Services Deepening and the Transmission of Monetary Policy*

Alessandro Galesi
Banco de España

Omar Rachedi
Banco de España

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Abstract

The structural transformation from manufacturing to services comes with a process of services deepening: the services share of intermediate inputs rises over time. Moreover, inflation reacts less to monetary policy shocks in countries which are more intensive in services intermediates. We rationalize these facts using a two-sector New Keynesian model where trends in sectoral productivities generate endogenous variations in the Input-Output matrix. Services deepening reduces the contemporaneous response of inflation to monetary policy shocks through a marginal cost channel. Since services prices are stickier than manufacturing prices, the rise of services intermediates raises the sluggishness of sectoral marginal costs and inflation rates.

Key Words: New Keynesian Model, Input-Output Matrix, Structural Change.
JEL Classification Codes: E31, E43, E52, O41.

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1 Introduction

Over time advanced economies undergo a process of structural transformation that shifts the economic activity from manufacturing to services. This phenomenon raises the services share of value added, consumption, and employment (Kongsamut et al., 2001; Duarte and Restuccia, 2010; Herrendorf et al., 2013). We document that structural transformation comes with a process of *services deepening*: both services and manufacturing are becoming more intensive in services intermediate inputs. For instance, in the U.S. in 1947 services intermediate inputs accounted for 62% of the total inputs used by the services sector, and 20% of the inputs used in manufacturing. In 2010 these shares peaked up to 83% and 35%, respectively.

Although the services deepening moves slowly over time, it generates important implications at the business cycle frequency. Indeed, the rise of services intermediates alters the transmission of monetary policy. We establish this fact by estimating a SVAR model for a set of advanced economies. We identify monetary policy shocks with sign restrictions, and find that both aggregate inflation and manufacturing inflation react less to monetary policy shocks in countries which are more intensive in services intermediate inputs.

To explore the implications of services deepening for the transmission of monetary policy, we build a New Keynesian model with two inter-connected sectors. We account for the process of services deepening by considering an Input-Output matrix that changes endogenously over time. This variation is driven by exogenous trends in sectoral productivities. We feed the model with the estimated series

of sectoral productivities and calibrate it to match the sectoral reallocation experienced by the U.S. economy from 1947 to 2005. Then, we compare the dynamics of the model following a 100 basis point drop in the nominal interest rate around the 1947 and 2005 steady-states. The two equilibria differ only in the levels of sectoral productivities. Throughout our exercise, we keep fixed all the other parameters, including those of the Taylor rule. In this way, we can ask to what extent the services deepening alone can alter the transmission of monetary policy shocks. The model predicts that moving from the 1947 steady-state to the 2005 steady-state reduces the response of inflation from 1.02% to 0.72%. The dampening in the reaction of inflation raises the real effects of monetary policy, as the response of aggregate output increases by 16 basis points. Importantly, also in the data the response of output to a monetary policy shock rises with the services share of intermediate inputs. This prediction of the model on the link between services deepening and the dynamics of output gives further support to our mechanism.

Although services deepening dampens the contemporaneous response of inflation to monetary policy shocks, it raises its persistence. Hence, the sectoral reallocation of intermediate inputs modifies entirely the dynamic response of inflation to monetary policy shocks, by raising the time-lag through which monetary policy shocks spill over to inflation. These changes alter substantially the dynamic properties of inflation between 1947 and 2005. The model predicts that services deepening reduces the standard deviation of aggregate inflation from 0.3 to 0.2 and raises its auto-correlation from 0.3 up to 0.6.

by 20%, and raises its auto-correlation by 55% (e.g., in 2005 the standard deviation of inflation drops to 0.22 whereas its autocorrelation raises up to 0.60).

Why does services deepening dampen the contemporaneous response of inflation to monetary policy shocks, while raising its persistence? The sectoral reallocation of intermediate inputs alters the dynamics of aggregate inflation through a *marginal cost channel*: since services prices are much stickier than manufacturing prices, the rise of services intermediates increases the sluggishness of marginal costs.[1] As firms in each sector purchase more and more services intermediate inputs, sectoral marginal costs become stickier. Indeed, moving from the 1947 steady-state to the 2005 steady-state the responses of the marginal costs in manufacturing and services decrease from 2.11% to 1.89% and from 2.98% to 2.78%, respectively. These changes in sectoral marginal costs alter the dynamics of sectoral prices, which also become stickier. As a result, sectoral inflation becomes less response to monetary policy shocks on impact, and more persistent later on.

In the model trends in sectoral productivities drive not only the process of services deepening, but also the structural transformation, intended as the sectoral reallocation of value added from manufacturing to services. Even structural transformation curbs the sensitivity of aggregate inflation to monetary policy shocks, although it does so

[1] There is ample evidence showing that services prices are much stickier than manufacturing prices, e.g. Bils and Klenow (2004), Klenow and Kryvtsov (2008), and Nakamura and Steinsson (2008). The average duration of manufacturing prices is around 3 months, whereas the average duration of services prices ranges between 8 months and 13 months. Section 2.3 reviews the empirical evidence on price stickiness across sectors.

through a *composition channel* that tilts the production towards services: aggregate inflation becomes stickier and less responsive to monetary policy shocks although neither sectoral marginal costs nor sectoral inflation rates change their dynamics. This composition channel is consistent with the findings of the literature on multi-sector New Keynesian models, which shows that the heterogeneity in the sectoral composition of value added is crucial to understand the properties of *aggregate* inflation (Carvalho, 2006; Bouakez et al., 2009, 2011, 2014; Nakamura and Steinsson, 2010; Imbs et al., 2011).[2] Pasten et al. (2016) extend these results and derive the sectoral dynamics as a function of the inter-sectoral linkages. Our contribution to this strand of the literature is twofold: first, we document the time-variation in the Input-Output matrix of advanced economies; second, we explicitly emphasize that the heterogeneity in the sectoral composition of intermediate inputs is crucial to understand not only the dynamics of aggregate inflation, but also the dynamics of *sectoral* inflation rates.

Our theoretical framework is a standard Calvo staggered price New Keynesian model with two sectors - services and manufacturing - which are connected by an Input-Output matrix: each sector produces output by using labor and a bundle of services and manufacturing intermediate inputs. Importantly, the two sectors differ in the degree of price stickiness to be consistent with the fact that in the data services prices are stickier than manufacturing prices.

[2]The importance of the Input-Output matrix as an amplification mechanism of macroeconomic shocks is pioneered by Long and Plosser (1983), Basu (1995), Foerster et al. (2011), and Acemoglu et al. (2012).

To account for the process of services deepening, we consider a CES aggregator of services and manufacturing inputs. In the empirically relevant case in which services intermediate inputs and manufacturing intermediate inputs are complementary, an increase in the productivity of manufacturing - relative to the productivity of services - raises firms' expenditure in services intermediate inputs. This mechanism is the firm-analogue of the Baumol (1967) cost disease channel that Ngai and Pissarides (2007) use to generate endogenous variations in the sectoral shares of consumption and value added. As the complementarity between services and manufacturing consumption is crucial for the results of Ngai and Pissarides (2007), the changes in the Input-Output matrix towards services intermediates hinge on the complementarity between services and manufacturing intermediate inputs.

Our paper adds to the literature that studies how the transmission of monetary policy has changed over the recent decades (e.g., Cogley and Sargent, 2001, 2005; Primiceri, 2005; Boivin and Giannoni, 2006; Pancrazi and Vukotic, 2016). We complement this strand of the literature by providing a novel channel that can generate low-frequency movements in the effectiveness of monetary policy. Since in our model both the Taylor rule and the volatility of shocks are constant over time, the variation in the transmission of monetary policy is entirely due to the process of sectoral reallocation.

This paper contributes to the literature on the interaction of nominal and real rigidities as a source of fluctuations (e.g., Ball and Romer, 1990; Kimball, 1995). Carvalho (2006) and Petrella et al. (2018)

discuss the role of inter-sectoral linkages as an important amplifier of nominal rigidities. We add to these papers by highlighting that real rigidities could become more important over time as the Input-Output matrix shifts towards the sector with the highest degree of price stickiness.

This paper relates to the structural change literature, which shows that advanced economies are experiencing a rise of the services share of GDP, employment, and consumption expenditures (e.g., Kongsamut et al., 2001; Duarte and Restuccia, 2010; Herrendorf et al., 2013). We complement this evidence by documenting that structural change comes together with a process of services deepening. This process reminds of the capital deepening emphasized by Acemoglu and Guerrieri (2008). Although capital deepening describes an increase in capital per capita, services deepening highlights the increase in the utilization of services inputs. As Moro (2012, 2015) and Carvalho and Gabaix (2013) discuss how the changes in the sectoral composition of value added affect business cycle fluctuations, we highlight how the changes in the sectoral composition of the Input-Output matrix alter the propagation of monetary policy shocks.

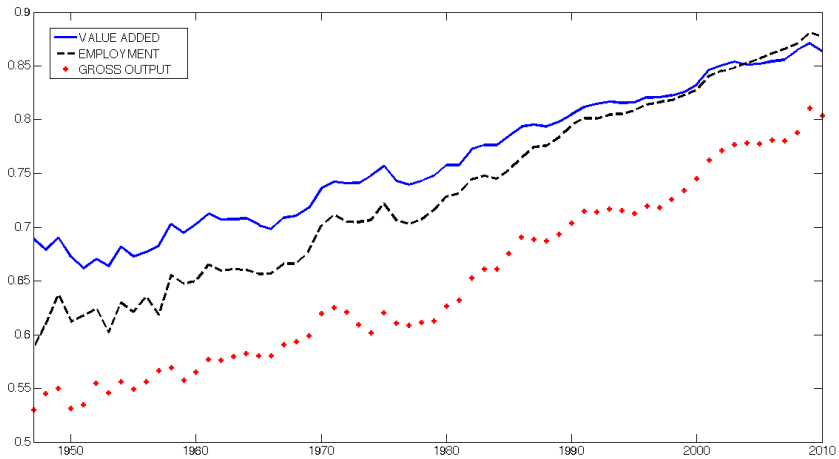
2 Empirical Evidence

2.1 The Process of Services Deepening

The structural transformation literature, such as Kongsamut et al. (2001), Duarte and Restuccia (2010), Buera and Kaboski (2012), and Herrendorf et al. (2013) among others, emphasizes that economies

reallocate resources from manufacturing to services as they develop. This literature mainly focuses on the dynamics of value added, employment, and gross output. Figure 1 plots these shares computed for the U.S. economy from 1947 to 2010. Each share has been trending up since the late 1940's. The services value added share rises from a value of 69% in 1947 to 86% in 2010. The services shares of employment and gross output display a similar behavior, increasing from 59% and 53% in 1947, up to 88% and 80% in 2010.

Figure 1: U.S. Services Value Added, Employment, and Gross Output Shares.



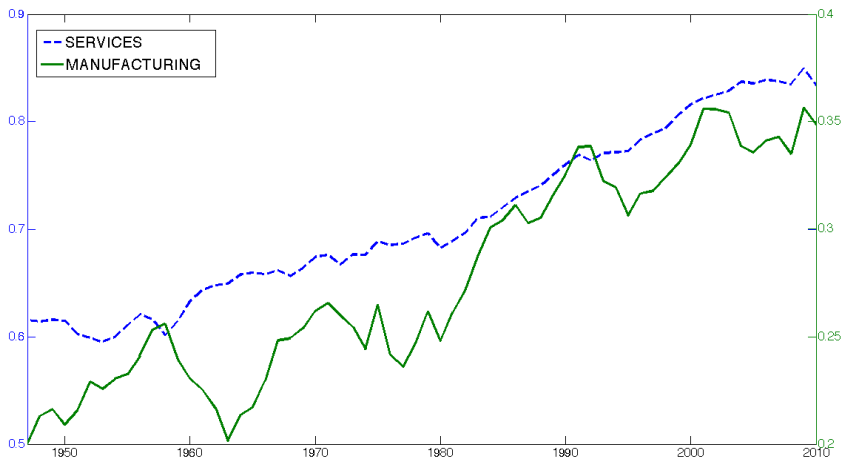
The figure shows the share of services in value added (continuous line), employment (dashed line), and gross output (dotted line) for the U.S. economy from 1947 to 2010. Data come from the Jorgenson (2007) dataset.

