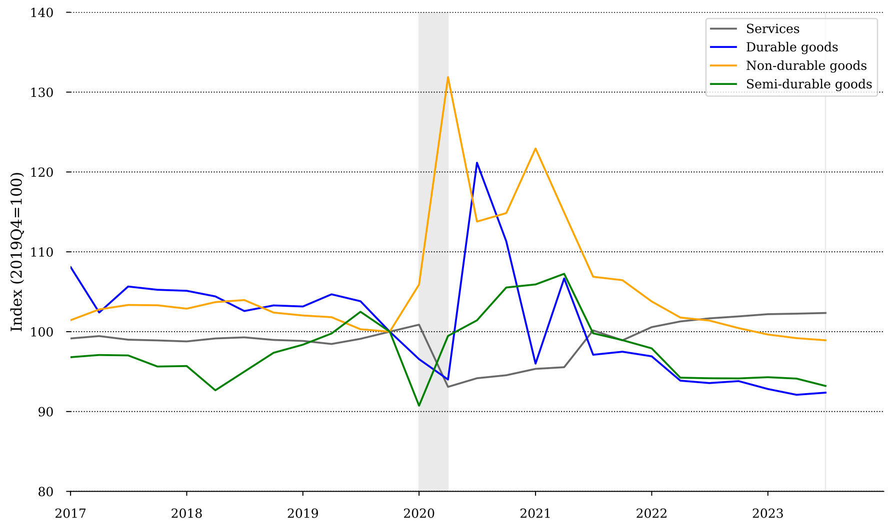
$$Y_t = Y_t^S + Q_t Y_t^G. \tag{43}$$

We refer to real fixed-weighted Gross Domestic Product, GDP_t, as total spending on final services and goods, after controlling for wage and price adjustment costs and using the steady-state expenditure share of goods and services as weights:

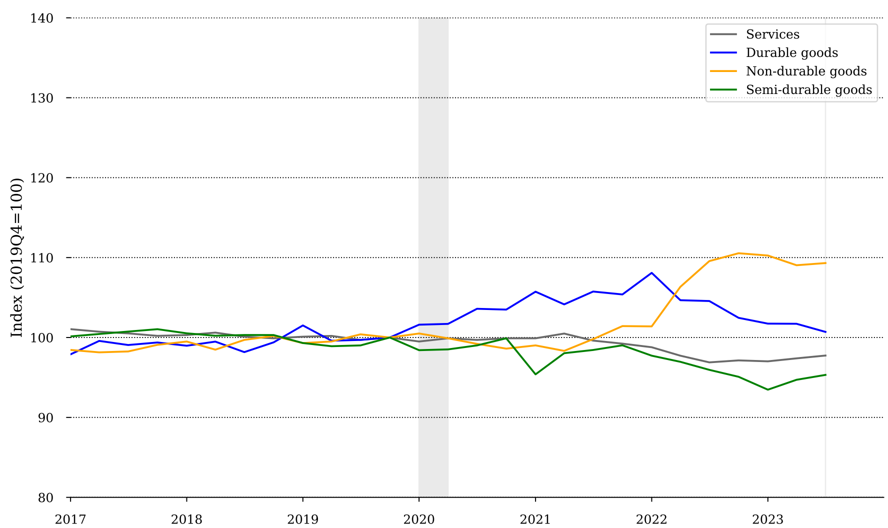
$$GDP_t = (1-\alpha) C_t^S + \alpha C_t^G. \tag{44}$$

B Additional results

B.1 Additional empirical evidence



(a) Relative quantities



(b) 2021

Figure B.1: Relative quantities and prices for major consumption categories, 2017-2023

Source: ONS Consumer Trends (National Accounts) and authors' calculations. Quantites relative to total consumer spending. Relative prices compared price of total consumer spending. Index (2019Q4=100)

