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What is Keeping U.S. Core Inflation Low: Insights from a Bottom-Up Approach

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What is Keeping U.S. Inflation Low: Insights from a Bottom-Up Approach

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Abstract

Over the past two decades, U.S. core PCE goods and services inflation have evolved differently. Against the backdrop of global concerns of low inflation, we use this trend as motivation to develop a bottom-up model of U.S. inflation. We find that domestic forces play a larger role relative to foreign factors in influencing core services inflation, while foreign factors predominantly drive core goods price changes. When comparing forecasting performance, we find that both the aggregate Phillips curve and the bottom up approach give low root mean square errors. The latter, however, is more informative in tracing the effects of shocks and understanding the exact channels through which they affect aggregate inflation. Using scenario analysis—and given a relatively low sensitivity of core inflation to changes in slack, both at the aggregate Phillips curve and sub-components levels—we find that global pressures will likely keep core PCE inflation below 2 percent for the foreseeable future unless the dollar starts to depreciate markedly and the unemployment rate goes well below the natural rate. These results support the accommodative stance of monetary policy pursued thus far and, going forward, underscore the need for proceeding cautiously and very gradually in raising the federal funds rate.

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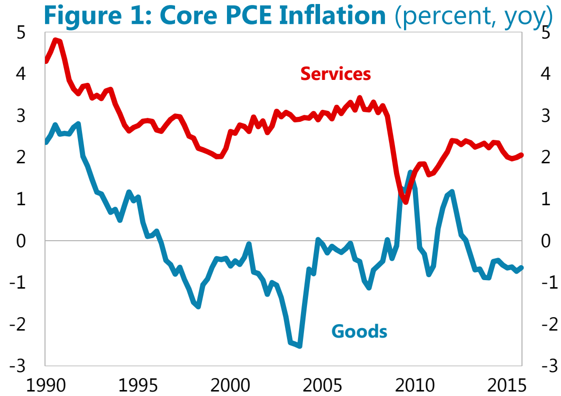
I. Introduction and Summary

A key question for U.S. monetary policy is future inflation dynamics.

Yet there is much uncertainty regarding these dynamics. Will core PCE inflation gradually rise towards 2 percent? Or will it continue the recent quite rapid increase and overshoot the 2 percent target fairly soon, forcing the Fed to raise the federal funds rate early and more quickly than currently expected?

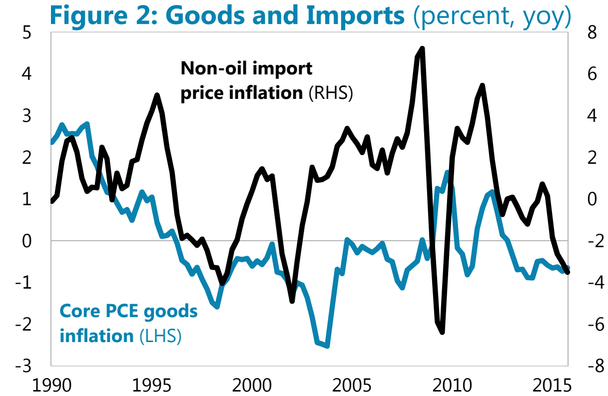
And the debate about the state and nature of the Phillips curve reflects this uncertainty. Many papers have documented the flattening of the Phillips curve from the mid-1970s through the early1990s (see for example Blanchard, 2016; and Gordon, 2013). Others have explored whether rather than an unemployment gap, some other measure of labor market slack should be used in the Phillips curve (e.g., the short-term unemployment rate, a broader employment gap measure, etc.—see Lansing, 2015; and Smith, 2014). And some commentators have argued that there may be a significant nonlinearity in the Phillips curve once the output gap gets close to zero or turns significantly positive (e.g., Clark and Laxton, 1997; Kumar and Orrenius, 2016).

Figure 1: Core PCE Inflation (percent, yoy)



Sources: BEA; Haver Analytics; and Authors' calculations

Figure 2: Goods and Imports (percent, yoy)



Sources: BEA; Haver Analytics; and Authors' calculations

Another key element of the current conjuncture is global concerns about low inflation. One way of seeing how this may be impacting the U.S. is to look at the very different trends in core PCE goods and services inflation (Figure 1).[2] Core services inflation declined through the 1990s from close to 5 percent to 2 percent, climbed again in the 2000s to reach 3.4 percent on the eve of the Great Recession, but then fell significantly during the Great Recession. It has recovered since then, but at around 2 percent remains significantly below levels seen earlier. Core goods inflation, on the other hand, has often been *negative* over the last twenty years, likely reflecting the impact of global pressures (Figure 2). Indeed, core goods inflation seems to react to nonpetroleum import prices with a lag, and the latter have been on a downward trend since late-2011.

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[2] We focus on the PCE measure of inflation as this is the preferred measure of the Federal Reserve. This is because PCE includes all goods and services consumed in the U.S. whether they are purchased by consumers or by employers or federal programs on behalf of consumers. The CPI on the other hand captures only what urban consumers spend out-of-pocket for a common basket of goods and services. Core services are total services less energy-related services, while core goods strip out the food component and energy goods from total goods.

Aggregate analysis only allows a limited understanding of the channels by which global pressures are impacting U.S. inflation. Moreover, it does not really facilitate the analysis of sector-specific factors such as the impact of the Affordable Care Act (ACA) on healthcare inflation. To really understand how external, domestic, and idiosyncratic factors drive the different components of inflation, one needs to develop a structural or "bottom-up" model, which is the goal of this paper. Specifically, we develop models of inflation for import prices, core goods, healthcare services, housing services, and core services excluding healthcare and housing. We then combine these models into one for aggregate PCE inflation.

The overall findings of the paper are:

- Core goods inflation is driven mainly by global price pressures and dollar movements. Domestic factors (e.g. the unemployment gap) help explain core services inflation, and it is important to separately model housing and healthcare subcomponents of services inflation.

- The aggregate inflation forecasts from this "bottom-up" approach have small root mean square errors (RMSEs), although the RMSEs using an aggregate Phillips curve equation are also small. The former, however, is more informative in tracing the effects of shocks and understanding the exact channels through which they affect overall inflation.

- When we use the bottom up model for forecasting inflation in 2016 and beyond, our benchmark scenario has inflation gradually rising towards but not reaching 2 percent by 2020, given the headwinds caused by global price pressures. This benchmark scenario uses the Congressional Budget Office's (CBO) forecast for the unemployment gap (which troughs at around -0.4 percent in 2017 before starting to increase and turning positive in 2019), assumes the dollar remains constant in nominal effective terms, house price inflation remains around levels of late 2015, and the impact of the public spending cuts on health care inflation gradually declines.[3]

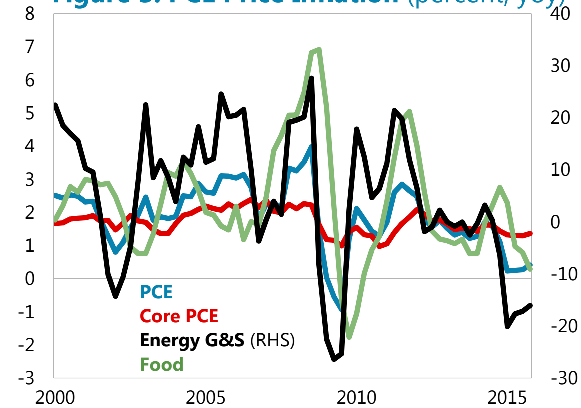
- Core PCE inflation could, however, reach as high as 2.4 percent by 2018 if the dollar were to depreciate, the unemployment rate goes well below the natural rate, house price inflation climbs, and there is a more temporary impact of public spending cuts on health services inflation.

- These forecasts assume inflation expectations stay well anchored. If inflation expectations do become unanchored, then of course inflation could rise more rapidly and reach a higher level. This, however, seems a very unlikely scenario. The forecasts also assume the absence of nonlinearities in the Phillips curve, which is empirically supported by our recursive analysis and direct tests.

[3] It is important to note that the analysis in this paper and resulting inflation forecasts are only one input into IMF staff's inflation forecasts for the U.S. in the World Economic Outlook. The latter are determined within a broader macroeconomic framework and so are not the same.

The rest of paper is structured as follows. Section II explains in more detail why looking at the subcomponents of core PCE inflation matters. Section III discusses the general-to-specific empirical methodology and uses the aggregate Phillips curve to illustrate it and to have a benchmark. Section IV discusses and estimates the various equations of the bottom-up model. Section V evaluates the model by looking at parameter stability tests and out of sample forecasting performance, including how it stacks up against the aggregate Phillips curve model. Section VI documents various PCE inflation forecast scenarios using the bottom-up model and Section VII concludes.

Figure 3: PCE Price Inflation (percent, yoy)

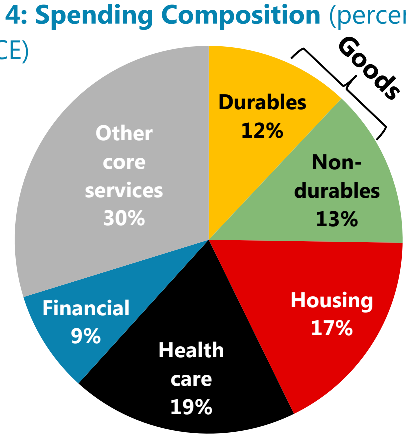


Sources: BEA; Haver Analytics; and Authors' calculations

II. Why Looking at The Subcomponents of Core PCE Inflation Matters

As shown in Figure 3, food and energy prices are very volatile and can drive major swings in headline inflation. Hence we focus on core PCE inflation in this paper. This is consistent with the actual practice of many advanced economy central banks, which focus on core inflation developments and prospects as a truer indicator of overall inflation pressures.

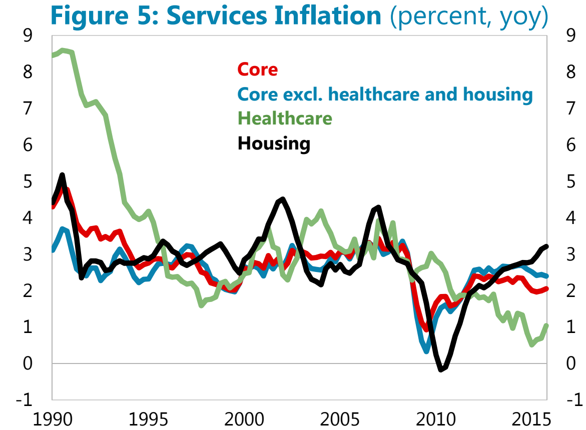
Figure 4: Spending Composition (percent of core PCE)



Sources: BEA; Haver Analytics; and Authors' calculations

Within core PCE, goods represent about ¼ of the consumption basket, while services make up the rest (Figure 4). Within services, housing and healthcare comprise nearly half of the expenditures.

Figure 5: Services Inflation (percent, yoy)



Sources: BEA; Haver Analytics; and Authors' calculations

And as shown in Figure 5, housing and healthcare inflation have displayed very different dynamics to inflation in other services' components.

If we look at core services inflation excluding housing and healthcare, this has oscillated between 2 and 3.5 percent from 1990 until the Great Recession.[4] During the Great Recession it declined significantly but has gradually increased since to about 2½ percent.

[4] Core services price changes are approximated as a weighted sum of the prices changes in: core services excluding housing and healthcare; housing services; and healthcare. The weights are spending shares in core services. Core services excluding housing and healthcare are computed as a residual.