We document a novel dimension of the sectoral reallocation towards services. We show that over time both services and manufacturing are becoming more intensive in services inputs. We refer to this new stylized fact as *services deepening*.

Figure 2 shows the dynamics of the share of services inputs in

services and manufacturing for the U.S. economy over the last six decades. Both shares increase over time. The share of services inputs in services rises up to 83% in 2010 from a value of 62% in 1947. Similarly, the share of services inputs in manufacturing rises up to 35% in 2010 from a value of 20% in 1947.

Figure 2: U.S. Services Intermediate Inputs in Services and Manufacturing.



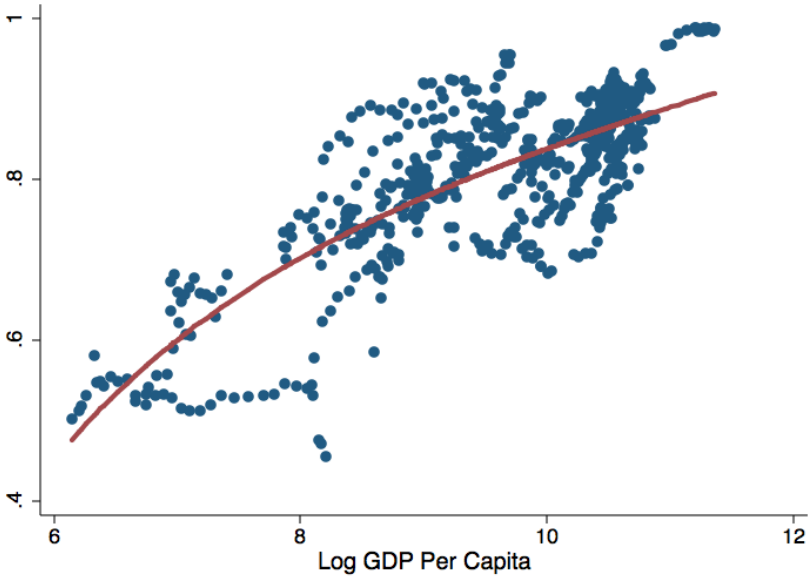
The figure shows the share of services intermediate inputs in the services sector (dashed line - left y-axis) and the share of services intermediate inputs in the manufacturing sector (continuous line - right y-axis) for the U.S. economy from 1947 to 2010. Data come from the Jorgenson (2007) dataset.

These dynamics are not unique to the U.S. economy. Using data from the World Input-Output Database, which covers a panel of 38 countries over the years 1995 - 2011, we document that many world economies feature a services deepening as they develop.[3] Figure 3

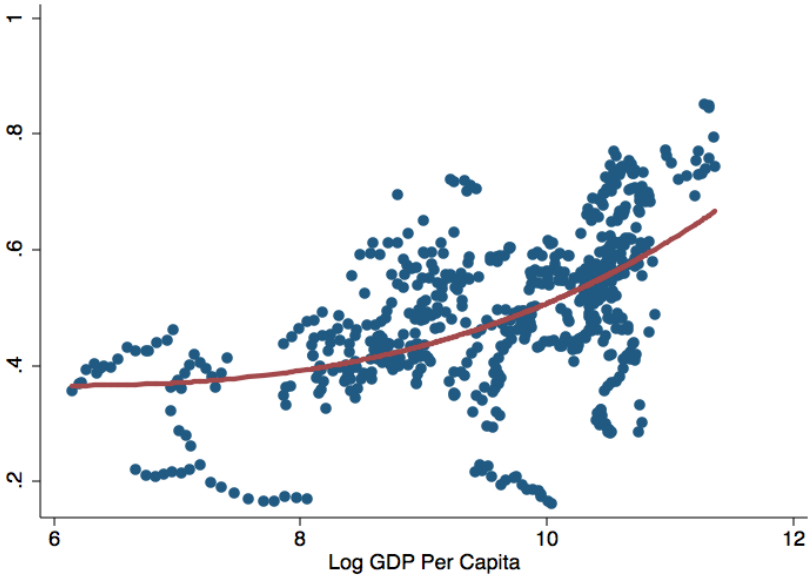
[3]The countries are Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Luxembourg, Malta, Mexico, Netherlands, Poland, Portugal, Romania, Russia, Slovenia, Slovakia, Spain, Sweden, Turkey, United Kingdom, and

Figure 3: Services Intermediate Inputs Across Countries.

(a) Services Industries



(b) Manufacturing Industries



Note: Panel (a) plots country-year shares of services inputs in services as a function of the logarithm of real GDP per capita. Panel (b) plots country-year shares of services inputs in manufacturing as a function of the logarithm of real GDP per capita. The red line indicates the fitted quadratic polynomial regression line. Data come from the World Input-Output database and cover 38 countries from 1995 to 2011.

shows the relationship between the share of services inputs in either services or manufacturing and the logarithm of real GDP per capita across countries. In both graphs, we plot each country-year observation, together with the fitted polynomial regression line. The graphs show that countries with higher GDP per-capita feature also higher shares of services intermediate inputs.[4]

The pattern of Figure 3 could be driven by a fixed cross-country heterogeneity in the sectoral composition of intermediate inputs if countries had a fixed services share of intermediate inputs during their growth path. In the Appendix we estimate the global dimension of services deepening following the approach of Karabarbounis and Neiman (2014). We consider a panel in which the services share of the intermediate inputs used either in services or manufacturing is regressed on time and country fixed effects. The estimated coefficients associated to the time fixed effects inform on the global components of services deepening, and show that there has been indeed a global increase in the services share of intermediate inputs.

In addition, in the Appendix we report the changes in both the services share of intermediate inputs used by services firms and the services share of intermediate inputs used by manufacturing firms *by country* over the period 1995-2011. We find that 35 out of 38 countries have experienced a services deepening in the services sector whereas 34 out of 38 countries have experienced a services deepening in the

United States.

[4]In the Appendix we use the cross-country data to run panel regressions to show that the share of services inputs increases with GDP per capita, even after controlling for other key characteristics such as financial development, trade openness, and human capital.

manufacturing sector.

The results of this Section should be interpreted with a caveat. We have computed the share of services in intermediate inputs and value added using the sectoral classification of the World KLEMS Initiative and the World Input-Output database. Yet, this classification does not explicitly take into account the fact that the distinction between manufacturing and services is becoming blurry over time. For instance, Crozet and Milet (2017) and Fontagne and Harrison (2017) highlight that manufacturing firms are experiencing a process of servitization, such that they offer services as complements of the goods they produce. In this case, our empirical analysis should be interpreted as a lower bound of the quantitative relevance of the services deepening, as we underestimate the rise of services. Nevertheless, we conjecture that this bias may not be very large, as the process of servitization is partially offset by the emergence of factoryless goods producing firms. Indeed, Bernard and Fort (2015) argue that some firms of the wholesale trade sector are nowadays designing and coordinating the production activities of manufacturing goods. Hence, although these firms belong to the services sector, they are actually implementing tasks typical of manufacturing firms.

2.2 Services Deepening and Monetary Policy Shocks

In this Section we document that the transmission of monetary policy changes with the sectoral composition of intermediate inputs. To identify this link, we exploit the cross-sectional variation of sectoral shares across a set of advanced economies.

We build a panel of quarterly output, inflation rates, and interest rates across twenty-five countries.[5] For each country we run a structural VAR on a vector of stationary variables $\left[\Delta \log Y_t,\ \Delta \log P_t,\ R_t\right]$, where Y_t denotes real GDP, P_t denotes the Consumer Price Index, and R_t is the nominal short-term interest rate. We estimate the model with four lags, and we identify monetary policy shocks using a sign restriction on impulse-responses. Specifically, we posit that a monetary policy shock raises the nominal interest rate while reducing both real output growth and the inflation rate. The sign restriction is imposed not only on impact but also in the following quarter.[6] Although we impose that both inflation and output raise following an expansionary monetary policy shock, we are completely agnostic about how the responses of inflation and output vary across countries with different sectoral composition of intermediate inputs. Consequently, the way through which the sectoral composition of intermediate inputs alters the transmission of monetary policy is left completely unrestricted.

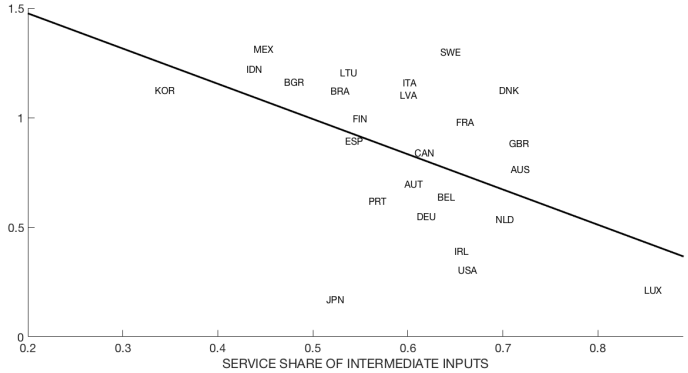
Panel (a) of Figure 4 reports the relationship across countries between the contemporaneous response of inflation to an expansionary monetary policy shock and the sectoral composition of intermediate

[5]The countries are Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Denmark, Finland, France, Germany, Indonesia, Ireland, Italy, Japan, Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, Portugal, Spain, Sweden, United Kingdom, and United States. The Appendix reports all the details and the sources of the data.

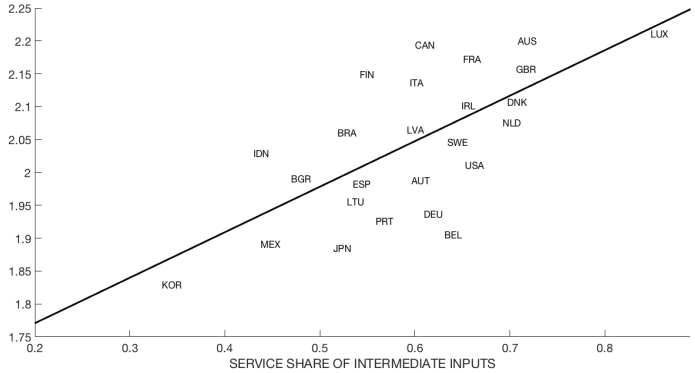
[6]We implement the sign restriction following the algorithm of Rubio-Ramirez et al. (2010), with 5000 draws from the posterior distribution of the reduced form parameters $B(L)$ and Σ with 5000 rotations each. We normalize each IRF such that the contemporaneous change in the nominal interest rate equals 100 basis points.

Figure 4: Intermediate Inputs and the Response to Expansionary Monetary Policy Shocks.