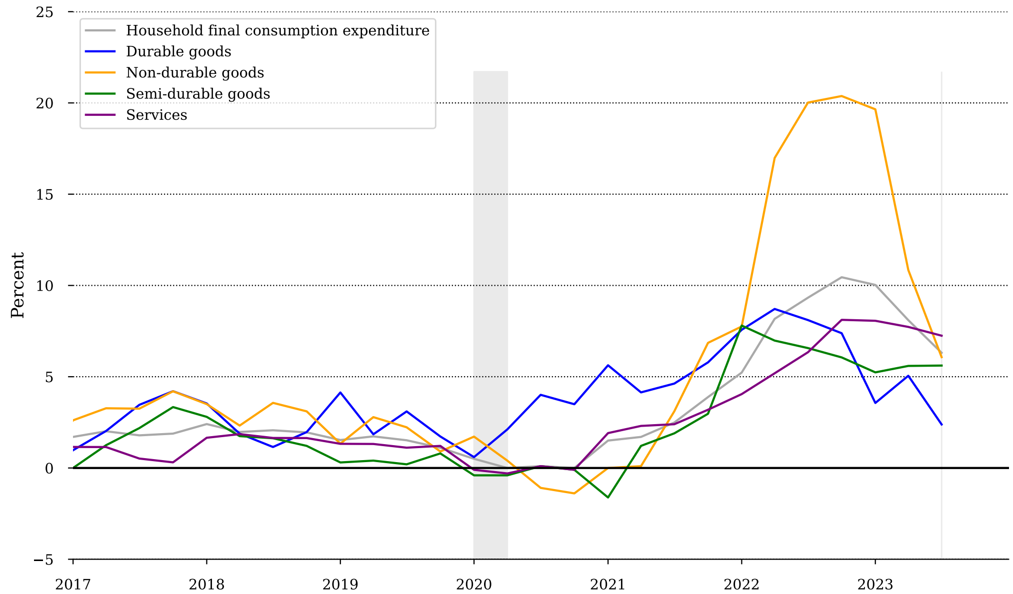


Figure B.2: 4-quarter inflation rate by major categories.

Source: ONS Consumer Trends (National Accounts) and authors' calculations.