By comparison, inflation in housing and healthcare services has been much more volatile. Healthcare inflation fell during the 90s from close to 10 percent to less than 2 percent. It started rising again in the late 90s and peaked above 4 percent in 2004. Since 2010, it has largely been on a secular decline although it started rising in 2015. Housing services inflation had two peaks in the 2000s of about 4½ percent (in 2002 and 2007). Following the Great Recession, housing services inflation fell precipitously, actually turning negative in 2010. Since then, it has steadily increased, and is now above 3 percent.

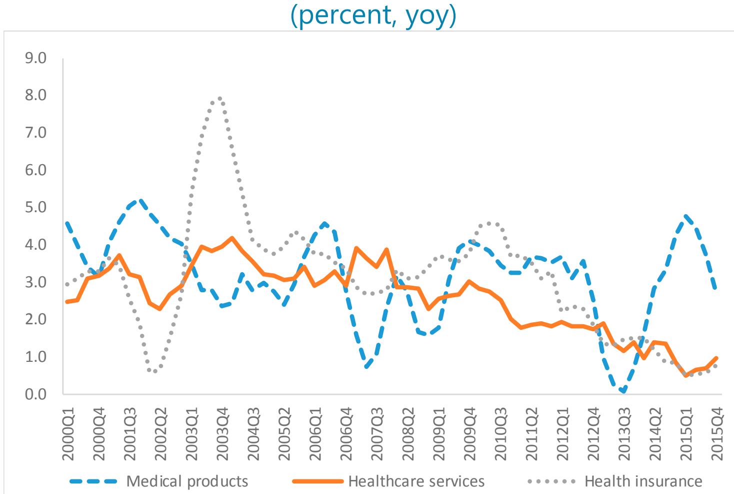
The dynamics of housing and healthcare inflation undoubtedly reflect cyclical economic factors, but they are also driven by important structural and idiosyncratic factors.

The sharp decline in healthcare inflation in the early 1990s and the rebound in late 1990s and early 2000s to a large extent were driven by the expansion of managed care and its subsequent retreat (Aaron, 2002). The credible threat of reform at the beginning of the Clinton administration may have also played a role (Altman and Levitt, 2002). The recent decline in healthcare inflation reflects a combination of factors such as the economic downturn since the global financial crisis and changes in healthcare policies (the Affordable Care Act (ACA) and sequestration) (Appendix I).

Even within healthcare, different components display very different patterns in terms of their inflation dynamics (Figure 6). Healthcare consists of three major components in PCE, medical products as part of PCE core goods and healthcare services and health insurance as part of PCE core services. Healthcare services account for the largest share, at around 77 percent in 2015 and medical products and health insurance account for 17 percent and 6 percent respectively. Consequently, healthcare services are modeled separately while medical goods are modeled as part of core goods and health insurance as part of core services excluding healthcare and housing.

Figure 6: Healthcare Inflation by Component

(percent, yoy)



Source: Haver DLX databases.

Turning to housing, the pickup in housing inflation in the mid-2000s coincided with a housing boom and a long period of house price appreciation. And the subsequent collapse in housing inflation coincided with the housing bust period.

In sum, core goods and core services inflation have displayed very different dynamics. And within services, housing and healthcare inflation have been more volatile and appear to contain important idiosyncratic structural components. Together this suggests that modeling some of these components of inflation separately will likely provide important insights into what is driving overall inflation, which is what we turn to next.

But first, an important point is in order. One might argue that such a bottom-up approach to modeling inflation entails some loss of information because it implicitly assumes that price changes in some core items move independently from other items. For example, the approach assumes that inflation in healthcare, housing or other core services contains no information that is useful to predict core goods inflation. The distinct dynamics of core goods and core services provides some evidence that such an assumption is reasonable. As will be seen in Section IV, we supplemented this intuition though with formal testing, and we found no statistical or economically meaningful evidence to support the hypothesis that the dynamics of core services prices and core goods prices mutually matter for one another.

III. Empirical Methodology

We employ the general-to-specific modeling approach advocated by David Hendry—see for example Campos, Ericsson, and Hendry (2005) for an overview and key papers. The approach begins by postulating a general model that includes everything that can potentially matter, as motivated by prior theoretical and empirical research. Statistically insignificant variables are then sequentially removed, and a final parsimonious model is selected. We use various information criteria and finite sample F-tests to guide the selection process. The final model includes only significant variables and is checked to ensure that it is not path dependent—that is, it is invariant to the sequence in which the insignificant variables are dropped. The residuals of the final model are also checked and subjected to extensive testing to ensure that they are approximately white noise. And the parameters are tested for constancy, which is a prerequisite for generating reliable forecasts.

A. A Benchmark Model—The Aggregate Phillips Curve

The General Unrestricted Model (GUM) for Core PCE. We begin by formulating and estimating the following dynamic model for aggregate core PCE inflation over the period 1996Q1-2015Q4, which will serve as a benchmark against which the bottom up approach would be assessed:

$$\begin{aligned} \text{CorPCE\_Gyoy}_t &= \sum_{i=1}^{4}\alpha_i \text{CorPCE\_Gyoy}_{t-i} + \sum_{i=0}^{4}\beta_i \text{Ugap\_CBO}_{t-i} + \sum_{i=0}^{4}\delta_i \text{ImNPRlagCor\_gyoy}_{t-i} \\ &+ \sum_{i=0}^{4}\varphi_i \text{OilPRlagCor\_gyoy}_{t-i} + \lambda\,\text{InfExp\_LongTerm}_t + \mu\,\text{InfExpShortTerm}_t + \sum_{i=1}^{4}\pi_i \text{ROWyoyInfla}_{t-i} \\ &+ \psi\,\text{ROWyoyInflExp1yr}_t + \varepsilon_t \end{aligned} \tag{1}$$

The model is a Phillips curve. Year-over-year core PCE inflation is modeled as a function of past inflation, and current and lagged values of: the deviation of unemployment from the natural rate (unemployment gap); growth of the relative price of non-petroleum imports; and changes in relative oil prices. Inflation is also postulated to depend not only on domestic inflation expectations but also on foreign inflation expectations, which are modeled as partly backward looking (proxied by past foreign inflation), and partly forward looking (measured by consensus forecasts of inflation in the rest of the world). This is intended to allow for a potential direct pass through from foreign to domestic inflation via an expectation channel. Otherwise, the specification of the Phillips curve is standard: inflation varies negatively with labor market slack and positively with changes in relative prices and inflation expectations—the so-called Gordon's triangular model (see, for example Gordon, 2011).[5] For the latter, we distinguish between short-term (1 year ahead) and long-term (5 to 10 years ahead) expectations (see Appendix II for a detailed definition of all the variables used in this paper).

To ease comparison with the literature, we use standard measures of the explanatory variables. We approximate the unemployment gap by the difference between the actual unemployment rate and the CBO's series for the long-run natural rate. We express the prices of non-oil imports and oil (West Texas Intermediate) relative to last period's core PCE price index, and measure inflation expectations by two alternatives: the first is the forecast of PCE inflation reported in the Survey of Professional Forecasters; and the second is households' inflation expectations from the University of Michigan's Surveys of Consumers.[6]

Estimating the GUM and employing the general-to-specific approach outlined above revealed the following:

What didn't Matter. We found no statistically significant effect, either individually or jointly, on core PCE inflation of:

- *Oil prices*. This is consistent with various studies that document a lack of a statistically significant pass through from oil prices to core measures of inflation since the 1990s. A significant pass through has been found in the literature only during the 1980s and 1970s (see, for example, Hooker, 2002; Cavallo, 2008; and Clark and Terry, 2010).

- *Foreign inflation*—both past values and consensus forecasts. This is evidence against a direct impact of foreign inflation on domestic inflation via expectations. However, this does not preclude an indirect impact operating through import prices, which we find and will discuss in the following section.[7]

- *Short-term measures of inflation expectations.* They drop once we control for past inflation and long-term inflation expectation measures. This result makes sense given that we also found that the latter two are empirically the primary determinants of short term expectations.

What Mattered. In Table 1 below, we report the results of the final model using both measures of inflation expectations. We report the statistically significant variables, their coefficient estimates, the sums of the coefficient estimates, and the long-run estimates that emerge after the models' dynamics have fully played out. The coefficients have the expected

[5] In Gordon's triangular model, changes in relative oil prices and in relative non-oil import prices are typically included to account for supply shocks.

[6] Note that we include not the current but the one-period lag of the price index for core PCE in the denominator of relative price variables. This is intended to avoid endogeneity issues given that current core PCE prices are what we are modeling.

[7] We experimented with versions of the model that replace foreign inflation with a global measure of the output gap excluding the United States. We found such a measure to also be statistically insignificant.

signs and are very similar across both measures of inflation expectations. The models indicate that past inflation, labor market slack, relative non-oil import prices, and inflation expectations are the key drivers of core PCE inflation. The unemployment gap has a small coefficient, both contemporaneously and in the long run, -0.04 and - 0.1, respectively. This is consistent with the literature that suggests a relatively flat Phillips curve since the 1990s. The long run coefficients of inflation expectations are close to unity, suggesting reasonably anchored expectations. Relative import prices have a contemporaneous coefficient of about 0.1 and a long run coefficient in the range of 0.12–0.14. Quantitatively, all these numbers are broadly in line with the literature (see, for example, Blanchard, 2016; Blanchard et. al, 2015; Yellen, 2015; IMF, 2013; and Gordon, 2013).

Table 1: Final Regressions for Core PCE Inflation

Modeling CorPCE_Gyoy, with Households' inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Coefficient	SE	t-value	t-prob
CorPCE_Gyoy_1	0.843	0.060	14.10	0.000
CorPCE_Gyoy_4	-0.220	0.054	-4.03	0.000
Ugap_CBO	-0.037	0.010	-3.88	0.000
ImNPRlagCor_gyoy	0.083	0.011	7.46	0.000
ImNPRlagCor_gyoy_1	-0.076	0.012	-6.34	0.000
ImNPRlagCor_gyoy_4	0.039	0.007	5.96	0.000
Inf_umexp_5to10yr	0.252	0.039	6.45	0.000

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
CorPCE_Gyoy	0.623235	0.0602	10.35
Ugap_CBO	-0.04	0.010	-3.88
ImNPRlagCor_gyoy	0.05	0.009	5.27
Inf_umexp_5to10yr	0.25	0.039	6.45

Solved static long-run equation for CorPCE_Gyoy

	Coefficient	SE	t-value	t-prob
Ugap_CBO	-0.10	0.023	-4.28	0.000
ImNPRlagCor_gyoy	0.12	0.023	5.32	0.000
Inf_umexp_5to10yr	0.67	0.019	36.20	0.000

Source: Authors' estimates

Modeling CorPCE_Gyoy, with SPF inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Coefficient	SE	t-value	t-prob
CorPCE_Gyoy_1	0.866	0.062	13.90	0.000
CorPCE_Gyoy_4	-0.180	0.055	-3.25	0.002
Ugap_CBO	-0.036	0.010	-3.52	0.001
ImNPRlagCor_gyoy	0.092	0.012	7.90	0.000
ImNPRlagCor_gyoy_1	-0.083	0.013	-6.63	0.000
ImNPRlagCor_gyoy_4	0.036	0.007	5.27	0.000
PCE_pfexp10yr_JY	0.290	0.052	5.58	0.000

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
CorPCE_Gyoy	0.69	0.058	11.75
Ugap_CBO	-0.04	0.010	-3.53
ImNPRlagCor_gyoy	0.05	0.009	4.84
PCE_pfexp10yr_JY	0.29	0.052	5.59

Solved static long-run equation for CorPCE_Gyoy

	Coefficient	SE	t-value	t-prob
Ugap_CBO	-0.11	0.029	-3.92	0.00
ImNPRlagCor_gyoy	0.14	0.029	4.87	0.00
PCE_pfexp10yr_JY	0.92	0.032	28.70	0.00

Source: Authors' estimates

IV. A Bottom-Up Empirical Model

There are 5 parts to modeling inflation from the bottom up. Below we build individual models for price changes in: imports; core goods; core services excluding healthcare and housing, housing services, and healthcare services. Then we combine forecasts from these models to form a composite forecast for overall core PCE inflation. We also conduct scenario analysis where we simulate the path of core PCE inflation from the bottom up under various assumptions underlying the economic environment.