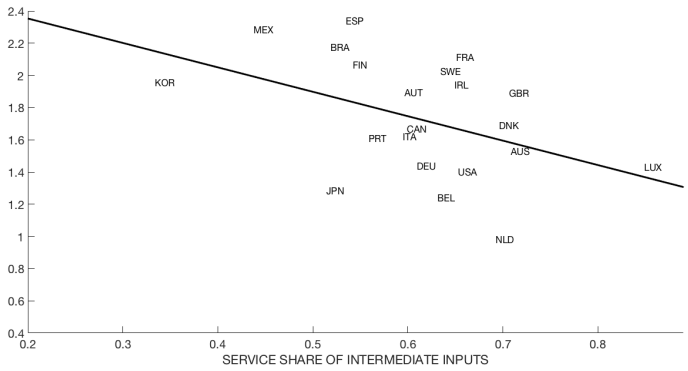
(a) Response of Inflation



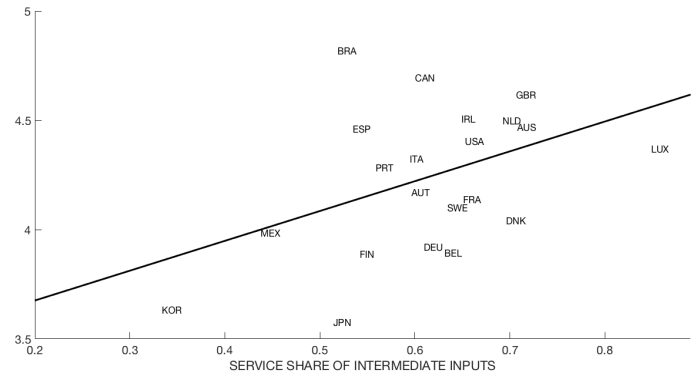
(b) Response of Output



(c) Response of Manufacturing Inflation



(d) Response of Manufacturing Output



Note: Panel (a) shows the relationship between the contemporaneous response of aggregate inflation and the services share of intermediate inputs across countries. Panel (b) shows the relationship between the contemporaneous response of aggregate output and the services share of intermediate inputs across countries. Panel (c) shows the relationship between the contemporaneous response of manufacturing inflation and the services share of intermediate inputs across countries. Panel (d) shows the relationship between the contemporaneous response of manufacturing output and the services share of intermediate inputs across countries. In all cases, the continuous line indicates the fitted linear regression line.

inputs.[7] The Figure shows that there is a strong negative relationship (the correlation equals -0.50 with a p-value of 0.01), such that inflation is less responsive to monetary policy shocks at higher shares of services intermediate inputs. If we use the changes in the Input-Output of the US economy from 1947 until 2010 as an example to interpret the economic significance of the relationship of Panel (a), then the response of inflation to a 100 basis point drop in the interest rate should have decreased from 1.24% to 0.67%.

On the other hand, Panel (b) of Figure 4 shows that output becomes more responsive at higher shares of services intermediate inputs. Although the statistical significance of this relationship is very high (the correlation equals 0.68 with a p-value below 0.001), the economic significance is much weaker than for the case of inflation. Indeed, the changes in the Input-Output of the US economy from 1947 until 2010 imply an increase in the response of output to a 100 basis point drop in the interest rate of just 25 basis points, from 1.87% to 2.12%.[8]

The literature on multi-sector New Keynesian models (Carvalho, 2006; Bouakez et al., 2009, 2011, 2014; Nakamura and Steinsson, 2010; Imbs et al., 2011; Pasten et al., 2016) argues that the sectoral composition of value added affects the dynamics of inflation and output. Since the sectoral composition of value added and intermediate inputs are highly correlated across countries, the relationships

[7] We measure the sectoral composition of intermediate inputs for each country as the average services share of intermediate inputs over the entire sample.

[8] We report the one standard deviation confidence bands of the contemporaneous responses of aggregate inflation and output to a monetary policy shock in the Appendix.

of Panel (a) and (b) could be driven by the variation in value added shares. To exclude this hypothesis, we study whether the relationship between the response of inflation and the services share of intermediate inputs holds even at the sectoral level.

Unfortunately high quality quarterly data on services and manufacturing value added across countries are not available. Yet, we can use measures of industrial production and all-commodities production prices to proxy for manufacturing output and manufacturing price.[9] Then, we run a structural VAR model in which we add manufacturing inflation and output to real GDP, aggregate inflation, and the nominal interest rate. In this case, we have just 21 countries because of lack of data for Bulgaria, Indonesia, Latvia, and Lithuania. As before, we identify monetary policy shocks using sign restrictions on aggregate inflation and output. Panel (c) and Panel (d) of Figure 4 report the relationship across countries between the services share of intermediate inputs and the estimated responses of manufacturing inflation and manufacturing output, respectively. The graphs show that countries with higher shares of services intermediate inputs feature also a milder response of manufacturing inflation - and a stronger response of manufacturing output - to monetary policy shocks. The correlations between sectoral shares and responses are lower than be-

[9] We consider industrial production as a proxy for manufacturing value added because in the U.S. manufacturing accounts for 85% of the entire industrial output. For the case of the all-commodities price, we can evaluate its fit as a proxy for the manufacturing prices since the U.S. Bureau of Economic Analysis releases a series of total manufacturing production price at the quarterly frequency. The correlation over the period 1957Q1-2016Q4 between the all-commodities inflation rate and the total manufacturing inflation rate is 0.96.

fore, but the statistical association keeps holding.[10] One possible explanation for the reduction in the correlations is the fact that by studying sectoral data we rule out the additional role of the sectoral composition of value added.

Although the link between the responses of aggregate inflation and aggregate output with the sectoral share of intermediate inputs could be partially driven by the cross-country variation in value added shares, the evidence on manufacturing inflation and manufacturing output suggests that the association between the sectoral composition of intermediate inputs and transmission of monetary policy shocks holds above and beyond the role of the sectoral composition of value added.

2.3 Price Stickiness Across Sectors

Firms' price setting behavior differs substantially across sectors. Table 1 reports the average duration of services prices and manufacturing prices, as estimated by Bils and Klenow (2004), Klenow and Kryvtsov (2008), and Nakamura and Steinsson (2008).[11] These au-

[10] The correlation between the sectoral composition of intermediate inputs and the response of aggregate inflation equals -0.5 with a p-value of 0.01. Instead, the correlation with the response of manufacturing inflation equals -0.44 with a p-value of 0.05. The correlation between the sectoral composition of intermediate inputs and the response of aggregate output equals 0.68 with a p-value of 0.001. Finally, the analogous correlation with the response of manufacturing output equals 0.45 with a p-value of 0.05.

[11] Bils and Klenow (2004) consider the micro data underlying the non-shelter components of the US Consumer Price Index from 1995 to 1997. Klenow and Kryvtsov (2008) and Nakamura and Steinsson (2008) study the micro data underlying the whole universe of items of the US Consumer Price Index from 1988 to 2005.

thors find that prices in services are stickier than in manufacturing: the median duration of a manufacturing price is around 3 months, whereas the median duration of a services price ranges between 8 and 13 months.

Table 1: Price Duration Across Sectors

	Sector	**Duration in Months**
Bils and Klenow (2004)	Services	7.8
	Manufacturing	3.2
Klenow and Kryvtsov (2008)	Services	9.6
	Manufacturing	3.4
Nakamura and Steinsson (2008)	Services	13.0
	Manufacturing	3.8

Why are prices in services stickier than in manufacturing? The longer duration of services prices can be due to multiple factors: (*i*) the share of labor in the gross output of services is almost twice as large as the share of labor in manufacturing. Since wages are rigid, the higher labor share of services could imply that services prices adjust less frequently; (*ii*) since services are largely non-tradable whereas manufacturing goods are largely tradable, services face a lower degree of price competition: the higher mark-up could allow services firms to adjust less frequently their prices; (*iii*) durables are characterized by a frequent product turnover which is likely to increase the frequency

of price adjustments in the manufacturing sector.[12]

3 The Model

The economy is a version of a cashless Calvo (1983) staggered price New Keynesian model. We consider two sectors - services and manufacturing - which are connected by an Input-Output structure: each sector produces output by using labor and a bundle of intermediate manufactured goods and services.

The two sectors differ in the degree of price stickiness to be consistent with the fact that in the data services price are stickier than manufacturing prices. While the sectoral heterogeneity in price stickiness is the key element for our mechanism to be at work, we also introduce additional ingredients so the model can quantitatively account for the effects of monetary policy shocks which we have estimated in previous Section. Specifically, the model includes sectoral heterogeneities in the durability of the consumption good, and in the relative use of labor, services inputs, and manufacturing inputs. We borrow these features from the literature on multi-sector New Keynesian models, which has shown their relevance for capturing the pass through of monetary policy shocks to prices and real activity in the data (Barsky et al., 2007; Bouakez et al., 2009; Petrella et al., 2018).

[12]The scope of this paper is not to micro-found the asymmetry in the duration of prices across sectors, but rather to evaluate its implications through the lenses of the process of sectoral reallocation. For this reason, we consider a model with an exogenous price stickiness that differs across sectors. All the potential factors that can rationalize the different duration of sectoral prices are captured in a reduced form by differences in the parameter of price stickiness.

In what follows we review the main features of the model, and all the details on the remaining parts of the model are reported in the Appendix.

3.1 Household

The economy is populated by an infinitely-lived representative household that has preferences over the consumption of services C_t^s, the consumption of durable manufactured goods D_t, and labor N_t. The lifetime utility of the household equals

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \psi \frac{N_t^{1+\gamma}}{1+\gamma} \right) \tag{1}$$

with

$$C_t = \left[\omega^{\frac{1}{\nu}} \times C_t^{s\,\frac{\nu-1}{\nu}} + (1-\omega)^{\frac{1}{\nu}} \times D_t^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \tag{2}$$

where β is the discount factor, σ denotes the risk aversion, γ is the inverse of the Frisch elasticity, ω denotes the share of services in the CES aggregator, and ν is the elasticity of substitution between services and manufactured goods.

The stock of manufactured goods D_t follows the law of motion

$$D_t = (1-\delta)\, D_{t-1} + C_t^m - \frac{\chi}{2} \left(\frac{C_t^m}{D_{t-1}} - \delta \right)^2 D_{t-1} \tag{3}$$

where C_t^m denotes the purchase of new manufactured goods, δ is the depreciation rate, and the last term captures convex adjustment costs, which depend on χ. We consider the role of durability of the manufacturing consumption good because since we want to compare the quantitative predictions of our parsimonious model with the data,

we need to capture empirically relevant distinctions between manufacturing and services other than the differences in the degree of price rigidity. Our choice connects to the literature on durable goods and the transmission of monetary policy, which argues that even in the presence of a symmetric degree of price rigidity, a higher durability of the consumption good is associated with a larger response of both output and inflation to a monetary policy shocks (Barsky et al., 2007; Bouakez et al., 2009; Petrella et al., 2018).

The household maximizes lifetime utility (1) subject to the budget constraint

$$P_t^s C_t^s + P_t^m C_t^m + B_t = W_t N_t + (1 + i_{t-1}) B_{t-1} + \Pi_t^s + \Pi_t^m. \qquad (4)$$

The household buys C_t^s services at the nominal price P_t^s and C_t^m manufactured goods at the nominal price P_t^m. The household also invests in a one-period bond B_t which yields a nominal interest rate i_t. In addition, the household earns a nominal labor income $W_t N_t$, and receives nominal profits from services firms Π_t^s and manufacturing firms Π_t^m.

3.2 Final Goods Firm

As in standard New Keynesian models, the production side in each sector is split in a competitive final goods firm and a continuum of intermediate goods firms. In particular, we consider a unit measure of services intermediate goods firms indexed by $i \in [0, 1]$, whose value added equals $Y_{i,t}^s$, and a unit measure of manufacturing intermediate goods firms indexed by $j \in [0, 1]$, whose value added equals $Y_{j,t}^m$.

In the services sector, the final goods firms aggregate the different varieties produced by the continuum of intermediate goods firms using the CES function

$$Y_t^s = \left(\int_0^1 Y_{i,t}^{s\,\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}. \tag{5}$$

Analogously, in the manufacturing sector, the final goods firms use the CES function

$$Y_t^m = \left(\int_0^1 Y_{j,t}^{m\,\frac{\varepsilon-1}{\varepsilon}} dj \right)^{\frac{\varepsilon}{\varepsilon-1}}. \tag{6}$$

The parameter ε denotes the elasticity of substitution across different varieties of intermediate goods. This elasticity is constant across sectors, but we relax this assumption in the robustness checks in the Appendix.