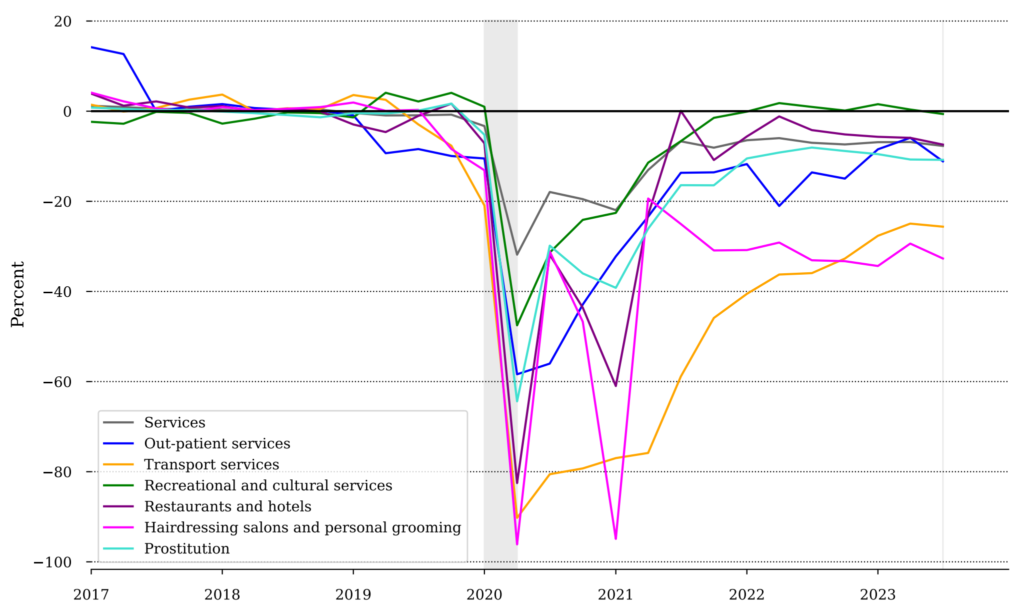
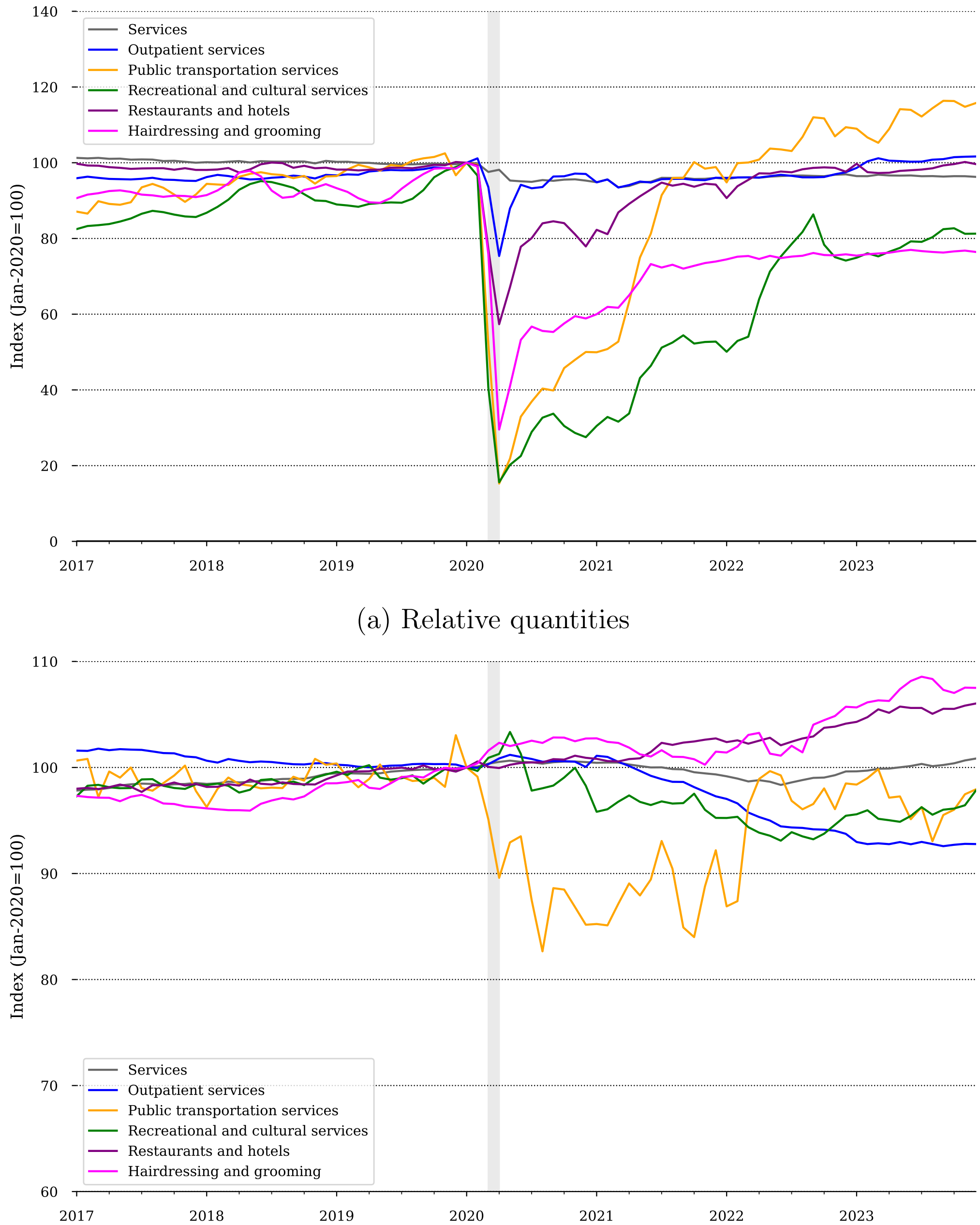


Figure B.3: Percentage deviations of real consumption by categories from pre-Covid trend.

Source: ONS Consumer Trends (National Accounts) and authors' calculations. Percent deviations from estimated pre-Covid log trend, estimated over 2014-2019



(a) Relative quantities

(b) Relative prices

Figure B.4: Relative quantities and prices for total and person-to-person services in U.S.