A. Import Price Equation

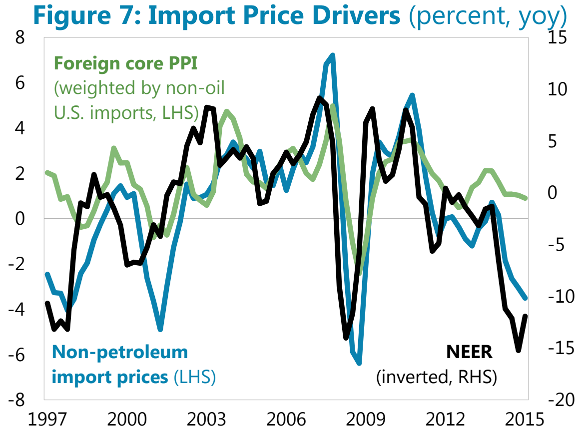
The GUM for Import Prices. We begin with a dynamic specification that is standard in the empirical literature, as in Gopinath, 2015; Burstein and Gopinath, 2014; and Campa and Goldberg, 2005:

$$\text{ImPNopet\_Gyoy}_t = \sum_{i=1}^{4} \alpha_i \, \text{ImPNopet\_Gyoy}_{t-i} + \sum_{i=0}^{4} \beta_i \, \text{NEER\_Gyoy}_{t-i} + \sum_{i=0}^{4} \mu_i \, \text{PPI\_CorNOImWt\_M4\_Rev\_Gyoy}_{t-i} + \varepsilon_t \quad (2)$$

Growth of non-oil import prices depends on its own lags, as well as current and lagged values of the growth of: the nominal effective exchange rate for the dollar; and the foreign core Producer Price Index (PPI). Intuitively, cheaper U.S. imports can potentially display inertia, and can come about from two key sources: a stronger currency and/or low inflation in key trading partners (Figure 7). An important modification to note is that the PPI index excludes oil to the extent possible, and includes 4 major zones/countries: China, the Euro zone, Mexico, and Canada, which account for about 80 percent of total U.S. non-oil imports. The overall Index is constructed as a weighted sum of the individual PPIs, with weights computed as non-oil import shares. As shown in Figure 8, the overall index moves very closely with China's PPI (China accounts for about 25 percent of U.S. imports).

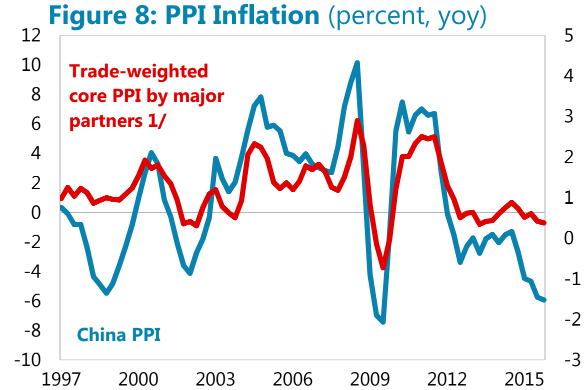
Results. The final model that best describes the data is reported in Table 2. A ten percent appreciation of the dollar in nominal effective terms is estimated to result in a fall in import prices by about 1.4 percent contemporaneously and 4.1 percent in the long run. A drop in foreign PPI inflation by 10 percent would lead to a cumulative fall in U.S. import prices by about 2 percent after a quarter and 5.5 percent in the long run. These results are broadly in line with the literature (see, for example, Gopinath, 2015; and Gruber, McCallum and Vigfussion, 2016).

Figure 7: Import Price Drivers (percent, yoy)



Sources: BEA; FRB; Haver Analytics; and Authors' calculations

Figure 8: PPI Inflation (percent, yoy)



Sources: China National Bureau of Statistics; Eurostat; FRB; Haver Analytics; INEGI; Statistics Canada; and Authors' calculations
1/ Canada, China, Euro Area, and Mexico

Table 2: Final Regressions for Nonpetroleum Import Price Inflation

Modeling ImPNopet_Gyoy

The estimation sample is: 1998(1) - 2015(4)

	Coefficient	SE	t-value	t-prob
ImPNopet_Gyoy_1	0.668	0.043	15.60	0.000
NEER_Gyoy	-0.136	0.015	-9.07	0.000
PPI_CorNOImWt_M4_Rev_Gyoy	0.681	0.073	9.39	0.000
PPI_CorNOImWt_M4_Rev_Gyoy_1	-0.497	0.082	-6.09	0.000

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
ImPNopet_Gyoy	0.668	0.0427	15.64
NEER_Gyoy	-0.14	0.015	-9.07
PPI_CorNOImWt_M4_Rev_Gyoy	0.18	0.046	4.02

Solved static long-run equation for ImPNopet_Gyoy

	Coefficient	SE	t-value	t-prob
NEER_Gyoy	-0.41	0.050	-8.18	0.00
PPI_CorNOImWt_M4_Rev_Gyoy	0.55	0.097	5.74	0.00

Source: Authors' estimates

B. Core Goods

The GUM for Core Goods. The set-up is very similar to the one for overall core PCE inflation:

$$\begin{aligned} CorPceGds\_Gyoy_t &= \sum_{i=1}^{4} \alpha_i \, CorPceGds\_Gyoy_{t-i} + \sum_{i=0}^{4} \beta_i \, Ugap\_CBO_{t-i} + \sum_{i=0}^{4} \delta_i \, ImNPRlagCorgds\_gyoy_{t-i} \\ &+ \sum_{i=0}^{4} \varphi_i \, OilPRlagCorgds\_gyoy_{t-i} + \lambda \, InfExp\_LongTerm_t + \mu \, InfExpShortTerm_t + \sum_{i=1}^{4} \pi_i \, ROWyoyInfl_{t-i} \\ &+ \psi \, ROWyoyInfExp1yr_t + constant + \rho \, I:2003\,(2) + \tau \, I:2009\,(2) + \varepsilon_t \end{aligned} \tag{3}$$

The difference is that now the lagged dependent variable is past growth of core goods prices; also non-oil import prices and oil prices are now expressed relative to last period's index of core PCE goods. Finally, two dummy variables are added to the specification. They take the value of unity in 2003Q2 and 2009Q2, respectively and zero otherwise. Statistically, the dummy variables improve residual diagnostics. Conceptually, they capture tobacco tax hikes.

Results. They are interesting. Like in the core PCE equation, oil prices, past foreign inflation, foreign inflation expectations, and the short term inflation expectations, all do not exert a statistically significant impact on core goods inflation. In addition, though, long term inflation expectations do not appear to matter, whether measured by professional forecasters or households. This is not surprising given that core goods inflation has been negative for most of the sample period, and hence the gravitational pull of expectations does not appear to work here. As will be shown below, expectations perform this role with core services. This result is also consistent with the view that sectors with relatively large import content (core goods in this case) are less linked to domestic inflation expectations. At the same time, we find the unemployment gap not to matter statistically. This is consistent with empirical research by the New York Fed (Peach, Rich, and Linder, 2013), and the view that global rather than domestic factors matter for core goods inflation. In fact, as shown in Table 3, our final model points to a specific channel through which global factors influence core goods inflation, and that is through import prices.[8]

C. Core Services excluding Healthcare and Housing

The GUM for Core Services Excluding Healthcare and Housing. Once again, we begin with the same set of explanatory variables as in the core PCE inflation; the difference of course is that now we adjust the lagged dependent variable to capture past price changes in core PCE services (excluding healthcare and housing). Also, we normalize relative prices by the last period's index of prices for core services (excluding healthcare and housing).

Results. They are broadly similar to those of core PCE. The only variables that statistically matter are past inflation, the unemployment gap, growth in relative non-oil import prices, and long-term inflation expectations. As shown in Table 4, the results are also very similar across the final models with the alternative inflation expectations measures. It is interesting to note that the coefficients on inflation expectations in the long run are large when compared to the Core PCE inflation final models, which is needed to offset the absence of the gravitational

[8] One might argue that price changes in goods may influence, and may be influenced by, price changes in services due to substitutability between them. We did not find empirical support for this notion in either direction.

pull of expectations in the core goods equation. As will be shown below, shelter and healthcare also contribute in this regard. Similarly, the lack of significance of the unemployment gap in the core goods inflation helps explain why the long run coefficient on the gap is much larger in the services equation than in the overall core PCE equation. Finally, relative import prices play a larger role in the core goods equation than the core services equation, consistent with the import content of goods being higher than services.

Table 3: Final Regressions for Core PCE Goods Inflation

Modeling CorPceGds_Gyoy

The estimation sample is: 1996(1) - 2015(4)

	Coefficient	SE	t-value	t-prob
CorPceGds_Gyoy_1	0.891	0.049	18.300	0.000
CorPceGds_Gyoy_4	-0.150	0.046	-3.250	0.002
Constant	-0.194	0.041	-4.760	0.000
ImNPRLagCorgds_gyoy	0.102	0.028	3.690	0.000
ImNPRLagCorgds_gyoy_1	-0.121	0.033	-3.710	0.000
ImNPRLagCorgds_gyoy_3	0.081	0.018	4.470	0.000
I:2003(2)	-0.675	0.295	-2.290	0.025
I:2009(2)	1.228	0.319	3.850	0.000

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
CorPceGds_Gyoy	0.74	0.05	15.15
Constant	-0.19	0.04	-4.75
ImNPRLagCorgds_gyoy	0.06	0.02	4.08
I:2003(2)	-0.68	0.30	-2.29
I:2009(2)	1.23	0.32	3.86

Solved static long-run equation for CorPceGds_Gyoy

	Coefficient	SE	t-value	t-prob
Constant	-0.75	0.149	-5.040	0.000
ImNPRLagCorgds_gyoy	0.24	0.079	3.060	0.003
I:2003(2)	-2.60	1.170	-2.230	0.029
I:2009(2)	4.74	1.547	3.070	0.003

Source: Authors' estimates

Table 4: Final Regressions for Core PCE Services Inflation (Excluding Healthcare and Housing)

Modelling CorPceSerExcHH_Gyoy, with Households' inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Coefficient	SE	t-value	t-prob
CorPceSerExcHH_Gyoy_1	1.027	0.060	17.10	0.000
CorPceSerExcHH_Gyoy_3	-0.259	0.057	-4.53	0.000
Ugap_CBO	-0.367	0.083	-4.41	0.000
Ugap_CBO_2	0.527	0.154	3.41	0.001
Ugap_CBO_4	-0.206	0.087	-2.36	0.021
ImNPRLagCorSerEHH_gyoy	0.061	0.014	4.27	0.000
ImNPRLagCorSerEHH_gyoy_2	-0.071	0.020	-3.62	0.001
ImNPRLagCorSerEHH_gyoy_4	0.052	0.014	3.61	0.001
Inf_umexp_5to10yr	0.240	0.053	4.52	0.000

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
CorPceSerExcHH_Gyoy	0.77	0.055	13.86
Ugap_CBO	-0.05	0.018	-2.58
ImNPRLagCorSerEHH_gyoy	0.04	0.014	2.97
Inf_umexp_5to10yr	0.24	0.053	4.53