3.3 Intermediate Goods Firm

In the services sector, each individual intermediate goods firm i produces gross output using labor $N_{i,t}^s$ and intermediate inputs $I_{i,t}^s$ as follows

$$G_{i,t}^s = A_t^s \left(N_{i,t}^s\right)^{\alpha_s} \left(I_{i,t}^s\right)^{1-\alpha_s} \tag{7}$$

where A_t^s denotes the level of services productivity and α_s is the labor share.

In the manufacturing sector, each individual intermediate goods firms j produces gross output with a technology

$$G_{j,t}^m = A_t^m \left(N_{j,t}^m\right)^{\alpha_m} \left(I_{j,t}^m\right)^{1-\alpha_m} \tag{8}$$

where A_t^m denotes the level of manufacturing productivity and α_m is the share of labor in gross output. We allow for the shares of labor in the production function α_s and α_m to differ across sectors to capture the fact that, in the data, services are more labor-intensive than manufacturing.[13]

The intermediate inputs are modelled as a bundle of services inputs and manufacturing inputs. We consider a CES aggregator for both sectors:

$$I_{i,t}^s = \left[\omega_s^{\frac{1}{\mu}} \left(S_{i,t}^s + \bar{s}_s\right)^{\frac{\mu-1}{\mu}} + (1-\omega_s)^{\frac{1}{\mu}} \left(M_{i,t}^s\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \tag{9}$$

and

$$I_{j,t}^m = \left[\omega_m^{\frac{1}{\mu}} \left(S_{j,t}^m + \bar{s}_m\right)^{\frac{\mu-1}{\mu}} + (1-\omega_m)^{\frac{1}{\mu}} \left(M_{j,t}^m\right)^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}}. \tag{10}$$

The variable $S_{i,t}^s$ denotes the services intermediate inputs used in the production of gross output by the firm i in the services sector at time t. Instead, $S_{j,t}^m$ denotes the services intermediate inputs used in the manufacturing sector. Analogously, $M_{i,t}^s$ and $M_{j,t}^m$ are the manufacturing intermediate inputs that are used in the production of gross output in the services sector and manufacturing sector, respectively.[14]

[13] Although the model is dynamic, we do not posit any law of motion for the level of sectoral productivities. This choice is motivated by our approach in the quantitative analysis, in which we compare the dynamics of the model around two steady-states which differ in the level of sectoral productivities.

[14] The U.S. Benchmark Input-Output Accounts of the Bureau of the Economic Analysis categorizes as intermediates all the inputs which are either *entirely consumed* in the production process. Accordingly, to be consistent with the accounting of intermediate inputs in the data, the model considers that both the services and the manufacturing intermediate inputs last one

The parameters ω_s and ω_m denote the weight of services inputs in total services intermediates and manufacturing intermediates, respectively. We also add a non-homothetic component in each aggregator. This component is heterogeneous across sectors: it equals $\bar{s}_s$ in the aggregator of services intermediates and $\bar{s}_m$ in the aggregator of manufacturing intermediates. Following the interpretation of Kongsamut et al. (2001), these parameters capture in a reduced form the amount of services inputs produced in-house by firms.[15] Finally, μ defines the elasticity of substitution across services and manufacturing intermediates.

Each intermediate is a CES aggregator that compounds different varieties into a single input. The services inputs used in the services sector equal

$$S^s_{i,t} = \left[\int_0^1 S^s_{l,i,t}{}^{\frac{\varepsilon-1}{\varepsilon}} dl \right]^{\frac{\varepsilon}{\varepsilon-1}} \tag{11}$$

where $S^s_{l,i,t}$ denotes the services inputs produced by the services firm l and used by the services firm i at time t. The services inputs used by manufacturing firms are

$$S^m_{j,t} = \left[\int_0^1 S^m_{l,j,t}{}^{\frac{\varepsilon-1}{\varepsilon}} dl \right]^{\frac{\varepsilon}{\varepsilon-1}} . \tag{12}$$

Analogously, we define the manufacturing inputs used in both sectors

single period.

[15] The non-homothetic parameters are not crucial for our results. The only rationale for these components is to allow the model to be able to match the entire variation in the Input-Output matrix observed in the data during the calibration exercise. In the robustness analysis in the Appendix we study the quantitative implications of a version of the model in which we abstract from the non-homothetic parameters.

as

$$M^s_{i,t} = \left[\int_0^1 M^s_{l,i,t}{}^{\frac{\varepsilon-1}{\varepsilon}} dl\right]^{\frac{\varepsilon}{\varepsilon-1}} \quad \text{and} \quad M^m_{j,t} = \left[\int_0^1 M^m_{l,j,t}{}^{\frac{\varepsilon-1}{\varepsilon}} dl\right]^{\frac{\varepsilon}{\varepsilon-1}}. \tag{13}$$

In each case, the elasticity of substitution is ε as in the aggregator of the different varieties of the final goods.

Equations (9) and (10) jointly define the Input-Output matrix of the economy. The role of the Input-Output matrix is a crucial ingredient for many reasons. First, it captures quantitatively relevant features of the data (Basu, 1995). Second, it amplifies the persistence of the effects arising from sectoral productivity and monetary policy shocks (Bouakez et al., 2009; Petrella et al., 2018). Third, it allows monetary policy shocks to generate a positive co-movement in the reaction of sectoral output (Bouakez et al., 2011). Finally, it is an important determinant of the process of the structural change of an economy, which in turn affects the dynamics of key macroeconomic variables (Moro, 2012, 2015).

As we show in Section 4, in our model the Input-Output matrix varies endogenously over time as a function of relative sectoral productivities and the amount of output produced in the economy. As either the manufacturing productivity rises relative to the services productivity or aggregate output increases, the shares of services inputs used in manufacturing and services rise. This endogenous variation in the inter-sectoral network structure pins down the process of services deepening.

Finally, firms face a Calvo staggered price setting mechanism. In

each period, a fraction ϕ_s of services intermediate goods producers and a fraction ϕ_m of manufacturing intermediate goods producers cannot reset prices, and maintain the price of the previous period. The fractions ϕ_s and ϕ_m are constant over time. Importantly, the Calvo friction parameters differ across sectors to match the empirical evidence on the stronger rigidity of services prices respect to manufacturing prices. We report the optimal pricing decisions in the Appendix.

3.4 Closing the Model

The aggregate nominal GDP equals the sum of the nominal services value added and the nominal manufacturing value added:

$$P_t Y_t = P_t^s Y_t^s + P_t^m Y_t^m. \tag{14}$$

To compute the series of real GDP we follow the same definition used by NIPA. We set the real aggregate GDP by fixing constant base year-prices. In particular, we normalize the base-year prices to one, such that the aggregate real GDP reads

$$Y_t = \bar{P}^s Y_t^s + \bar{P}^m Y_t^m = Y_t^s + Y_t^m. \tag{15}$$

The aggregate price level is then derived as a GDP deflator, obtained by computing the ratio of nominal GDP to real GDP

$$P_t = \frac{P_t^s Y_t^s + P_t^m Y_t^m}{Y_t} \tag{16}$$

so that the aggregate inflation rate equals $1 + \pi_t = \frac{P_t}{P_{t-1}}$.

To close the model, we define the Taylor rule as

$$\frac{1 + i_t}{1 + \bar{i}} = \left(\frac{1 + i_{t-1}}{1 + \bar{i}} \right)^{\rho_i} \left[(1 + \pi_t)^{\phi_\pi} (x_t)^{\phi_y} \right]^{1-\rho_i} \exp(\epsilon_t^r) \tag{17}$$

where x_t defines the output gap, that is $x_t = \log\left(\frac{Y_t}{Y_t^{FLEX}}\right)$, where Y_t^{FLEX} is real GDP of the economy with fully flexible prices, $\bar{i}$ denotes the steady-state interest rate, ρ_i captures the degree of the inertia in the nominal interest rate, ϕ_π and ϕ_y define the elasticity at which monetary authorities adjust the interest rate to movements in the current inflation rate and output gap, respectively, and ϵ_t^r is an IID monetary policy shock such that $\epsilon_t^r \sim IID\ N(0, \sigma_{\epsilon^r})$.

4 A Characterization of Services Deepening

We propose a mechanism that generates an endogenous variation of the Input-Output matrix through two channels:

(i) a Baumol (1967) cost disease channel that raises the share of services inputs when the relative productivity of manufacturing rises, as in Ngai and Pissarides (2007);

(ii) the non-homotheticicities in the intermediate aggregators, which raise the share of services inputs when output increases, as in Kongsamut et al. (2000).

In this Section, we characterize analytically the process of services deepening. For ease of exposition we make the following assumptions: (i) the weight given to services inputs in the CES aggregator of intermediates is the same across sectors, that is, $\omega_s = \omega_m = \omega$; (ii)

the gross output of both sectors is just a function of productivities and intermediate inputs, that is, $\alpha_s = \alpha_m = 0$. Given these assumptions, in the steady-state the shares of services inputs in services and manufacturing equal respectively

$$\frac{P^s S^s}{P^{I^s} I^s} = \frac{\omega Z^{1-\mu}}{\omega Z^{1-\mu} + (1-\omega)} - \frac{\bar{s}_s}{A^s}\left(\omega + \frac{1-\omega}{Z^{1-\mu}}\right) \tag{18}$$

and

$$\frac{P^s S^m}{P^{I^m} I^m} = \frac{\omega Z^{1-\mu}}{\omega Z^{1-\mu} + (1-\omega)} - \frac{\bar{s}_m}{A^m}\left(\omega + \frac{1-\omega}{Z^{1-\mu}}\right) \tag{19}$$

where $Z = A^m/A^s$ denotes the relative productivity of manufacturing. Equations (18) and (19) show that the shares of services inputs in both sectors depend on two components. The first one highlights the contribution of the Baumol disease channel and the second one captures the variation due to the non-homothetic components.

First, let us abstract from the non-homothetic components by setting $\bar{s}_s = \bar{s}_m = 0$. In this case, the shares of services inputs are the same across sectors and depend on the weight of services inputs in the CES aggregators ω, the relative productivity of manufacturing Z, and the elasticity of substitution between services inputs and manufacturing inputs μ. As long as manufacturing and services intermediates are relatively poor substitutes (i.e., $\mu < 1$), an increase in the relative productivity of manufacturing raises the share of services inputs:

$$\frac{\partial\left(\frac{P^s S^s}{P^{I^s} I^s}\right)}{\partial Z} = \frac{\partial\left(\frac{P^s S^m}{P^{I^m} I^m}\right)}{\partial Z} = \frac{\partial\left(\frac{\omega Z^{1-\mu}}{\omega Z^{1-\mu}+(1-\omega)}\right)}{\partial Z} > 0.$$

This derivative captures the Baumol cost disease channel, according to which the relative productivity affects the sectoral allocation of inputs by changing the relative price across sectors. The services share increases with the relative productivity Z only if $\mu < 1$. In the following Section, we estimate the elasticity of substitution μ and find that the empirically relevant value of the elasticity of substitutions between services and manufacturing inputs is indeed below unity. This result is consistent with the literature on structural change, that has extensively documented that the analogous elasticity in the consumption bundle of the households is well below unity. For instance, Duarte and Restuccia (2010) consider an elasticity of substitution of 0.8 while Herrendorf et al. (2013) estimate a value as low as 0.002.