Source: Bureau of Economic Analysis and authors' calculations. Quantites relative to total consumer spending. Relative prices compared price of total consumer spending. Index (Jan-2020=100). Person-to-person services are 'Out-patient health services', 'Public transportation services', 'Recreational and cultural services', 'Restaurants and hotels', and 'Hairdressing salons and personal grooming'.

B.2 Additional results from model

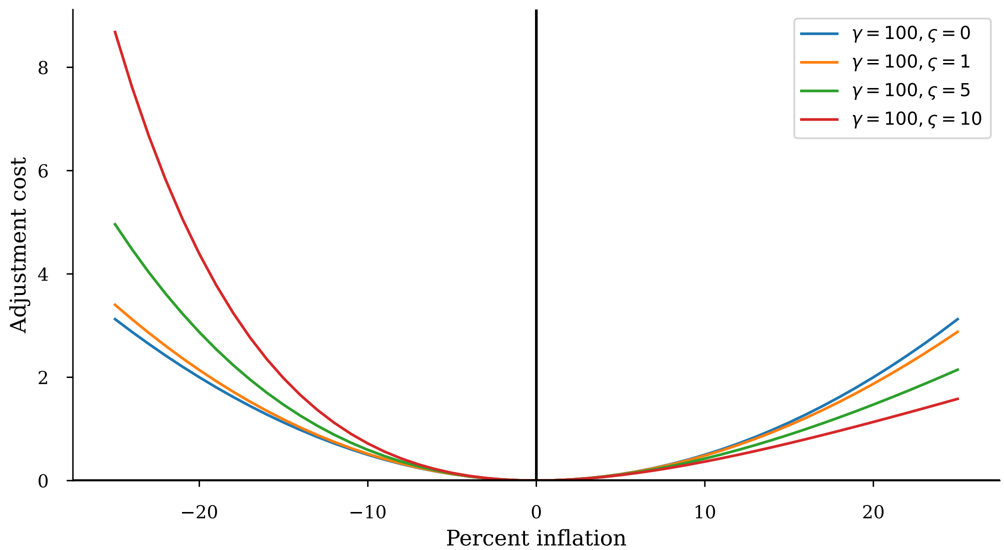
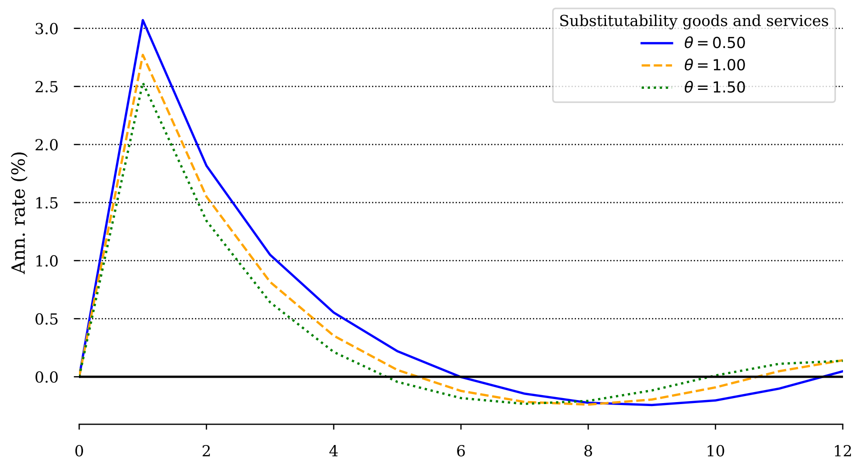
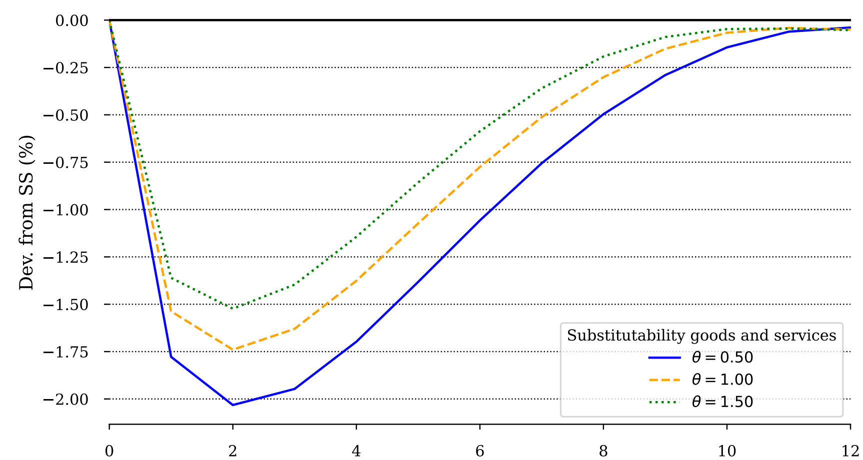