Solved static long-run equation for CorPceSerExcHH_Gyoy

	Coefficient	SE	t-value	t-prob
Ugap_CBO	-0.20	0.077	-2.58	0.012
ImNPRLagCorSerEHH_gyoy	0.18	0.067	2.65	0.010
Inf_umexp_5to10yr	1.03	0.070	14.8	0.000

Source: Authors' estimates

Modelling CorPceSerExcHH_Gyoy, with SPF inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Coefficient	SE	t-value	t-prob
CorPceSerExcHH_Gyoy_1	1.001	0.063	15.90	0.000
CorPceSerExcHH_Gyoy_3	-0.225	0.055	-4.12	0.000
Ugap_CBO	-0.376	0.083	-4.52	0.000
Ugap_CBO_2	0.532	0.154	3.47	0.001
Ugap_CBO_4	-0.205	0.087	-2.36	0.021
ImNPRLagCorSerEHH_gyoy	0.070	0.014	4.92	0.000
ImNPRLagCorSerEHH_gyoy_2	-0.073	0.020	-3.74	0.000
ImNPRLagCorSerEHH_gyoy_4	0.047	0.014	3.31	0.001
PCE_pfexp10yr_JY	0.319	0.070	4.56	0.000

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
CorPceSerExcHH_Gyoy	0.78	0.053	14.59
Ugap_CBO	-0.05	0.018	-2.67
ImNPRLagCorSerEHH_gyoy	0.04	0.014	3.16
PCE_pfexp10yr_JY	0.32	0.070	4.56

Solved static long-run equation for CorPceSerExcHH_Gyoy

	Coefficient	SE	t-value	t-prob
Ugap_CBO	-0.22	0.080	-2.68	0.009
ImNPRLagCorSerEHH_gyoy	0.20	0.070	2.82	0.006
PCE_pfexp10yr_JY	1.42	0.100	14.30	0.000

Source: Authors' estimates

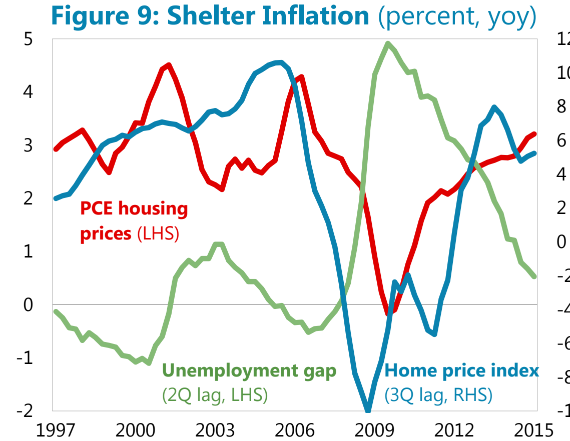
D. Housing

The GUM for Housing. We postulate the following dynamic model for price changes in housing services that incorporates typically-suggested explanatory variables in the literature (see for example Higgins and Verbrugge (2014) for a discussion):

$$\begin{aligned} PCE\_HousSer\_Gyoy_t &= \sum_{i=1}^{4} \alpha_i \, PCE\_HousSer\_Gyoy_{t-i} + \sum_{i=0}^{4} \beta_i \, Ugap\_CBO_{t-i} \\ &+ \sum_{i=0}^{4} \delta_i \, HPI\_PO\_Gyoy_{t-i} + \sum_{i=0}^{4} \rho_i \, Mor30yrReal_{t-i} + \sum_{i=1}^{4} \mu_i \, VacanRate\_rent_{t-i} \\ &+ \sum_{i=1}^{4} \psi_i \, VacanRate\_HomOwn_{t-i} + \sum_{i=1}^{4} \tau_i \, Pop\_Gyoy_{t-i} + \lambda \, InfExp\_LongTerm_t \\ &+ \varphi \, RntP\_HPI\_PO_{t-1} + \varepsilon_t \end{aligned} \tag{4}$$

Growth of the price index for housing services/shelter (which captures mostly rents) potentially depends on its lags; current and lagged values of: the unemployment gap, growth of housing prices, and real mortgage rates; lagged values of: vacancy rates—considered by some as leading indicators—and population growth; long term inflation expectations; and last period's rent/home price ratio. Conceptually, declining slack, vacancy rates, rent-price ratios and mortgage rates could potentially feed into higher rent inflation. And so could rising home prices, population, and inflation expectations.

Figure 9: Shelter Inflation (percent, yoy)



Sources: BEA; Haver Analytics; and Authors' calculations

Results. We find housing services inflation to display considerable inertia. We also find lagged slack and home price appreciation, as well as long-term inflation expectations to be housing services inflation's key drivers (see Figure 9 and Table 5). The other commonly suggested indicators do not appear to matter. These results are in line with prior work in this area (see, for example Mericle (2014), and Higgins and Verbrugge (2014)).[9]

[9] Our results are robust to using average effective mortgage rates as alternatives to the 30 year fixed rates. They are also robust to including relative import prices in the empirical specification. These turn out to be insignificant, which is not surprising given the low import content in rents.

Table 5: Final Regressions for PCE Housing Services Inflation

Modeling PCE_HousSer_Gyoy, with Households' inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Coefficient	SE	t-value	t-prob
PCE_HousSer_Gyoy_1	1.505	0.07	21.20	0.000
PCE_HousSer_Gyoy_2	-0.704	0.07	-10.60	0.000
HPI_PO_Gyoy_3	0.014	0.00	3.18	0.002
Inf_umexp_5to10yr	0.185	0.03	5.50	0.000
Ugap_CBO_2	-0.053	0.02	-2.98	0.004

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
PCE_HousSer_Gyoy	0.80	0.031	25.93
HPI_PO_Gyoy	0.01	0.005	3.19
Inf_umexp_5to10yr	0.19	0.034	5.51
Ugap_CBO	-0.05	0.018	-2.97

Solved static long-run equation for PCE_HousSer_Gyoy

	Coefficient	SE	t-value	t-prob
HPI_PO_Gyoy	0.07	0.024	3.04	0.003
Inf_umexp_5to10yr	0.93	0.056	16.50	0.000
Ugap_CBO	-0.26	0.069	-3.82	0.000

Source: Authors' estimates

Modeling PCE_HousSer_Gyoy, with SPF inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Coefficient	Std.Error	t-value	t-prob
PCE_HousSer_Gyoy_1	1.519	0.072	21.10	0.00
PCE_HousSer_Gyoy_2	-0.707	0.068	-10.40	0.00
HPI_PO_Gyoy_3	0.017	0.005	3.66	0.00
PCE_pfexp10yr_JY	0.228	0.044	5.15	0.00
Ugap_CBO_2	-0.045	0.017	-2.58	0.01

Analysis of lag structure, coefficients:

	Sum	SE(Sum)	t-value
PCE_HousSer_Gyoy	0.81	0.03	26.37
HPI_PO_Gyoy	0.02	0.00	3.67
PCE_pfexp10yr_JY	0.23	0.04	5.16
Ugap_CBO	-0.04	0.02	-2.58

Solved static long-run equation for PCE_HousSer_Gyoy

	Coefficient	Std.Error	t-value	t-prob
HPI_PO_Gyoy	0.09	0.03	3.55	0.00
PCE_pfexp10yr_JY	1.21	0.08	15.10	0.00
Ugap_CBO	-0.24	0.07	-3.21	0.00

Source: Authors' estimates

E. Healthcare Services

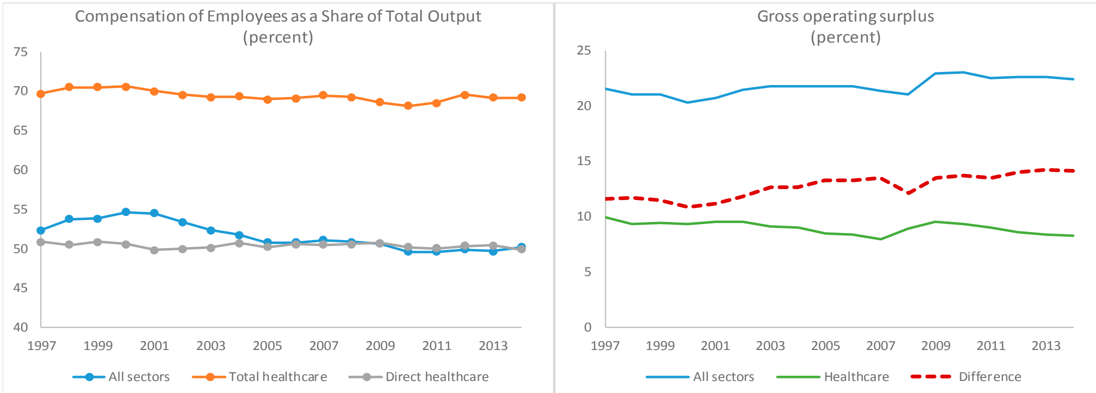
Healthcare services inflation is driven by various factors which often are interlinked among themselves (see Appendix I). A structural model approach aims to uncover exactly how these factors affect each other and ultimately healthcare services inflation. The key advantage of such an approach is that it allows for a better understanding of the channels through which each factor contributes to inflation, and thus is better equipped to analyze the potential impacts of different policies. Alternatively, a reduced-form approach ignores the intermediate steps and focuses on the relationship between healthcare services inflation and the ultimate determinants. The key advantage of this approach is its simplicity. In addition, reduced-form models are likely to have a better goodness-of-fit relative to structural models.

Here we try to strike a good balance between these two approaches. We only model key intermediate determinants of healthcare services inflation so that we understand the main channels—for example, growth of the healthcare employment cost index (ECI)—and at the same time minimize modeling errors by not having structural equations for other intermediate determinants. A consistent approach in model selection is applied here in determining the final specifications as for the other components of core inflation.

ECI Health Equation

Analysis based on input-output tables indicates that compensation of employees accounts for about 50 percent of the output for the economy as a whole. The share in the healthcare services is much higher at 70 percent, of which 50 percent is for direct compensation of employees and the rest is for compensation of employees through intermediate inputs (Figure 10). This suggests that healthcare ECI growth could be a key driver of overall health inflation, especially given low productivity growth in the sector (Figure 11).

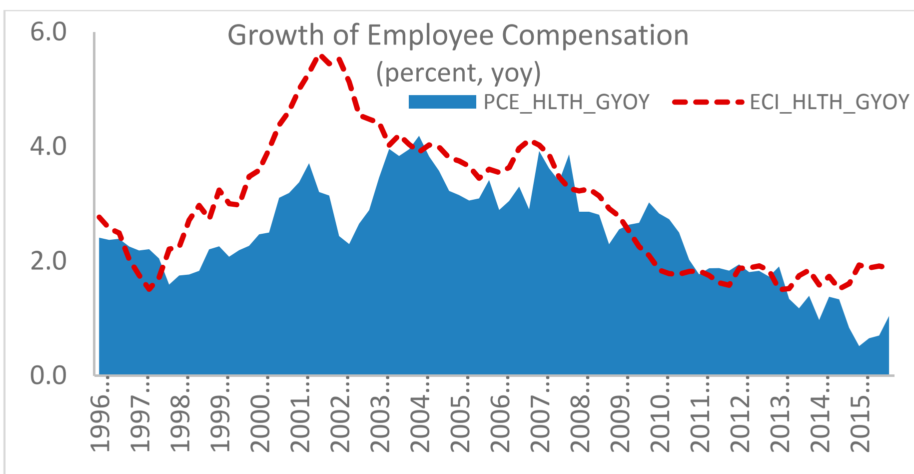
Figure 10: Compensation of Employees and Operating Surplus



Source: 1997-2014 input-output tables from Bureau of Economic Analysis and IMF staff calculations.