Now let us abstract from the changes in the relative productivity by setting $Z = 1$, such that $A^s = A^m = A$. In this case, the share of services inputs in services equals

$$\frac{P^s S^s}{P^{I^s} I^s} = \omega - \frac{\bar{s}_s}{A}$$

and the share of services inputs in manufacturing equals

$$\frac{P^s S^m}{P^{I^m} I^m} = \omega - \frac{\bar{s}_m}{A}.$$

These conditions posit that the shares of services inputs in both sectors are inversely related to the non-homothetic components $\bar{s}_s$ and $\bar{s}_m$. Nevertheless, when productivity rises, the negative contribution of the non-homothetic components vanishes over time. In this way, an increase in output leads to a switch towards services inputs even

in the absence of movements in the relative productivity.

5 Quantitative Analysis

5.1 Empirical Strategy

Ngai and Pissarides (2007) show that in general models featuring structural change do not follow a balanced growth path.[16] As manufacturing productivity increases more than services productivity, the economy experiences a continuous process of reallocation towards services. In the limit, the services sector takes over the entire economy. This feature characterizes also our model. For this reason, we use our model to study the transmission of monetary policy shocks around two steady-states. As standard business cycle studies evaluate the dynamics of the model around a given equilibrium, we evaluate a similar exercise across two steady-states which differ only in the level of their sectoral productivity, and therefore also in their sectoral composition of intermediate inputs.[17]

Since we compare the dynamics of the model around two different steady-states, we want to consider two points in time which are far enough. We choose 1947 as the first steady-state because the data on sectoral composition of intermediate inputs start exactly in that year.

[16] Structural change can follow a balanced growth path if either preferences are of the non-Gorman family (Boppart, 2014; Leon-Ledesma and Moro, 2017) or for some specific values of the parameters of the model (Kongsamut et al. 2001; Ngai and Pissarides, 2007).

[17] Moro (2012) evaluates the performance of a structural change model in terms of output volatility by comparing two steady-states which are calibrated to the value added shares of 1960 and 2005, respectively. Our approach is the natural extension of the analysis of Moro (2012) to the case of a model with price rigidities.

We choose 2005 as the second steady-state to have a final reference point which is not affected by the Great Recession and the following zero lower bound period. We choose the 2005 as the reference year of our calibration, such that, our economy matches the features of the U.S. economy as of 2005. Then, we calibrate the structure of the Input-Output matrix such that when we change the values of the sectoral productivities to the ones observed in 1947, the services share of intermediates used in both services and manufacturing are consistent with the values registered in 1947.

The 1947 and the 2005 steady-states differ only in the levels of sectoral productivities. Throughout our analysis, we keep fixed all the other parameters, included those of the Taylor rule. In this way, we can ask to what extent structural change and services deepening alone can alter the transmission of monetary policy shocks.[18]

To isolate the role of services deepening, we compare the performance of the benchmark model with a counterfactual economy which abstracts from the process of services deepening. By setting a unitary elasticity of substitution across services and manufacturing inputs (i.e., $\mu = 1$), the sectoral composition of intermediate inputs is constant and fixed to the 2005 shares even when we change the values of sectoral productivities.

Finally, in the Appendix we test the robustness of our calibration

[18] We consider the monetary policy of the 1947 steady-state as described by a Taylor rule to define a counterfactual economy, in which everything is similar to the 2005 steady-state but for both the level of sectoral productivities and the services shares of the intermediate inputs. Our choice aims at identifying the effects of sectoral reallocation on the transmission of monetary policy, by keeping constant the stance of monetary policy.

choices by studying an extensive number of variations of the benchmark model.

5.2 Calibration

We calibrate the economy such that it matches contemporaneously some salient statistics of the U.S. economy as of 2005 and the changes in the sectoral composition of intermediate inputs between 1947 and 2005. Throughout the calibration, one period of the model coincides with a quarter. Table 2 reports the calibration choices of all the parameters.

First, we derive the values for the labor shares α_s and α_m using data from the 35-sector Jorgenson (2007) database on sectoral value added and sectoral intermediate inputs value in 2005. We derive from the data a model-consistent definition of gross output, which sums the labor compensation to the compensation of intermediate inputs. Then, we compute the average share of intermediates in gross output over the sample period for both sectors. For manufacturing, the share of intermediates in value added equals 0.7073. This value implies a labor share for manufacturing that equals $\alpha_m = 0.2927$. For services, the share of intermediates in value added equals 0.4717, which implies a labor share of $\alpha_s = 0.5283$.

In the previous Section we have shown that the relationship between changes in relative sectoral productivities and changes in the sectoral composition of intermediate inputs hinges on the value of the elasticity of substitution between services and manufacturing inputs μ. To discipline the calibration of this key parameter, we estimate the

Table 2: Calibration.

Parameter	**Value**	**Target/Source**
Elasticity of Substitution Inputs	$\mu = 0.4$	Estimated
Elasticity of Substitution Consumption	$\nu = 0.4$	$\nu = \mu$
Labor Share Services	$\alpha_s = 0.5283$	Data
Labor Share Manufacturing	$\alpha_m = 0.2927$	Data
Services Productivity in 1947	$A^s_{1947} = 1$	Normalization
Manufacturing Productivity in 1947	$A^m_{1947} = 1$	Normalization
Services Productivity in 2005	$A^s_{2005} = 1.27$	Data
Manufacturing Productivity in 2005	$A^m_{2005} = 1.65$	Data
Weight Services Consumption Aggregator	$\omega = 0.6196$	2005 Services Share of Value Added
Weight Services Inputs - Services	$\omega_s = 0.8801$	2005 Services Share of Intermediates - Services
Weight Services Inputs - Manufacturing	$\omega_m = 0.5120$	2005 Services Share of Intermediates - Manuf.
Non-Homothetic Component - Services	$\bar{s}_s = 0.0388$	1947 Services Share of Intermediates - Services
Non-Homothetic Component - Manufacturing	$\bar{s}_m = 0.0133$	1947 Services Share of Intermediates - Manuf.
Interest Rate Inertia	$\rho_i = 0.8$	Clarida et al. (2000)
Taylor Parameter Inflation	$\phi_\pi = 1.5$	Clarida et al. (2000)
Taylor Parameter Output Gap	$\phi_\pi = 0.2$	Clarida et al. (2000)
Standard Deviation Monetary Policy Shock	$\sigma_{\epsilon^r} = 0.1$	Standard Value
Calvo Frequency Services	$\phi_s = 0.75$	12 Months Duration of Prices
Calvo Frequency Manufacturing	$\phi_m = 0.25$	3 Months Duration of Prices
Depreciation Rate Manufacturing	$\delta = 0.154$	Avg. Depreciation of Manufactured Goods
Adjustment Cost	$\chi = 2.05$	Output Response to Monetary Policy Shock
Elasticity Intertemporal Substitution	$\sigma = 2$	Standard value
Inverse Frisch elasticity	$\gamma = 1$	Standard value
Relative Disutility of Labor	$\psi = 16.45$	Steady-State Labor = 0.33
Time discount	$\beta = 0.995$	Steady-State Annual Interest Rate = 0.02
Elasticity of Substitution Intermediate Goods	$\varepsilon = 6$	Standard value

elasticity of substitution between services and manufacturing inputs μ using the optimal condition on the firms' choice of manufacturing intermediate inputs used in manufacturing. Namely, we use data from the World KLEMS initiative on the price and quantities of manufacturing and total intermediate inputs used by the manufacturing sector of the U.S., and estimate the regression

$$\log M_{m,t} - \log I_{m,t} = \text{constant} - \mu \left[\log P_t^m - \log P_t^{I^m}\right] + \text{error}_t.$$

We find that $\hat{\mu} = 0.33$, which means that services and manufacturing intermediate inputs are relatively poor substitutes. Accordingly, we set the elasticity of substitution between services and manufacturing input to $\mu = 0.4$. Then, we set the elasticity of substitution between services and manufacturing in consumption as $\nu = 0.4$ to equalize the elasticity of substitution on the inputs side. This choice lies exactly in the middle of the ballpark of the values used in the literature. For instance, Duarte and Restuccia (2010) considers an elasticity of $\nu = 0.8$, whereas Herrendorf et al. (2013) estimate an elasticity of $\nu = 0.002$.

Given a value for the elasticity of substitution across intermediate inputs, the process of services deepening hinges on changes in the sectoral productivities. Again, we tie our hands in the calibration of these values by looking at the data. In this way, we can properly quantify the relevances of sectoral productivities as a driver of the rise of the services share of intermediate inputs. We compute gross output productivities using data from the 35-sector Jorgenson (2007)

dataset.[19] Then, we normalize the productivities in 1947 to unity. This procedure yields 2005 values for the services productivity and the manufacturing productivity which equal $A^s_{2005} = 1.27$ and $A^m_{2005} = 1.65$, respectively.

Then, we calibrate the weight of services in the consumption aggregator ω, the weight of services in the aggregator of services inputs ω_s, the weight of services in the aggregator of manufacturing inputs ω_m, and the non-homothetic parameters $\bar{s}_s$ and $\bar{s}_m$. Although all the parameters of the model jointly determine the changes in the sectoral composition of the economy, these five parameters are those which affect the most the services share of value added and intermediate inputs. To set these five parameters we calibrate the model to match five targets. Given the level of sectoral productivities in 2005 A^s_{2005} and A^m_{2005}, we calibrate the model to match the 2005 services shares in value added (85.2%), intermediate inputs used by the services sector (83.6%), and intermediate inputs used by the manufacturing sector (33.6%). Then, we set the sectoral productivities to their 1947 values A^s_{1947} and A^m_{1947} and calibrate the model to match the 1947 services shares of intermediate inputs in the services sector (61.5%) and in manufacturing sector (20%). In this way, the model matches the changes in the U.S. Input-Output matrix between 1947

[19] To avoid that the noise on the size of mark-ups could affect the estimates of productivities, we introduce in the model a fixed production subsidy which offsets firms' market power. This feature alters only the steady-state of the model and not its dynamics. In this way, we can derive in the data the equivalent version of gross output productivities defined in the model and abstract from the computation of mark-ups.

and 2005.[20] This procedure leads to the following values: $\omega = 0.6196$, $\omega_s = 0.8801$, $\omega_m = 0.5120$, $\bar{s}_s = 0.0388$, and $\bar{s}_m = 0.0133$.

Moving then to the block of parameters which is standard in the New Keynesian literature, we set the parameters of the Taylor rule following the estimates of Clarida et al. (2000). We set the inertia in nominal interest rate to $\rho_i = 0.8$ and the Taylor rule coefficients of inflation and output gap are set to $\phi_\pi = 1.5$ and $\phi_y = 0.2$, respectively. Instead, the standard deviation of the monetary policy shock is set to $\sigma_{\epsilon^r} = 0.1$. For the price friction, we follow the evidence of Bils and Klenow (2004), Klenow and Kryvtsov (2008), and Nakamura and Steinsson (2008), who point out that the median duration of prices in the services sector ranges between 8 months and 13 months, while manufactured goods have a much lower duration of 3.2 months. Accordingly, we set $\phi_s = 0.75$ for services firms, which implies an average duration of 12 months, and $\phi_m = 0.25$ for manufacturing firms, which implies an average duration of 3 months.

To set the depreciation rate of the manufactured good, we consider the fact that around 60% of the manufactured goods are durable while the remaining 40% are non-durable. We weight the depreciation rates of durables and non-durables with their shares in total manufacturing and find that the implied average quarterly depreciation rate of manufactured goods equals $\delta = 0.154$. The adjustment cost parameter is calibrated to match the relative contemporaneous response of

[20] The calibration of this block of parameters has to be then interpreted as follows: once all the rest of parameters have been set, these five parameters are *jointly* calibrated such that the model matches contemporaneously the sectoral composition of the economy as of 2005 and the changes in the sectoral composition of the Input-Output matrix between 1947 and 2005.

manufacturing output with respect to services output to a monetary policy shock. To do so, we run a SVAR model with services inflation, services output, manufacturing inflation, manufacturing output, and nominal interest rates, using data of the U.S. Bureau of the Economic Analysis over the period 1995Q1-2005Q4. We identify monetary policy shocks using sign restrictions by assuming that a monetary policy shock raises on impact (and the following quarter) the nominal interest rate, and decreases sectoral outputs and inflation rates. We find that the contemporaneous response of manufacturing output is 2.511 times as large as the one of services output. The model matches this value with an adjustment cost parameter of $\chi = 2.05$. Although we are calibrating the relative response of sectoral output, which is directly affected by services deepening, our choice does not restrict the way services deepening alters the dynamics of sectoral output. By calibrating the adjustment cost parameter, we are normalizing the relative response of sectoral output in the 2005 equilibrium to the value observed in the data. The relative response in the 1947 is completely left unrestricted. Hence, the predictions of the model on the responses to monetary policy shocks in 1947 are informative on the effects of services deepening on the dynamics of sectoral output.