Figure B.5: Linex cost function for different parameter values.

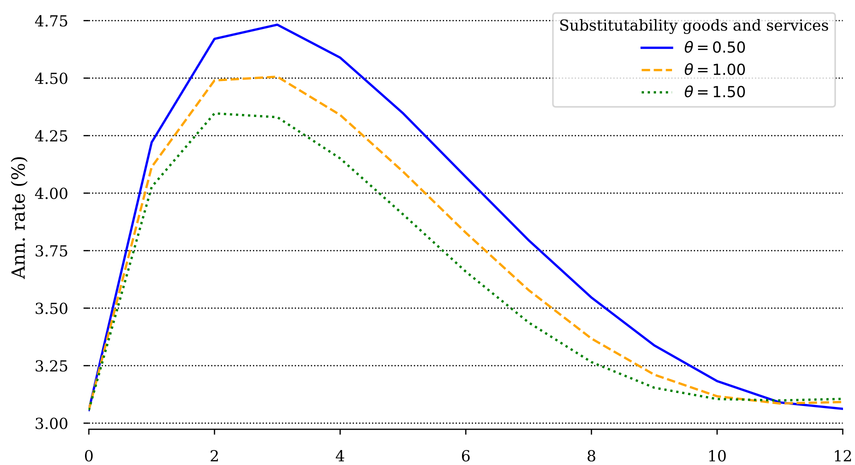
Source: Authors' calculations based on Linex cost function specification from Kim and Ruge-Murcia (2009)



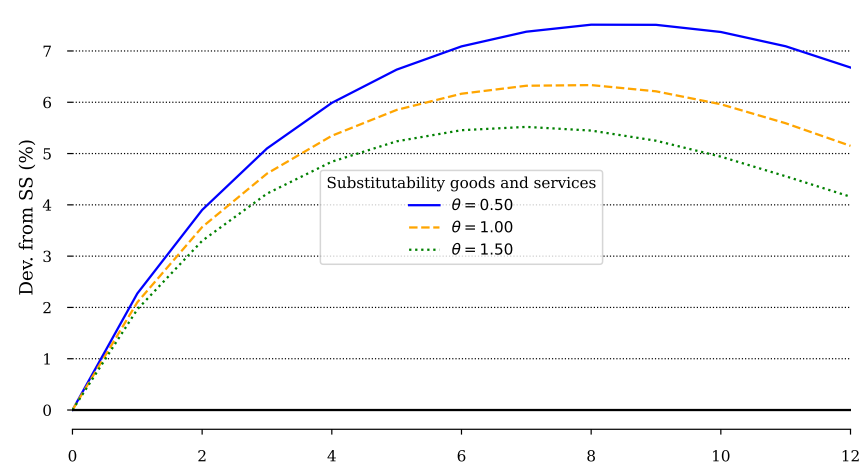
(a) Inflation, π_t



(b) GDP, Y_t



(c) Policy rate, R_t



(d) Relative price of goods, P_t^G/P_t^S

Figure B.6: Real rigidities (substitutability of labor supply) and inflationary impact of relative demand shocks.

Note: Time period is a quarter. Prices in services are downwardly rigid, i.e. $\varsigma_S = 1000$. Shock is $(\alpha_t - 0.5) = 0.9\,(\alpha_{t-1} - 0.5)$, where $\alpha_1 = 0.58$.