The GUM for Healthcare ECI. We therefore have a structural model for healthcare ECI growth, where the latter is postulated to depend on its own lags (up to four), inflation expectations, as well as current and four lags of: the change in the gross operating surplus in all the sectors of the economy; the unemployment gap; growth in relative import prices; the change in the proportion of the population that is not insured (henceforth, the un-insurance rate); the change in gross operating surplus in the health sector; and payment cuts in the public sector.[10]

Figure 11: Growth of Healthcare ECI and Healthcare Services Inflation



Source: 2004-2015 ECI for total compensation (healthcare and social assistance, hospitals, nursing and residential care facilities) from the Bureau of Labor Statistics; healthcare ECI is a weighted average of the three components with weights from input-output tables; healthcare ECI prior to 2004 is imputed using the ECI series for hospitals and private nursing and residential care facilities. The imputed healthcare ECI is only included here and is not used in later regression analysis; Haver DLX databases; and IMF staff calculations.

[10] Payment cuts in the public sector are measured by the policy effects of payment cuts (including coverage shift from the Affordable Care Act) as reported in Phillips (2015).

Results. The key findings are as follows:

- The change in the un-insurance rate appears significant in some specifications with the expected sign (an increase in the un-insurance rate reduces ECI health growth). But this result does not appear to be very robust, and the specification tests and pseudo out-of-sample predictions favor the model without it. The Massachusetts experience indicates that healthcare employment grew more rapidly in Massachusetts than the rest of the country after its healthcare reform (Staiger, Auerbach and Buerhaus, 2011). This suggests that the Affordable Care Act (ACA) could have a similar effect but at a much larger scale, leading to higher demand for healthcare workers and potentially more wage growth in the healthcare sector. This is therefore a key factor that needs to be carefully monitored as additional post-ACA data become available.

- In the final model, all of the variables are significant with the exception of the change in the un-insurance rate, which is dropped (Table 6). It is interesting to note that the unemployment gap has a very large impact (the sum of coefficients of the current and lagged value is about -⅓) consistent with the high labor share in the sector, while the long run coefficient on the public spending cuts variable is greater than one, suggesting a fairly strong effect on wages in the sector.

PCE Healthcare Services Equation

The GUM for Healthcare Services. We model PCE health inflation as a function of four of its own lags, inflation expectations, as well as current and four lags of: healthcare ECI growth; change in the un-insurance rate; the public sector payment cuts; the change in gross operating surplus in the health sector; the unemployment gap, and relative import prices[11].

Results. The key findings are as follows (also see Table 6):

- Even though all the regressors in the healthcare ECI growth model are included in the GUM of health inflation, ECI growth still emerges as a key predictor of healthcare services inflation, suggesting that it is a more direct determinant of healthcare services inflation and that it may contain additional information not captured by its regressors.

- The variable for payment cuts in the public sector is also a strong predictor of healthcare services inflation. The long-run coefficient of greater than one indicates that the impact of such cuts is beyond their direct impact on wages and is suggestive that they also lead to price reductions in the private sector, consistent with the latest literature.

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[11] While what matters most for healthcare services inflation is likely the difference between healthcare ECI growth and the growth of labor productivity in the health sector rather than healthcare ECI growth itself (i.e. the sector's unit labor cost growth), we do not include labor productivity growth as a regressor because it is difficult to project and its effect on healthcare service inflation should largely be captured by the constant, inflation expectations, healthcare ECI growth, or other regressors that correlate with labor productivity growth in the health sector.

- We do not find a significant effect for the change in the operating surplus in the health sector. This may be partly due to the small share of the surplus in total output (less than 10 percent), but also could reflect data limitations.[12]

- The final model indicates that the change in the economy-wide operating surplus, the unemployment gap, growth of relative import prices, and inflation expectations only affect healthcare services inflation through their impact on healthcare ECI growth.

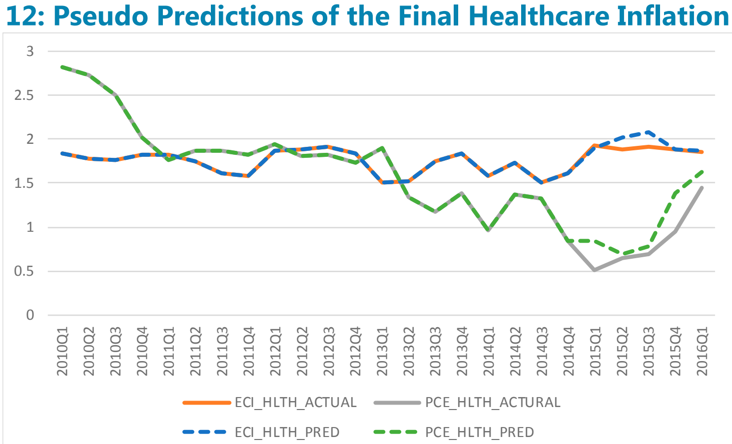
- The final model fits the data very well with high goodness of fit.[13] Pseudo predictions—estimating the model based on data from 2005-2014 and predicting for 2015—also indicate that the model performs well out-of-sample (Figure 12).

Table 6: Final Model Specifications for ECI Healthcare Growth and Healthcare Services Inflation

	ECI_hlth_Gyoy	PCE_hlth_Gyoy
PCE_hlth_Gyoy_1		0.241 **
PCE_hlth_Gyoy_2		0.246 **
PCE_hlth_Gyoy_3		0.312 ***
PCE_hlth_Gyoy_4		-0.630 ***
Pub_payment_cut		-0.975 ***
Pub_payment_cut_2	-0.276 **	0.625 ***
Pub_payment_cut_3	-0.612 ***	
Pub_payment_cut_4		-0.732 ***
ECI_hlth_Gyoy_1	0.518 ***	
ECI_hlth_Gyoy_2		0.493 ***
ECI_hlth_Gyoy_3	0.310 ***	
ECI_hlth_Gyoy_4	-0.393 ***	
Ch_prof_hlth_1	0.198 ***	
Ch_prof_hlth_2	0.276 ***	
Ch_prof_all	0.255 ***	
Ch_prof_all_4	0.224 ***	
Ugap_CBO	-0.740 ***	
Ugap_CBO_1	0.403 ***	
ImNPRLagCorSer_gyoy	0.055 ***	
ImNPRLagCorSer_gyoy_1	-0.105 ***	
ImNPRLagCorSer_gyoy_2	0.081 ***	
PCE_pfexp10yr_JY	1.051 ***	
Constant		0.900 ***

Note: Robust standard errors are reported; *** denotes statistically significance at 1%; ** denotes statistically significance at 5% and * denotes statistically significance at 10%.

Figure 12: Pseudo Predictions of the Final Healthcare Inflation Model



Source: IMF staff calculation.

[12] Gross operating surplus data is only available annually up to 2014 from the input-output tables.

[13] The key regressors, even in the absence of lagged dependent variables, can very well predict PCE health inflation.

V. Model Evaluation

Constructing reliable inflation forecasts from the bottom up requires four desirable properties to be satisfied. First, the various models need to display parameter constancy over time. Second, they ought to not suffer from misspecification. Third, the models should have good pseudo out-of-sample forecasting performance; and, fourth, they need to produce a composite forecast of core PCE inflation that is not significantly different from one generated by a well-specified aggregate Phillips curve model. Below, we discuss how our models fare on all these fronts.

A. Parameter Constancy

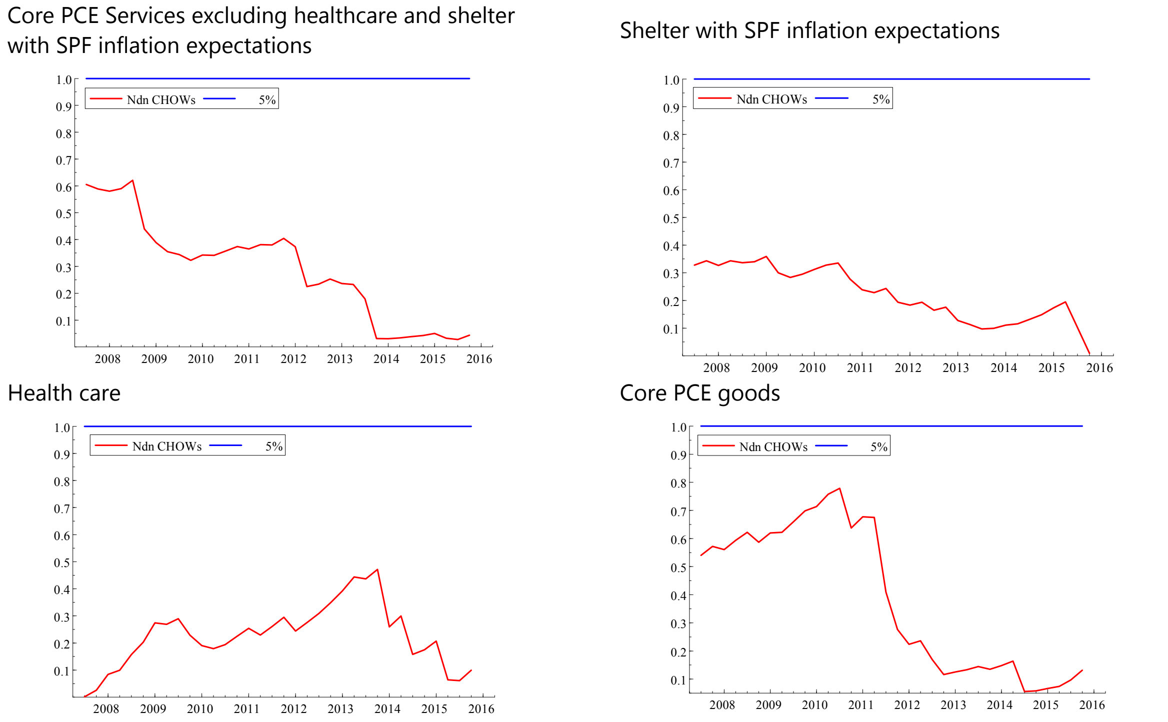
The data generating process underlying our models may have undergone changes, raising concerns about the stability of the coefficient estimates. An important aspect of diagnostic checking is then to test for model constancy. For that purpose, we conduct recursively estimated Chow tests.

Figure 13 shows the results from recursively estimating our key models, using the survey of professional forecasters' measure of inflation expectations.[14] Specifically—and with an initial sample set through mid-2007, right before the Great Recession—the Figure reports recursive N-down/Break-Point Chow statistics, denoted Ndn CHOWs. For a given quarter, these statistics test the null hypothesis that the coefficients estimated up to that quarter are the same as those estimated for the entire sample. The Chow statistics are normalized by the 5 percent critical value, so that the horizontal line at 1 gives the critical value. The results from the plots strongly indicate that the estimated coefficients of all of our models have been constant, displaying invariance to the Great Recession.[15] These results are robust to using the households' inflation expectations measure.

[14] The basic idea behind recursive estimation is to fit a given model to an initial sample of *m-1* observations, and then fit the model to samples of *m, m+1, …,* up to *T* observations, where *T* is the total sample size.

[15] To save space, Figure 13 shows results for the key models only. It is worth nothing, though, that the Chow tests are also passed for all other models in the paper (e.g. import prices, ECI health, and core PCE).