Then, we choose the parameters of the utility function such that the risk aversion is $\sigma = 2$ and the inverse of the Frisch elasticity is $\gamma = 1$, which are standard values in the literature. The relative disutility of labor is set to $\psi = 16.45$ to match a steady-state labor of $\bar{N} = 0.33$. We set the time discount parameter to $\beta = 0.995$ to have a steady-state annual interest rate of 2%. We set the elasticity

of substitution across intermediate goods in both the services sector and manufacturing sector to $\varepsilon = 6$, which is the value estimated by Christiano et al. (2005).

5.3 The Role of Sectoral Productivities

Our mechanism driving the process of services deepening hinges on the exogenous trends in sectoral productivities. As the productivity of manufacturing grows faster than the productivity of services, as it happens in the data, then the Input-Output matrix undergoes an endogenous process of sectoral reallocation towards services intermediate inputs. In this Section, we propose a simple numerical illustration of the effects of the changes in sectoral productivities on both the sectoral reallocation of intermediate inputs and the transmission of monetary policy.

The Panels (a) and (b) of Figure 5 report the model implications on the services share of intermediate inputs used by the service sector and the services share of intermediate inputs used by the manufacturing sector as a function of the relative sectoral productivity, measured as the ratio between the productivity of manufacturing over the productivity of services. Hence, the relative sectoral productivity rises when the productivity of manufacturing increases more than the productivity of services. To highlight the role of the CES intermediate aggregator for the endogenous variation of the Input-Output matrix, in each Panel we show the predictions of both the benchmark model and a counterfactual model without services deepening, in which the intermediate aggregator is a Cobb-Douglas function.

Consistently with the previous analytical characterization of services deepening, Panels (a) and (b) show that the services share of intermediate inputs in either sector rises with the relative sectoral productivity. In the case we consider a Cobb-Douglas aggregator for the intermediate inputs (i.e., when $\mu = 1$), then the process of services deepening is shut down and the sectoral shares of the Input-Output matrix are constant over time, independently of the level of sectoral productivities.

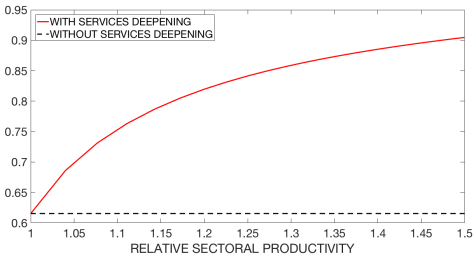
What are the implications of the changes in sectoral productivities for the transmission of monetary policy? Panels (c) and (d) report the responses of services inflation and manufacturing inflation to a monetary policy shock as a function of the relative sectoral productivity. In the model with services deepening, the rise in the relative sectoral productivity dampens the response of both services inflation and manufacturing inflation to a monetary policy shock. Instead, when we shut down the services deepening, the responses of sectoral inflation rates hardly change.[21]

How does the services deepening affect the dynamics of sectoral inflation rates? Panels (e) and (f) show the responses of services marginal costs and manufacturing marginal costs to a monetary policy shock as a function of the relative sectoral productivity. The plots show that the rise in the relative sectoral productivity curbs substan-

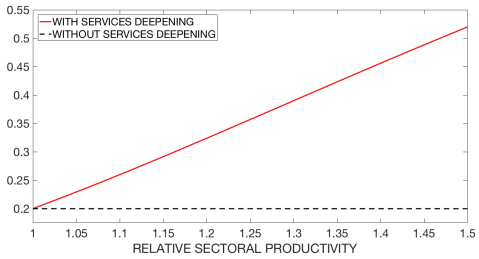
[21] As the model without services deepening still features a structural change that shifts the sectoral shares of value added, the rise of services value added alters the degree of strategic complementarities across sectors and varies the responses of sectoral inflation rates. Yet, these changes are very small. In the following subsection, we show that indeed the strategic complementarities channel of structural change is quantitatively negligible.

Figure 5: Relative Sectoral Productivity and the Response to Monetary Policy Shocks.

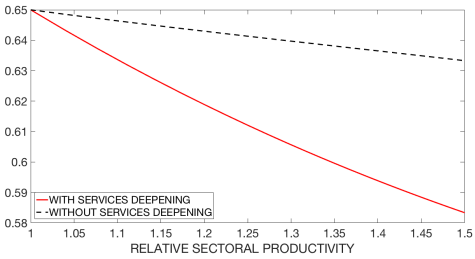
(a) Services Intermediates Share in Services



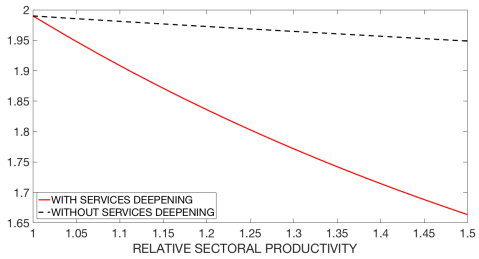
(b) Services Intermediates Share in Manufacturing



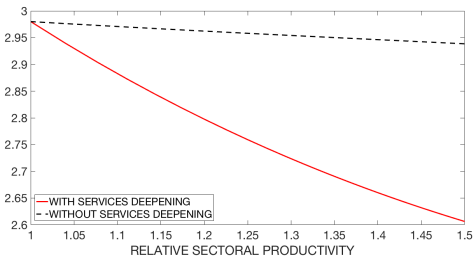
(c) Services Inflation



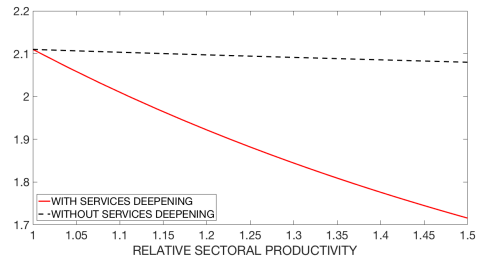
(d) Manufacturing Inflation



(e) Services Marginal Cost



(f) Manufacturing Marginal Cost

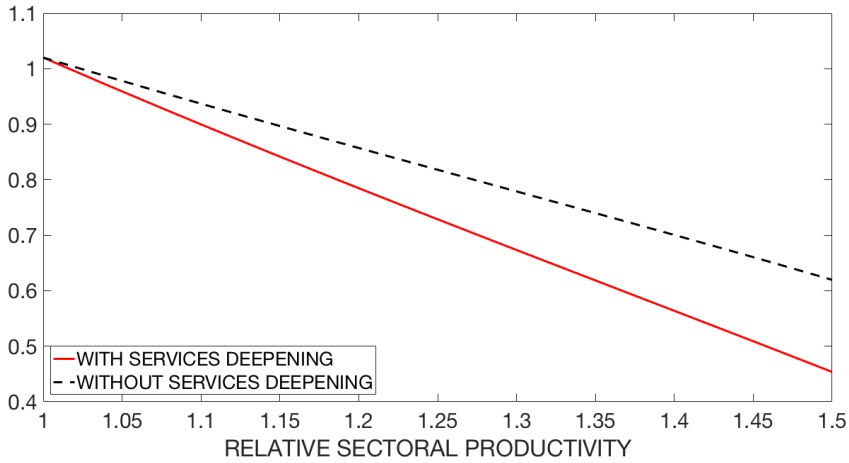


Note: Panel (a) plots the model prediction on the share of services intermediate inputs used by the service sector as a function of the relative sectoral productivity, measured as the ratio between the productivity of manufacturing over the productivity of services. Panel (b) plots the model prediction on the share of services intermediate inputs used by the manufacturing sector as a function of the relative sectoral productivity. Panel (c) plots the model prediction on the response response of services inflation to an expansionary monetary policy shock as a function of the relative sectoral productivity. Panel (d) plots the model prediction on the response response of manufacturing inflation to an expansionary monetary policy shock as a function of the relative sectoral productivity. Panel (e) plots the model prediction on the response response of services marginal costs to an expansionary monetary policy shock as a function of the relative sectoral productivity. Panel (f) plots the model prediction on the response response of manufacturing marginal costs to an expansionary monetary policy shock as a function of the relative sectoral productivity. In each Panel, the continuous line indicates the predictions of a model with services deepening, whereas the dashed line indicates the predictions of a model without services deepening.

tially the responsiveness of sectoral marginal costs. Again, without services deepening the behavior of the marginal costs barely change. These plots highlight that services deepening propagates through a *marginal cost channel* that alters the dynamics of each sectoral price. As both sectors increase the use of services inputs, marginal costs become stickier and less responsive to shocks. Then, the changes in the dynamics of marginal costs spill over in the behavior of sectoral prices.

Figure 6 plots the response of aggregate inflation to a monetary policy shock for different values of the relative sectoral productivity. As the relative productivity rises, the increase in the services share of intermediate inputs dampens the responsiveness of aggregate inflation.

Figure 6: The Response of Aggregate Inflation to Monetary Policy Shocks.



Note: The Figure plots the model prediction on the response response of aggregate inflation to an expansionary monetary policy shock as a function of the relative sectoral productivity. The continuous line indicates the predictions of a model with services deepening, whereas the dashed line indicates the predictions of a model without services deepening.

When we shut down the changes in the Input-Output matrix, the model still experiences a reduction in the responsiveness of aggregation inflation, even though to a lesser extent. Also in the absence of services deepening, the model features a structural transformation in value added shares, which shifts the economic activity towards services, that is the sector with the highest degree of price rigidity and the lowest responsiveness to monetary policy shocks. Consequently, the rise of services value added raises the stickiness of aggregate inflation, which then becomes less responsive to monetary policy shocks. This result points out that the sectoral reallocation in value added affects the transmission of monetary policy through a *composition channel*, which raises the relative importance of the sector with the highest degree of price rigidity in the economy, without altering the behavior of each individual sectoral inflation rate.

Overall we find that services deepening alters the transmission of monetary policy through a marginal cost channel. This novel channel adds to the literature on multi-sector New Keynesian models, that studies the link between the sectoral composition of the economy and the dynamics of inflation (Carvalho, 2006; Bouakez et al., 2009, 2011, 2014; Nakamura and Steinsson, 2010; Imbs et al., 2011; Pasten et al., 2016). This strand of the literature shows that modeling the heterogeneity in the sectoral composition of value added is crucial to understand the properties of *aggregate* inflation. Instead, we highlight that modeling the heterogeneity in the sectoral composition of intermediate inputs is crucial to understand not only the dynamics of aggregate inflation, but also the dynamics of *sectoral* inflation rates.

The next subsection quantifies the importance of the marginal cost channel of services deepening.

5.4 The Transmission of Monetary Policy

Table 3 reports the contemporaneous reaction of inflation, marginal costs, and output to an expansionary monetary policy shock - a drop of 100 basis points in the nominal interest rate - in 1947 and 2005, and the ratio of 2005-response over 1947-response for both the benchmark economy and a counterfactual economy which does not feature services deepening.