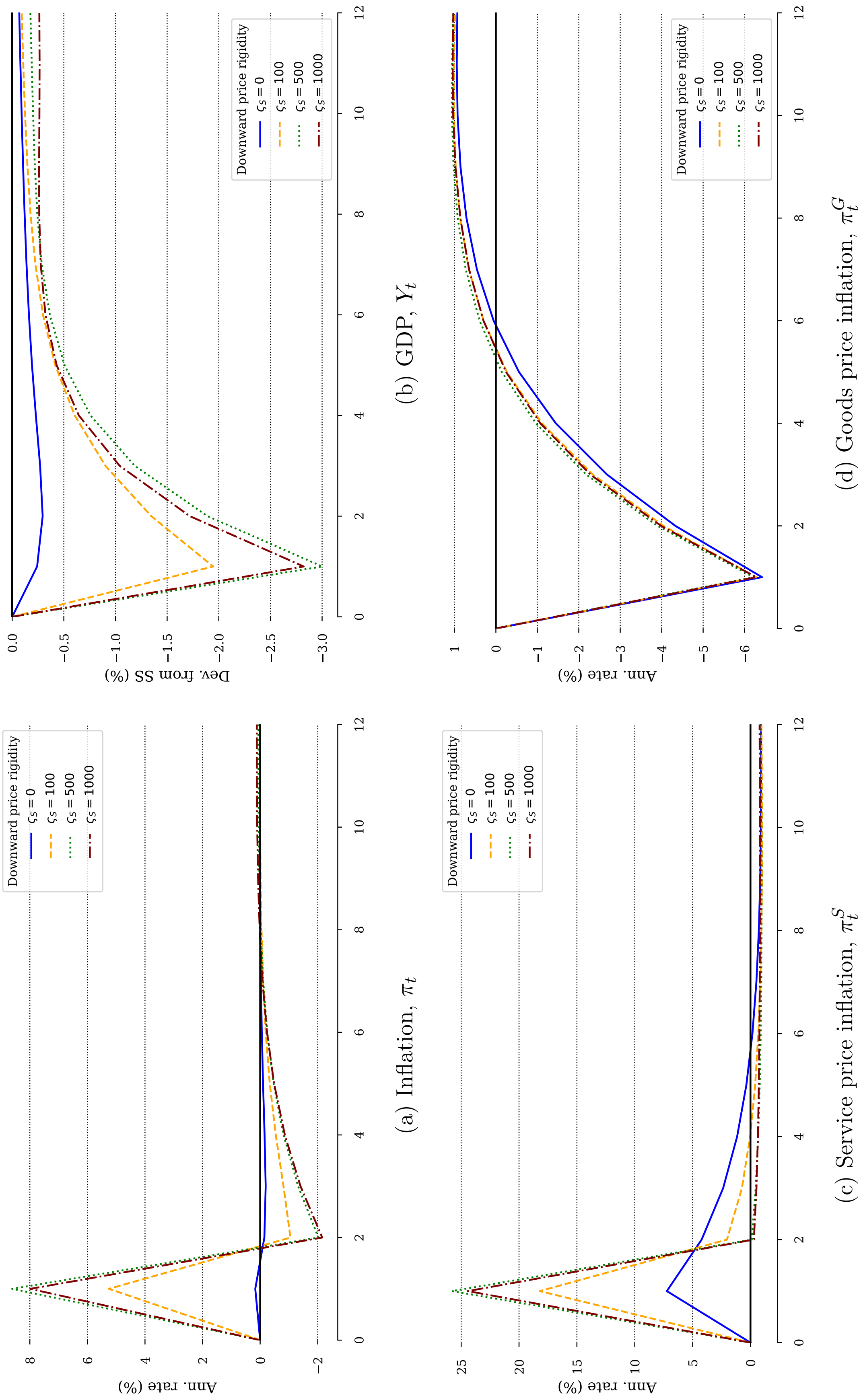


Figure B.7: Impact of degree of DPR in services, ς_S, in case of positive relative demand shock for services.

Note: Time period is a quarter. Shock is $(\alpha_t - 0.5) = 0.9(\alpha_{t-1} - 0.5)$, where $\alpha_1 = -0.42$.