Figure 13: Recursive Chow Tests



Source: Authors' calculations

B. Misspecification—Nonlinearities

The models estimated above assume that overall inflation in core PCE and the various components are a linear function of the unemployment gap. If, however, nonlinearities exist, then a closing or, more accurately, a significantly negative unemployment gap would trigger a larger increase in inflation than what our estimated models suggest. In this case, our estimated (linear) models would be misspecified. We directly tested for potential nonlinearities by including in the various models an interaction term defined as the product of the unemployment gap and a dummy variable that takes a value of zero except for unity when the unemployment gap is significantly negative.

Over the sample period, negative values of the unemployment gap range from -0.01 to -1.1 percentage points. We define a "significant" negative gap as one that is less than or equal to -0.7 percentage points. While our choice of this number is somewhat arbitrary, we nonetheless found the results to be invariant to alternative thresholds. Table 7 reports the results for three models where we found in sections III and IV the unemployment gap to have played a key role: the aggregate Phillips curve, core services excluding healthcare and housing, and housing/shelter. As can be seen in Table 7, the coefficient of the interaction term is not statistically or economically significant, providing evidence against nonlinearities.[16] It is interesting to note that this can also be inferred from the recursive

[16] It is worth highlighting two points here. First, testing for nonlinearities in the ECI health model was not feasible because of the shorter sample size. Specifically, in this sample, and with an unemployment gap threshold of -0.7 percentage points, the interaction term always took a value of zero. Estimation was feasible though for some other values of the threshold, but in those cases we did not find any evidence of nonlinearities. Second, Table 7 shows results using the survey of professional

(continued…)

analysis of the previous section. Otherwise, we would have probably seen big jumps in the Chow statistics and rejections of constancy during periods of tight labor market conditions. We have seen none of these throughout the sample period.

Table 7: Testing for Nonlinearities

Modeling CorPCE_Gyoy, with SPF inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Final Model		Model with Non-Linearities	
	Coefficient	t-value	Coefficient	t-value
CorPCE_Gyoy_1	0.866	13.90	0.860	13.70
CorPCE_Gyoy_4	-0.180	-3.25	-0.195	-3.31
Ugap_CBO	-0.036	-3.52	-0.040	-3.46
ImNPRlagCor_gyoy	0.092	7.90	0.093	7.91
ImNPRlagCor_gyoy_1	-0.083	-6.63	-0.083	-6.64
ImNPRlagCor_gyoy_4	0.036	5.27	0.036	5.26
PCE_pfexp10yr_JY	0.290	5.58	0.311	5.27
Ugap_CBODumUgap	...	...	0.047	0.77
Analysis of lag structure, coefficients:				
	Sum	t-value	Sum	t-value
CorPCE_Gyoy	0.69	11.75	0.66	10.27
Ugap_CBO	-0.04	-3.53	-0.04	-3.44
ImNPRlagCor_gyoy	0.05	4.84	0.05	4.86
PCE_pfexp10yr_JY	0.29	5.59	0.31	5.27
Ugap_CBODumUgap	...	...	0.05	0.77
Solved static long-run equation for CorPCE_Gyoy				
	Coefficient	t-value	Coefficient	t-value
Ugap_CBO	-0.11	-3.92	-0.12	-4.22
ImNPRlagCor_gyoy	0.14	4.87	0.14	4.69
PCE_pfexp10yr_JY	0.92	28.70	0.93	29.80
Ugap_CBODumUgap	...	...	0.14	0.82

Source: Authors' estimates

Modelling CorPceSerExcHH_Gyoy, with SPF inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Final Model		Model with Non-Linearities	
	Coefficient	t-value	Coefficient	t-value
CorPceSerExcHH_Gyoy_1	1.001	15.90	0.928	13.80
CorPceSerExcHH_Gyoy_3	-0.225	-4.12	-0.224	-4.03
Ugap_CBO	-0.376	-4.52	-0.407	-4.91
Ugap_CBO_2	0.532	3.47	0.510	3.32
Ugap_CBO_4	-0.205	-2.36	-0.175	-2.04
ImNPRLagCorSerEHH_gyoy	0.070	4.92	0.079	5.53
ImNPRLagCorSerEHH_gyoy_2	-0.073	-3.74	-0.068	-3.52
ImNPRLagCorSerEHH_gyoy_4	0.047	3.31	0.037	2.56
PCE_pfexp10yr_JY	0.319	4.56	0.426	4.97
Ugap_CBODumUgap	...	...	0.333	2.35
Ugap_CBODumUgap_2	...	...	-0.025	-0.14
Ugap_CBODumUgap_4	...	...	-0.111	-0.78
Analysis of lag structure, coefficients:				
	Sum	t-value	Coefficient	t-value
CorPceSerExcHH_Gyoy	0.78	14.59	0.70	11.38
Ugap_CBO	-0.05	-2.67	-0.07	-3.38
ImNPRLagCorSerEHH_gyoy	0.04	3.16	0.05	3.41
PCE_pfexp10yr_JY	0.32	4.56	0.43	4.97
Ugap_CBODumUgap	...	...	0.20	1.61
Solved static long-run equation for CorPceSerExcHH_Gyoy				
	Coefficient	t-value	Coefficient	t-value
Ugap_CBO	-0.22	-2.68	-0.24	-3.92
ImNPRLagCorSerEHH_gyoy	0.20	2.82	0.16	3.16
PCE_pfexp10yr_JY	1.42	14.30	1.44	19.20
Ugap_CBODumUgap	...	...	0.66	1.86

Source: Authors' estimates

Modeling PCE_HousSer_Gyoy, with SPF inflation expectations

The estimation sample is: 1996(1) - 2015(4)

	Final Model		Model with Non-Linearities	
	Coefficient	t-value	Coefficient	t-value
PCE_HousSer_Gyoy_1	1.519	21.10	1.518	21.00
PCE_HousSer_Gyoy_2	-0.707	-10.40	-0.700	-10.20
HPI_PO_Gyoy_3	0.017	3.66	0.017	3.65
PCE_pfexp10yr_JY	0.228	5.15	0.216	4.60
Ugap_CBO_2	-0.045	-2.58	-0.039	-2.05
Ugap_CBODumUgap_2	...	...	-0.056	-0.79
Analysis of lag structure, coefficients:				
	Sum	t-value	Sum	t-value
PCE_HousSer_Gyoy	0.81	26.37	0.82	25.80
HPI_PO_Gyoy	0.02	3.67	0.02	3.65
PCE_pfexp10yr_JY	0.23	5.16	0.22	4.61
Ugap_CBO	-0.04	-2.58	-0.04	-2.05
Ugap_CBODumUgap_2	...	...	-0.06	-0.79
Solved static long-run equation for PCE_HousSer_Gyoy				
	Coefficient	t-value	Coefficient	t-value
HPI_PO_Gyoy	0.09	3.55	0.09	3.49
PCE_pfexp10yr_JY	1.21	15.10	1.18	12.70
Ugap_CBO	-0.24	-3.21	-0.21	-2.52
Ugap_CBODumUgap_2	...	...	-0.30	-0.76

Source: Authors' estimates

C. Pseudo Out-of-Sample Forecasting Performance

In parallel to the above analysis, we estimated all of our final models through 2014-Q4, and then utilized the coefficient estimates from these models together with the 2015 actual values of the explanatory variables to construct forecasts for the four quarters of 2015. The forecasts are dynamic in that they themselves are plugged in the lagged dependent variable term(s) of the model to produce subsequent forecasts rather than the actual 2015 values of the lagged dependent variable.

For any given final model, we then computed the root mean square error (RMSE), a standard measure of forecast accuracy, and compared it to the RMSE of the initial generalized

forecasters' measure of inflation expectations. The results continue to hold when using the households' inflation expectations measure as an alternative.

unrestricted model (GUM) and to that of the auto-regression version of the final model—both models also estimated through 2014-Q4. Evaluating the forecasting performance of the final models against their respective initial GUMs sheds light on whether the exclusion of the variables that did not matter statistically "within sample" also improves out-of-sample forecast accuracy. Comparing a given final model with its auto-regression (AR) version—that is, with an estimated model where all the explanatory variables are dropped except for the lagged dependent variable(s)—gives a sense of whether the variables that best describe the data and the underlying theory are also useful for forecasting purposes. An RMSE for the naïve AR model that is substantially lower than that of the final model is evidence to the contrary. As Table 8 shows, all the final models have RMSEs that are less than that of the two alternatives.

Table 8: Evaluation of Forecast Accuracy

Root Mean Square Error (RMSE) for Models' Forecasts over 2015

(in percent)

	GUM	Final model	AR
Goods	0.693	0.127	0.180
Serv. Excl. HH--households infl. exp.	0.154	0.106	0.226
Serv. Excl. HH--SPF infl. exp.	0.343	0.158	0.226
Shelter--households infl. exp.	0.698	0.279	0.552
Shelter--SPF infl. exp.	0.665	0.314	0.552
Import prices	1.497	1.121	2.921
Core PCE--households infl. exp.	0.172	0.025	0.218
Core PCE--SPF infl. exp.	0.134	0.086	0.218
ECI health--households infl. exp.	1.123	0.116	0.382
ECI health--SPF infl. exp.	0.507	0.110	0.391
Health care prices	0.561	0.221	0.441

Notes: Serv. Excl. HH denotes core services excluding healthcare and housing; infl. =inflation; exp. = expectations; SPF = survey of professional forecasters; and ECI = employment cost Index.

Source: Authors' calculations

We went one step further, however. We considered other alternatives to the final models that retain the economic content but have variations of the lag structure of the various variables. Once again, the RMSE is minimized with the final models. The only exception is the model for core PCE services excluding healthcare and housing, where we found that an alternative model with a simpler lag structure on the relative non-oil import price variable—but otherwise displays very similar medium and long run coefficients—improves forecast accuracy (see Table 9). Thus, and without any loss of generality or loss to the economic content to the services equation, we will use this alternative model for core PCE services excluding healthcare and housing in the simulation exercises of the next section.