Table 3 shows that on impact prices in services respond less than in manufacturing: the contemporaneous response of manufacturing inflation is thrice as large as the contemporaneous response of services inflation, both in 1947 and in 2005. Consequently, when moving from the 1947 steady-state to the 2005 one, the rise of services reduces the contemporaneous reaction of aggregate inflation from 1.02% to 0.72%. Instead, when we shut down the process of services deepening, by considering an economy with a constant Input-Output matrix, the reduction of the response of aggregate inflation equals just 20 basis points. Hence, services deepening accounts for roughly one third of the reduction in the contemporaneous response of aggregate inflation to a monetary policy shock.

The process of sectoral reallocation also reduces the contemporaneous response of sectoral inflation rates. Comparing the two steady-states, the reaction of services inflation to a 100 basis point drop in interest rate shrinks by 3 basis points, and the reaction of manufac-

Table 3: Response of Inflation and Output to Monetary Policy Shock

	Benchmark Economy			Economy without Services Deepening		
	Model 1947	Model 2005	Ratio 2005/1947	Model 1947	Model 2005	Ratio 2005/1947
	(1)	(2)	(3)	(4)	(5)	(6)
π_t	1.02%	0.72%	0.71	0.85%	0.76%	0.80
π_t^s	0.65%	0.62%	0.95	0.61%	0.60%	0.98
π_t^m	1.99%	1.81%	0.91	1.59%	1.58%	0.99
MC_t^s	2.98%	2.78%	0.93	2.60%	2.59%	0.99
MC_t^m	2.11%	1.89%	0.90	1.56%	1.55%	0.99
Y_t	2.00%	2.16%	1.08	2.05%	2.09%	1.04
Y_t^s	1.66%	1.71%	1.03	1.71%	1.72%	1.01
Y_t^m	3.93%	4.28%	1.09	4.28%	4.32%	1.02

Note: The entries report the contemporaneous response (in log-deviations from the steady-state) of each variable to a drop of 100 basis points in the nominal interest rate. π_t denotes the aggregate inflation rate, π_t^s is the inflation rate of services, π_t^m is the inflation rate of manufacturing, MC_t^s is the real marginal cost of services, MC_t^m is the real marginal cost of manufacturing, Y_t denotes the aggregate output growth, Y_t^s is the output growth of services and Y_t^m is the output growth of manufacturing. "Model 1947" refers to the equilibrium calibrated to the shares of services in intermediates observed in the U.S. in 1947. "Model 2005" refers to the equilibrium calibrated to the shares of services in intermediates observed in the U.S. in 2005. "Model 1947" and "Model 2005" differ just in the values of sectoral productivities. "Economy without Services Deepening" refers to the equilibrium in which the intermediates aggregators are Cobb-Douglas functions and there is no non-homothetic component, that is, $\mu = 1$ and $\bar{s}_s = \bar{s}_m = 0$. We calibrate the shares of services inputs in services and manufacturing to the values observed in 2005. The levels of TFP in the counterfactual economy are model-consistent.

turing inflation decreases by 18 basis points. The drop in the reaction of sectoral prices is mirrored by the fall in the reactions of sectoral marginal costs, which decrease by about 22 basis points in services and 20 basis points in manufacturing. Without services deepening, the responses of sectoral marginal costs do not change. These results support the relevance of the marginal cost channel of services deepening, through which the sectoral reallocation of the Input-Output matrix towards services intermediate inputs reduces the responsiveness of both sectoral marginal costs and sectoral inflation rates to monetary policy shocks.

When looking at the contemporaneous response of output, Table 3 displays that monetary policy shocks nowadays have slightly larger real effects. Over the two steady-states, the reaction of aggregate output rises by 16 basis points, while the reaction of services output and manufacturing output increases by 5 basis points and 35 basis points, respectively. Abstracting from the services deepening halves the increase in the real effects of monetary policy.

Why do monetary policy shocks have larger real effects? Sectoral reallocation shifts economic activities towards services, whose prices are much stickier than manufacturing prices. Hence, the rise of services raises the average duration of prices in the economy. As prices get stickier, inflation reacts less to shocks, and therefore quantities have to react by a larger amount. This mechanism explains why monetary policy shock have larger contemporaneous effects on output, at the cost of a lower influence on the dynamics of inflation.

Then, we report in Table 4 the 2-year cumulative responses of

Table 4: 2 Year Cumulative Reponse

	Benchmark Economy			Economy without Services Deepening		
	Model 1947	Model 2005	Ratio 2005/1947	Model 1947	Model 2005	Ratio 2005/1947
	(1)	(2)	(3)	(4)	(5)	(6)
π_t	0.69%	0.66%	0.97	0.63%	0.63%	1.00
π_t^s	0.69%	0.67%	0.97	0.63%	0.63%	1.00
π_t^m	0.70%	0.68%	0.97	0.64%	0.64%	1.00
MC_t^s	3.09%	2.94%	0.95	2.74%	2.74%	1.00
MC_t^m	2.42%	2.18%	0.90	1.69%	1.69%	1.00
Y_t	2.10%	2.12%	1.01	2.08%	2.08%	1.00
Y_t^s	2.13%	2.14%	1.00	2.07%	2.07%	1.00
Y_t^m	1.89%	1.98%	1.05	2.17%	2.17%	1.00

Note: The entries report the 2-year cumulative response (in log-deviations from the steady-state) of each variable to a drop of 100 basis points in the nominal interest rate. π_t denotes the aggregate inflation rate, π_t^s is the inflation rate of services, π_t^m is the inflation rate of manufacturing, MC_t^s is the real marginal cost of services, MC_t^m is the real marginal cost of manufacturing, Y_t denotes the aggregate output growth, Y_t^s is the output growth of services and Y_t^m is the output growth of manufacturing. "Model 1947" refers to the equilibrium calibrated to the shares of services in intermediates observed in the U.S. in 1947. "Model 2005" refers to the equilibrium calibrated to the shares of services in intermediates observed in the U.S. in 2005. "Model 1947" and "Model 2005" differ just in the values of sectoral productivities. "Economy without Services Deepening" refers to the equilibrium in which the intermediates aggregators are Cobb-Douglas functions and there is no non-homothetic component, that is, $\mu = 1$ and $\bar{s}_s = \bar{s}_m = 0$. We calibrate the shares of services inputs in services and manufacturing to the values observed in 2005. The levels of TFP in the counterfactual economy are model-consistent.

inflation, marginal costs, and output for both the benchmark economy and a counterfactual economy which does not feature services deepening. In this case, the dampening effect of services deepening on aggregate and sectoral inflation rates becomes much more muted. Moving from 1947 to 2005 reduces the cumulative responses of the inflation rates by just 3 basis points. This result points out that the dampening effect of services deepening comes with an increase in the the persistence of the response of inflation. As the services share of intermediate inputs rises, sectoral marginal costs become stickier, and therefore their response to shocks is more distributed over time. These properties then spill over into the response of aggregate inflation. Hence, the sectoral reallocation of intermediate inputs alters entirely the *dynamic* response of inflation to monetary policy shocks, by raising the time-lag through which monetary policy shocks affect inflation. These changes alter substantially the dynamic properties of inflation: the model predicts that services deepening reduces the standard deviation of aggregate inflation from 0.3 to 0.2 and raises its auto-correlation from 0.3 up to 0.6.[22]

5.5 Comparing the Model with the Data

The model predicts that services deepening dampens the contemporaneous response of aggregate inflation and sectoral inflation to monetary policy shocks. Are the quantitative results of the model in line

[22]The reduction in the volatility of inflation and the rise in its persistence suggest that in the model services deepening flattens the slope of the Phillips curve. This prediction is consistent with the evidence on the progressive flattening of the Phillips curve in advanced economies (Mishkin, 2007; Coibon, Gorodnichenko, and Koustas, 2013; Coibon and Gorodnichenko, 2015).

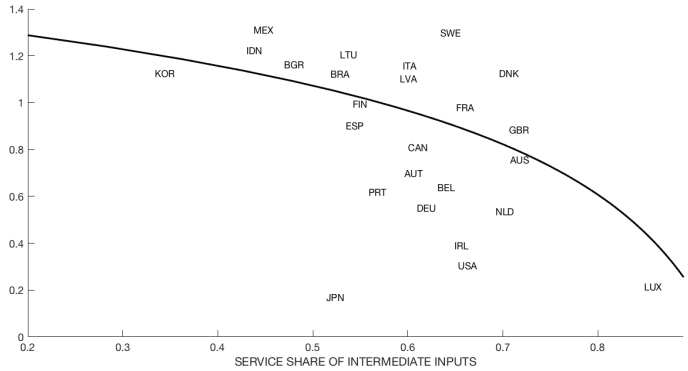
with our empirical evidence on the relationship between the response of inflation to monetary policy shocks and the sectoral composition of intermediate inputs? To validate the quantitative implications of our theory, we compare the relationship between the services share of intermediate inputs and the contemporaneous responses of aggregate inflation, aggregate output, manufacturing inflation, and manufacturing output across countries in the data and in the model. On the one hand, we take the estimates of the SVAR exercise of Section 2.2. On the other hand, we compute the contemporaneous responses of inflation and output to a monetary policy shock in the model in a series of steady-states with different levels of sectoral productivities and therefore different services shares of intermediate inputs.

Panel (a) of Figure 7 compares the response of aggregate inflation to a monetary policy shock in the data and in the model, for given shares of services intermediate inputs. The quantitative results of the model are successfully in line with the magnitude of the estimates from the data on the relationship between the sectoral composition of intermediate inputs and the response of inflation to monetary policy shocks. The model can account for the low responsiveness of inflation in a country highly intensive in services intermediate inputs, like Luxembourg, while being able at the same time to explain the high sensitivity of inflation in a country very intensive in manufacturing intermediate inputs, like Korea.

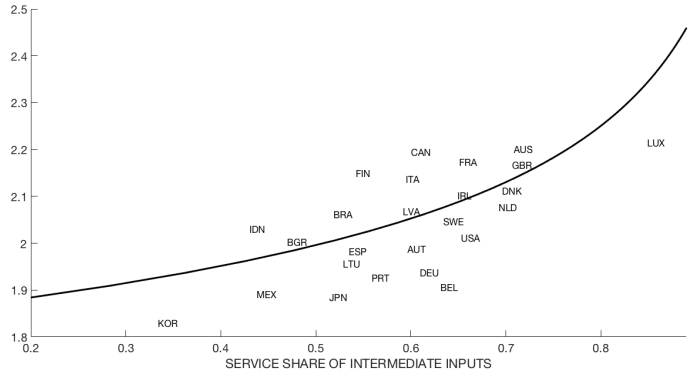
Panel (b) of Figure 7 compares the response of aggregate output to a monetary policy shock in the data and in the model, for given shares of services intermediate inputs. Even in this case, the model can suc-

Figure 7: Intermediate Inputs and the Response to Expansionary Monetary Policy Shocks: Data vs. Model.

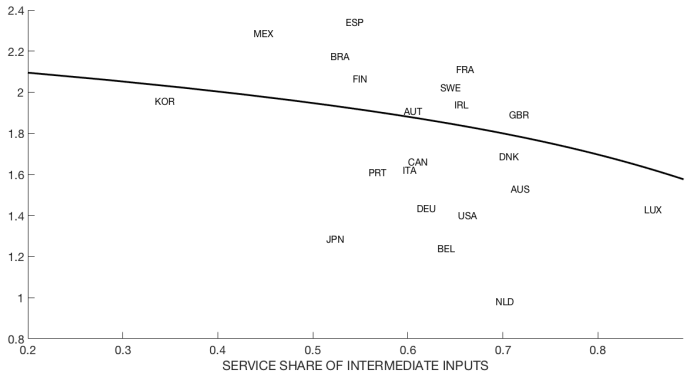
(a) Response of Aggregate Inflation



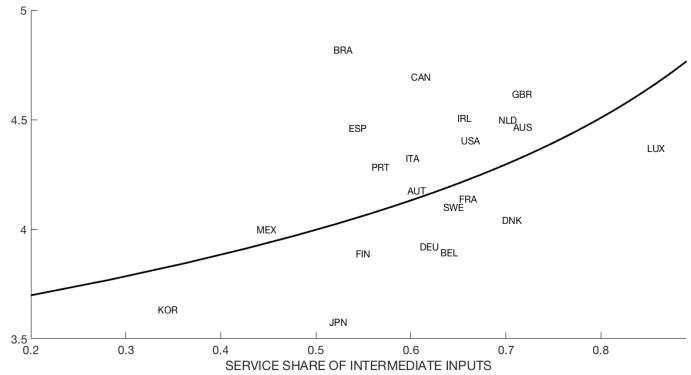
(b) Response of Aggregate Output



(c) Response of Manufacturing Inflation



(d) Response of Manufacturing Output



Note: Panel (a) shows the relationship between the contemporaneous response of aggregate inflation and the services share of intermediate inputs across countries in the data (the country identifiers) and in the model (the continuous line). Panel (b) shows the relationship between the contemporaneous response of aggregate output and the services share of intermediate inputs across countries in the data (the country identifiers) and in the model (the continuous line). Panel (c) shows the relationship between the contemporaneous response of manufacturing inflation and the services share of intermediate inputs across countries in the data (the country identifiers) and in the model (the continuous line). Panel (d) shows the relationship between the contemporaneous response of manufacturing output and the services share of intermediate inputs across countries in the data (the country identifiers) and in the model (the continuous line).

cessfully account not only for the sign of the relationship between the response of output to monetary policy shocks and the services share of intermediate inputs, but also for the magnitude of this relationship across countries.

Similarly, Panel (c) and Panel (d) of Figure 7 reports the comparison between the model and the data on the responses of manufacturing inflation and manufacturing output, respectively. These graphs show that the model is able to explain how the sectoral composition of intermediate inputs not only affects aggregate inflation and output, but also sectoral variables. Overall, the consistency of the model with our empirical estimates gives further support and validation to the quantitative appeal of the marginal cost channel of services deepening.

6 Conclusion

In this paper we document that advanced economies are experiencing a process of services deepening that raises the services share of intermediate inputs. In addition, we show that inflation becomes less responsive to monetary policy shocks in countries which are more intensive in services inputs.

To rationalize these facts, we build a New Keynesian model with two sectors connected by an Input-Output matrix, which changes endogenously over time. We use the model to understand the effects of the sectoral reallocation experienced by the U.S. from 1947 to 2005. We find that over these six decades the reaction of aggregate inflation to a 100 basis point drop in the nominal interest rate decreases by

30 basis points, whereas the response of aggregate output rises by 16 basis points. The reduction in the responsiveness of inflation is driven by services deepening, through a marginal cost channel that affects the behavior of firms in either sector. As services and manufacturing increase the intensity of services inputs, marginal costs becomes stickier. Thus, even sectoral prices become stickier and less reactive to monetary policy shocks.

Overall our results show that the process of services deepening alters the response of inflation and output to monetary policy shocks. A recent strand of the literature has emphasized a reduction in the responsiveness of inflation to monetary policy shocks over the recent decades. The conventional view rationalizes this fact with changes in either the stance of monetary policy or the volatility of shocks. We provide a novel channel that can generate low-frequency movements in the effectiveness of monetary policy. Since in our model both the Taylor rule parameters and the volatility of shocks are constant over time, the variation in the transmission of monetary policy is entirely due to the process of sectoral reallocation.

References

Acemoglu, Daron, Vasco Carvalho, Asuman Ozdaglar, and Alireza Tahbaz-Salehi (2012) "The Network Origins of Aggregate Fluctuations". *Econometrica*, 80, 1977-2016.

Acemoglu, Daron, and Veronica Guerrieri (2008) "Capital Deepening and Nonbalanced Economic Growth". *Journal of Political Economy*, 116, 467-498.

Ball, Laurence, and David Romer (1990) "Real Rigidities and the Non-Neutrality of Money". *Review of Economic Studies*, 57, 183-203.

Barsky, Robert, Christopher House, and Miles Kimball (2007) "Sticky-Price Models and Durable Goods". *American Economic Review*, 97, 984-998.

Basu, Susanto (1995) "Intermediate Goods and Business Cycles: Implications for Productivity and Welfare". *American Economic Review*, 85, 512-531.

Baumol, William (1967) "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis". *American Economic Review*, 57, 415-426.

Bernard, Andrew, and Teresa Fort (2015) "Factoryless Goods Producing Firms". *American Economic Review: Papers & Proceedings*, 105, 518-523.

Bils, Mark, and Peter Klenow (2004) "Some Evidence on the Importance of Sticky Prices". *Journal of Political Economy*, 112, 947-985.

Boivin, Jean, and Marc Giannoni (2006) "Has Monetary Policy

Become More Effective?" *Review of Economics and Statistics*, 88, 445-462.

Boppart, Timo (2014) "Structural Change and the Kaldor Facts in a Growth Model with Relative Price Effects and non-Gorman Preferences". *Econometrica*, 82, 2167-2196.

Bouakez, Hafedh, Emanuela Cardia, and Francisco Ruge-Murcia (2009) "The Transmission of Monetary Policy in a Multi-Sector Economy". *International Economic Review*, 50, 1243-1266.

Bouakez, Hafedh, Emanuela Cardia, and Francisco Ruge-Murcia (2011) "Durable Goods, Inter-Sectoral Linkages and Monetary Policy". *Journal of Economic Dynamics and Control*, 35, 730-745.

Bouakez, Hafedh, Emanuela Cardia, and Francisco Ruge-Murcia (2014) "Sectoral Price Rigidity and Aggregate Dynamics". *European Economic Review*, 65, 1-22.

Buera, Francisco, and Joseph Kaboski (2012) "The Rise of the Services Economy". *American Economic Review*, 102, 2540-2569.

Calvo, Guillermo (1983) "Staggered Prices in a Utility-Maximizing Framework". *Journal of Monetary Economics*, 12, 383-398.

Carvalho, Carlos (2006) "Heterogeneity in Price Stickiness and the Real Effects of Monetary Shocks". *B.E. Journal of Macroeconomics*, 2, 1-56.

Carvalho, Vasco, and Xavier Gabaix (2013) "The Great Diversification and Its Undoing". *American Economic Review*, 103, 1697-1727.

Clarida, Richard, Jordi Gali, and Mark Gertler (2000) "Mone-

tary Policy Rules And Macroeconomic Stability: Evidence And Some Theory". *Quarterly Journal of Economics*, 115, 147-180.

Christiano, Lawrence, Martin Eichenbaum, and Charles Evans (2005) "Nominal Rigidities and the Effects of a Shock to Monetary Policy". *Journal of Political Economy*, 113, 1-45.

Cogley, Timothy, and Thomas Sargent (2001) "Evolving Post-World War II U.S. Inflation Dynamics". *NBER Macroeconomics Annual*, 16, 331-388.

Cogley, Timothy, and Thomas Sargent (2005) "Drifts and Volatilities: Monetary Policies and Outcomes in the Post-WWII US". *Review of Economic Dynamics*, 8, 262-302.

Coibon, Olivier, and Yuriy Gorodnichenko (2015) "Is the Phillips Curve Alive and Well After All? Inflation Expectations and the Missing Disinflation". *American Economic Journal: Macroeconomics*, 7, 197-232.

Coibion, Olivier, Yuriy Gorodnichenko, and D. Koustas (2013) "Amerisclerosis? The Puzzle of Rising U.S. Unemployment Persistence". *Brookings Papers on Economic Activity*, Fall.

Crozet, Matthieu, and Emmanuel Milet (2017) "Should Everybody Be in Services? The Effect of Servitization on Manufacturing Firm Performance". *Journal of Economics & Management Strategy*, 26, 820-841.

Duarte, Margarida, and Diego Restuccia (2010) "The Role of Structural Transformation in Aggregate Productivity". *Quarterly Journal of Economics*, 125, 129-173.

Foerster, Andrew, Pierre-Daniel Sarte, and Mark Watson

(2011) "Sectoral versus Aggregate Shocks: A Structural Factor Analysis of Industrial Production". *Journal of Political Economy*, 119, 1-38.

Fonagne, Lionel, and Ann Harrison (2017) "The Factory-Free Economy: Outsourcing, Servitization and the Future of Industry". *NBER Working Paper*, 23016.

Herrendorf, Berthold, Richard Rogerson and Akos Valentinyi (2013) "Two Perspectives on Preferences and Structural Transformation". *American Economic Review*, 103, 2752-2589.

Imbs, Jean, Eric Jondeau, and Florian Pelgrin (2011) "Sectoral Phillips Curves and the Aggregate Phillips Curve". *Journal of Monetary Economics*, 58, 328-344.

Jorgenson, Dale (2007) "35 Sector KLEM". Harvard Dataverse.

Karabarbounis, Loukas, and Brent Neiman (2014) "The Global Decline of the Labor Share". *Quarterly Journal of Economics*, 129, 61-103.

Kimball, Miles (1995) "The Quantitative Analytics of the Basic Neomonetarist Model". *Journal of Money, Credit and Banking*, 27, 1241-1277.

Klenow, Peter, and Oleksiy Kryvtsov (2008) "State-Dependent and Time-Dependent Pricing: Does It Matter for U.S. Inflation?" *Quarterly Journal of Economics*, 123, 863-904.

Kongsamut, Piyabha, Sergio Rebelo, and Danyang Xie (2001) "Beyond Balanced Growth". *Review of Economic Studies*, 68, 869-882.

Leon-Ledesma, Miguel, and Alessio Moro (2017) "The Rise of

Services and Balanced Growth in Theory and Data". *Mimeo*, University of Kent School of Economics.

Long, John, and Charles Plosser (1983) "Real Business Cycles". *Journal of Political Economy*, 91, 39-69.

Mishkin, Frederic (2008) "Inflation Dynamics". *International Finance*, 10, 317-334.

Moro, Alessio (2012) "The Structural Transformation Between Manufacturing and Services and the Decline in the US GDP Volatility". *Review of Economic Dynamics*, 15, 402-415.

Moro, Alessio (2015) "Structural Change, Growth, and Volatility". *American Economic Journal: Macroeconomics*, 7, 259-294.

Nakamura, Emi, and Jon Steinsson (2008) "Five Facts about Prices: A Reevaluation of Menu Cost Models". *Quarterly Journal of Economics*, 123, 1415-1464.

Nakamura, Emi, and Jon Steinsson (2010) "Monetary Non-Neutrality in a Multisector Menu Cost Model". *Quarterly Journal of Economics*, 125, 961-1013.

Ngai, Rachel, and Christopher Pissarides (2007) "Structural Change in a Multisector Model of Growth". *American Economic Review*, 97, 429-443.

Pancrazi, Roberto, and Marija Vukotic (2016) "On the Effectiveness of Conventional Monetary Policy". *Mimeo*, University of Warwick.

Pasten, Ernesto, Raphael Schoenle, and Michael Weber (2016) "The Propagation of Monetary Policy Shocks in a Heterogeneous Production Economy". *Mimeo*, Booth School of Business, University of

Chicago.

Petrella, Ivan, Raffaele Rossi, and Emiliano Santoro (2018) "Monetary Policy with Sectoral Trade-offs". *Scandinavian Journal of Economics*, forthcoming.

Primiceri, Giorgio (2005) "Time Varying Structural Vector Autoregressions and Monetary Policy". *Review of Economic Studies*, 72, 821-852.

Rubio-Ramirez, Juan, Daniel Waggoner, and Tao Zha (2010) "Structural Vector Autoregressions: Theory of Identification and Algorithms for Inference." *Review of Economic Studies*, 77, 665-696.