Table 9: Alternative Model for Core PCE Services Inflation (Excluding Healthcare and Housing)

Modeling CorPceSerExcHH_Gyoy, with households' inflation expectations				
Sample : 1996(1) - 2015(4)				
	Final model		Alternative model	
	Coefficient	t-value	Coefficient	t-value
CorPceSerExcHH_Gyoy_1	1.03	17.1	0.94	15.3
CorPceSerExcHH_Gyoy_3	-0.26	-4.53	-0.18	-3.2
Ugap_CBO	-0.37	-4.41	-0.50	-6.62
Ugap_CBO_2	0.53	3.41	0.79	5.43
Ugap_CBO_4	-0.21	-2.36	-0.34	-3.96
lmNPRLagCorSerEHH_gyoy	0.06	4.27	0.04	2.97
lmNPRLagCorSerEHH_gyoy_2	-0.07	-3.62	…	…
lmNPRLagCorSerEHH_gyoy_4	0.05	3.61	…	…
Inf_umexp_5to10yr	0.24	4.52	0.24	4.48
	Final model		Alternative model	
	Coefficients Sum	t-value (Sum)	Coefficients Sum	t-value (Sum)
CorPceSerExcHH_Gyoy	0.77	13.86	0.76	13.04
Ugap_CBO	-0.05	-2.58	-0.05	-2.87
lmNPRLagCorSerEHH_gyoy	0.04	2.97	0.04	2.96
Inf_umexp_5to10yr	0.24	4.53	0.24	4.47
Solved static long-run equation	Final model		Alternative model	
	Coefficient	t-value	Coefficient	t-value
Ugap_CBO	-0.20	-2.58	-0.22	-2.66
lmNPRLagCorSerEHH_gyoy	0.18	2.65	0.15	2.43
Inf_umexp_5to10yr	1.03	14.80	1.03	14.40
RMSE for 2015 forecasts based on estimation through 2014-Q4	Final model		Alternative model	
	0.1063		0.0669	
Source: Authors' calculations				

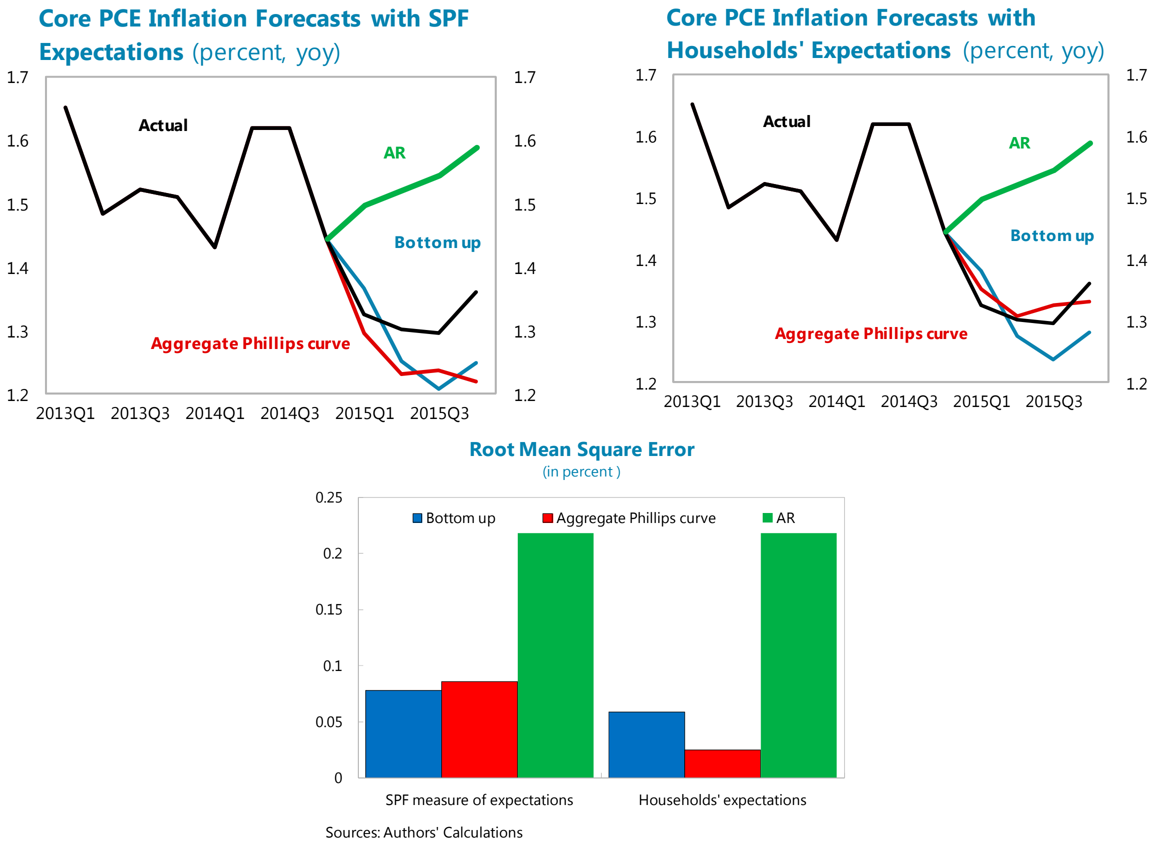
Modeling CorPceSerExcHH_Gyoy, with SPF expectations				
Sample is: 1996(1) - 2015(4)				
	Final model		Alternative model	
	Coefficient	t-value	Coefficient	t-value
CorPceSerExcHH_Gyoy_1	1.00	15.9	0.92	14.3
CorPceSerExcHH_Gyoy_3	-0.22	-4.12	-0.15	-2.86
Ugap_CBO	-0.38	-4.52	-0.52	-7.03
Ugap_CBO_2	0.53	3.47	0.80	5.68
Ugap_CBO_4	-0.20	-2.36	-0.34	-4.06
lmNPRLagCorSerEHH_gyoy	0.07	4.92	0.04	3.51
lmNPRLagCorSerEHH_gyoy_2	-0.07	-3.74	…	…
lmNPRLagCorSerEHH_gyoy_4	0.05	3.31	…	…
PCE_pfexp10yr_JY	0.32	4.56	0.34	4.6
	Final model		Alternative model	
	Coefficients Sum	t-value (Sum)	Coefficients Sum	t-value (Sum)
CorPceSerExcHH_Gyoy	0.78	14.59	0.76	13.33
Ugap_CBO	-0.05	-2.67	-0.06	-3.14
lmNPRLagCorSerEHH_gyoy	0.04	3.16	0.04	3.51
PCE_pfexp10yr_JY	0.32	4.56	0.34	4.60
Solved static long-run equation	Final model		Alternative model	
	Coefficient	t-value	Coefficient	t-value
Ugap_CBO	-0.22	-2.68	-0.24	-2.94
lmNPRLagCorSerEHH_gyoy	0.20	2.82	0.18	2.91
PCE_pfexp10yr_JY	1.42	14.30	1.43	14.6
RMSE for 2015 forecasts based on estimation through 2014-Q4	Final model		Alternative model	
	0.1579		0.0374	
Source: Authors' calculations				

As a robustness check, we repeated the same exercise above but now fitting all the models above through 2013-Q4, and through 2012-Q4. We then computed dynamic forecasts for all the quarters in 2014–15 and 2013–15, respectively. The healthcare models (for both prices and wages) are the only exception where such an exercise was not feasible because of the shorter sample, the nature of the variable that captures public healthcare spending cuts—which takes a value of zero prior to 2012—and its lag structure in the final specification. Aside from this issue, all the results discussed above continue to hold.

D. Comparing Bottom-Up Model to Aggregate Phillips Curve

We combine the 2015 inflation forecasts of the components of core PCE obtained from their respective models estimated through 2014-Q4 and form a composite/bottom-up forecast for overall core PCE inflation. Specifically, for each quarter in 2015, we generate the composite forecast as a weighted sum of the price changes of: core goods; core services (excluding shelter and healthcare services); shelter services; and healthcare services—with the weights computed as spending shares in total core PCE. Figure 14 compares this forecast to that generated from the aggregate Phillips curve model, and the naïve auto-regression (AR) version of the aggregate Phillips curve model, to the actual core PCE inflation data. It also reports the associated RMSEs of the models' forecasts.

Figure 14: Pseudo Out of Sample Forecasting Performances



Sources: Federal Reserve Bank of Philadelphia; Haver Analytics; University of Michigan; and Authors' calculations

The results are interesting. Both the bottom up and the aggregate Phillips curve forecasts are much more accurate than those of the naïve AR model. Both forecasts track actual core PCE inflation pretty well. This also shows up as small RMSEs for both models. Forecast accuracy is slightly better in the bottom-up model when inflation expectations are measured by those of professional forecasters. The reverse, though, is true when household's inflation expectations are used. Overall, these results suggest that both the aggregate Phillips curve and the bottom up approach are useful in forecasting inflation. The latter, however, could be more informative in tracing the effects of shocks and understanding the exact channels through which they affect aggregate inflation.[17] We turn to this next.

VI. Core Inflation Forecasts

In this section, we combine the estimated equations for the components of PCE in section IV with various scenarios for some of the key variables. These scenarios should be viewed as indicative and just to give a flavor of how different aggregate PCE dynamics could be. They include:

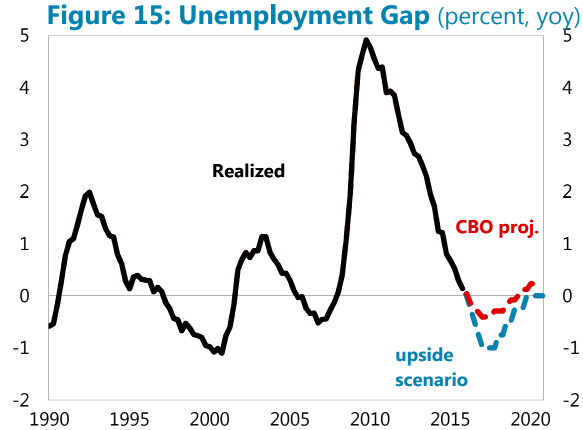
[17] Ideally, one might want to try to see if some combination forecast from both approaches does better than the forecast from either one approach. Typically, this is done by regressing the actual outcomes of core PCE inflation on the pseudo out of sample forecasts from both approaches. The fitted values would then give an estimate of the combination forecast. Unfortunately, regression analysis is not feasible here because the forecast horizon is only one year, constrained by the sample and structure of the healthcare inflation model.

- **Foreign PPIs**. In the benchmark scenario, we assume that the foreign PPI deflation stays constant at the level of 2015Q4 (P1). In the upside risks scenario, we assume that PPI inflation gradually returns to its mean level during the 2000s by 2017 (1.6 percent) and remains at that level thereafter (P2).

- **Dollar**. Given the recent sharp appreciation and subsequent depreciation of the dollar, we use three scenarios for the nominal effective exchange rate: (i) constant (D1); (ii) a further 10 percent appreciation over 2016 and then remaining constant (D2); (iii) a 10 percent depreciation during 2016 and the remaining constant (D3).

- **Unemployment gap**. In the benchmark scenario, we use the CBO's forecast for the unemployment gap (U1). This has the unemployment gap going slightly negative in 2016 and 2017 before it starts increasing and turns positive in 2019 (Figure 15). In the upside risks scenario, we have the unemployment gap gradually declining to -1 percent by 2017, before it increases slowly back to zero. The CBO gap reached -1 percent in 2000Q3 and breached this ceiling on quite a few occasions during the 1950-70s.

Figure 15: Unemployment Gap (percent, yoy)



Sources: CBO; Haver Analytics; and Authors' calculations

- **Inflation expectations**. We use the survey of professional forecasters' inflation expectation variable rather than the University of Michigan one for our scenarios. This is because it is easier to relate it to the Fed's 2 percent target (the Michigan survey expectation has consistently been significantly above 2 percent). Given the credibility of the Fed, we assume inflation expectations stay anchored at 2 percent.

- **House price inflation**. In the baseline, we assume this stays at the level of 2015Q4 (5 ¾ percent yoy; H1). In the upside risk scenario, we assume it gradually increases to 10 percent (H2), which is above the level it reached in 2013 but below the peak in the mid-2000s.

- **Public Healthcare spending cuts**. One key uncertainty in the projections of healthcare services inflation is to what extent the payment cuts in existing legislations will be actually implemented and whether further cuts are possible. A general view appears to be that in the short run, it may be still possible to make further payment cuts, but over the longer term, that may not be sustainable. In our baseline, we assume that the payment cuts will continue to hold down healthcare inflation but would decline to zero by 2020 (PH1). In alternative scenarios, we assume either the payment cuts would stay at 2016 levels (PH2) or there are no further cuts starting 2017 (PH3). We assume the overall operating surplus and that in the health sector stay at 2015 levels.

The different scenarios for the individual variables described above are then combined to generate 3 aggregate PCE scenarios: Benchmark, Downside, and Upside (Table 10). One key consideration when generating the upside and downside aggregate scenarios is how likely is it that the scenarios for the individual variables will come together. Certainly, a significantly negative unemployment gap has been associated with higher house prices in the past (for example during the boom of the mid-2000s). However, trends in foreign PPIs are much less associated with domestic U.S. developments, while the public healthcare spending cuts are recent and more associated with health sector policy decisions rather than the other variables in the scenarios. As is well known, dollar movements are far from straightforward to explain, with no clear association with the other variables in Table 10 (see for example Balakrishnan, Laseen, and Pescatori, 2016). Hence, it is very difficult to say how likely the upside and downside scenarios are relative to the benchmark. As discussed earlier, they should be viewed more as indicative of how different core PCE dynamics could be depending on how various factors come together.

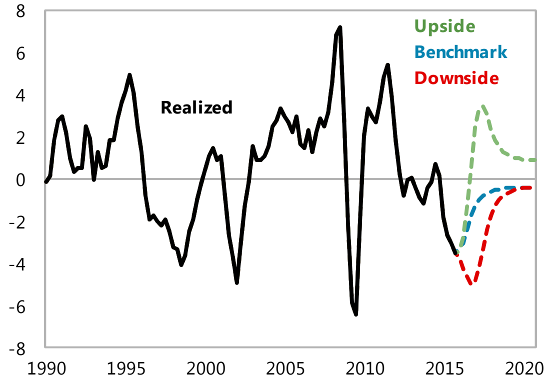
Table 10: PCE Inflation Scenario Assumptions

		Benchmark	Downside	Upside
Foreign PPIs				
P1	Constant at 2015Q4 level	x	x	
P2	Return to mean of 2000s			x
Dollar				
D1	Constant	x		
D2	10% appreciation		x	
D3	10% depreciation			x
Unemployment gap				
U1	CBO forecast	x	x	
U2	Decline to -1%			x
Inflation expectations				
I1	Anchored at 2 percent target	x	x	x
House price inflation				
H1	Constant at 2015Q4 level	x	x	
H2	Increase to 10%			x
Public healthcare spending cuts				
PH1	Decline to zero by 2020	x		
PH2	Constant at 2016 levels		x	
PH3	No further cuts from 2017			x

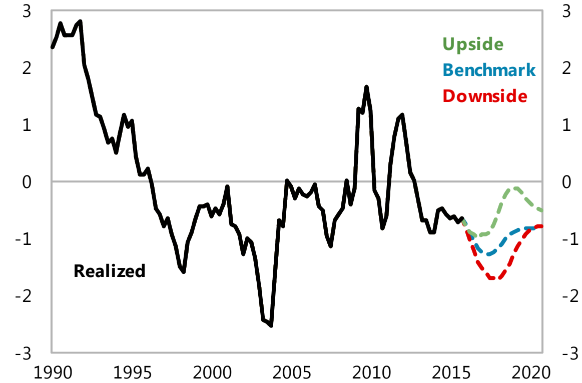
Figure 16 shows the impact of the various scenarios on the components of PCE inflation and aggregate core PCE inflation. In the benchmark scenario, core PCE inflation gradually increases but does not reach 2 percent by the end of 2020. The services components all pick up and stay above 2, especially healthcare services inflation which is particularly responsive to the declining unemployment gap. But core goods inflation remains significantly negative given foreign PPI deflation, and this weighs on aggregate core PCE inflation. In the upside scenario, core PCE inflation does break the 2 percent threshold, peaking at 2.4 percent in 2018, driven by healthcare services inflation, which breaches 4 percent, and core services inflation excluding healthcare and housing getting close to 3 percent. Again, despite dollar depreciation and foreign PPI inflation turning positive, core goods inflation is still negative in this scenario—unsurprising given recent trends—and hence weighs on aggregate core PCE inflation.

Figure 16: Core PCE Inflation Scenarios

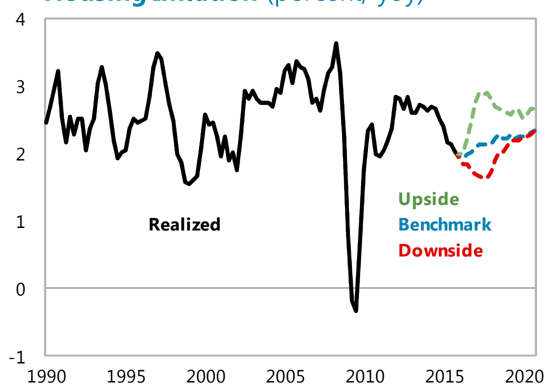
Non-oil Import Price Inflation Scenarios
(percent, yoy)



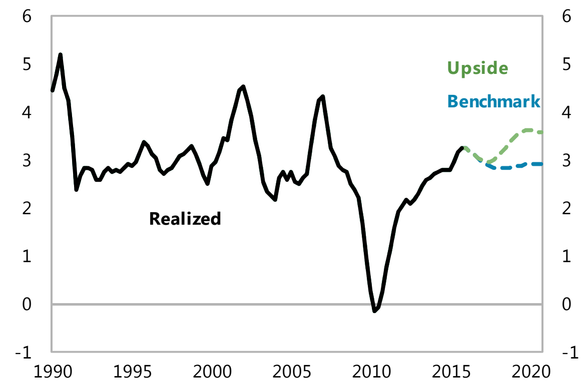
Core PCE Goods Inflation Scenarios
(percent, yoy)



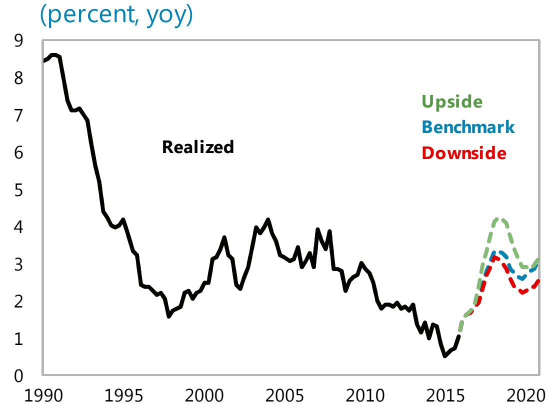
Core PCE Services ex. Healthcare and Housing Inflation (percent, yoy)



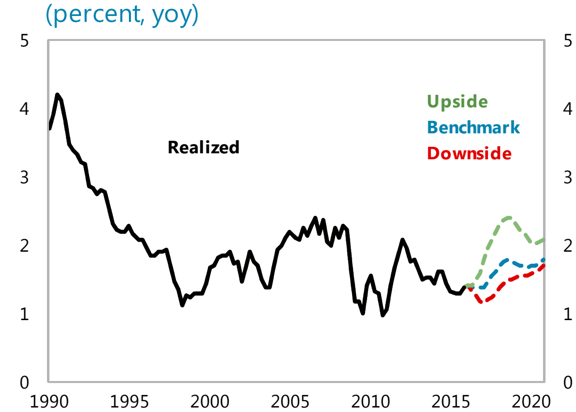
PCE Housing Inflation Scenarios (percent, yoy)



Core PCE Healthcare Inflation Scenarios
(percent, yoy)



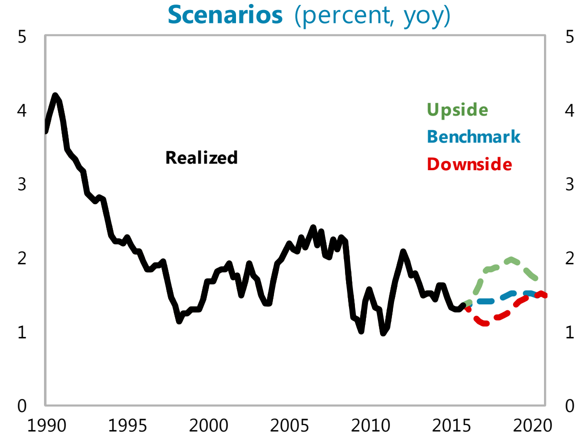
Overall Core PCE Inflation Scenarios
(percent, yoy)



Sources: BEA; Haver Analytics; and Authors' estimates

For comparison, Figure 17 shows the impact of the various scenarios if we use the aggregate core PCE equation rather than the bottom-up model. Of course, when we use this equation, the different scenarios for house price inflation and public healthcare spending cuts are not reflected as they do not enter the equation (foreign PPI and dollar scenarios do play a role as they impact the relative import price term). And this matters, as we can see that even in the upside scenario, core PCE inflation does not breach 2 percent. This is because the aggregate Phillips curve is relatively flat and there is no upward drag from healthcare and housing services inflation as in the bottom-up model. Overall, this suggests that the bottom-up approach contains important insights for inflation forecasting.

Figure 17: Aggregate Core PCE Inflation Scenarios (percent, yoy)



All the proceeding analysis assumes inflation expectations stay well anchored given the credibility of the Fed, which has been earned over many years. If inflation expectations do become unanchored and drift upwards, then of course inflation could rise more rapidly and reach a higher level. But, equally, U.S. inflation expectations could drift downwards with inflation rising more slowly if global concerns of low inflation spillover to U.S. expectations formation. These scenarios, however, seems unlikely. At the same time, the analysis assumes the absence of nonlinearities in the Phillips curve. But this assumption appears to be supported by the data as the analysis in the previous sections has shown.

VII. Conclusions

Price changes in PCE core goods and core services have evolved differently over the past few decades. This motivated us to look deeper into inflation dynamics and investigate whether the underlying determinants of core goods and core services inflation also differ.

Our empirical work indicated that that this is indeed the case. In particular, we found that foreign rather than domestic factors drive core goods inflation, with a specific channel operating through import prices. The latter were, in turn, found to be primarily determined by the strength of the dollar as well as inflation in countries that are major non-oil commodity exporters of to the U.S.—most notably, China, Canada, the Euro area, and Mexico.

Our work also found the degree of domestic resource utilization and long-term inflation expectations to be key driving forces behind core services inflation, including its largest components, housing and healthcare. Although not as big, relative import prices also played a role. Other specific factors that we also found important to understand price dynamics in shelter and healthcare were home price changes and public healthcare spending, respectively.

We then tested the bottom up model against an aggregate Phillips curve model. Specifically, we combined pseudo-out of-sample forecasts of price changes in core goods, housing, and healthcare, and other core services to generate a composite forecast of overall core PCE inflation. This forecast compared favorably with that generated from an aggregate Phillips curve model—which we also found to have good economic and forecasting properties.

Using the bottom up approach, we finally undertook scenario analysis, allowing us to trace in more detail and depth the channels through which shocks affect core PCE inflation. This is a big advantage over the aggregate Phillips curve approach, where it is hard or even not feasible to trace shocks that originate in healthcare, housing, or from inflation abroad, to mention a few. Our benchmark scenario has inflation gradually rising towards but not reaching 2 percent by 2020, given the headwinds caused by global price pressures and a relatively flat Phillips curve. The monetary policy implications of the benchmark scenario are clear. The accommodative policy stance has been appropriate. Looking ahead, there is a need to remain data dependent and, absent any sizable surprises, to proceed cautiously and gradually with interest rate normalization.

Core PCE inflation could, however, reach as high as 2.4 percent by 2018 if the dollar continues its recent depreciation, the unemployment rate goes well below the natural rate, house price inflation climbs closer to 10 percent, and the impact of public spending cuts on health services inflation declines more rapidly. All this assumes inflation expectations stay well anchored given the credibility of the Fed, which has been earned over many years. If inflation expectations do become unanchored, then of course inflation could rise more rapidly and reach a higher level. This, however, seems an unlikely scenario.

We believe the bottom up approach has value added to understanding inflation dynamics. Future research could extend the analysis to other inflation measures, like the CPI, or other countries. It could even take a more disaggregated approach. Looking deeper into specific issues like understanding better the impact of policy on healthcare can also be useful.

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APPENDIX I. RECENT TRENDS AND DRIVERS OF HEALTHCARE SERVICES INFLATION

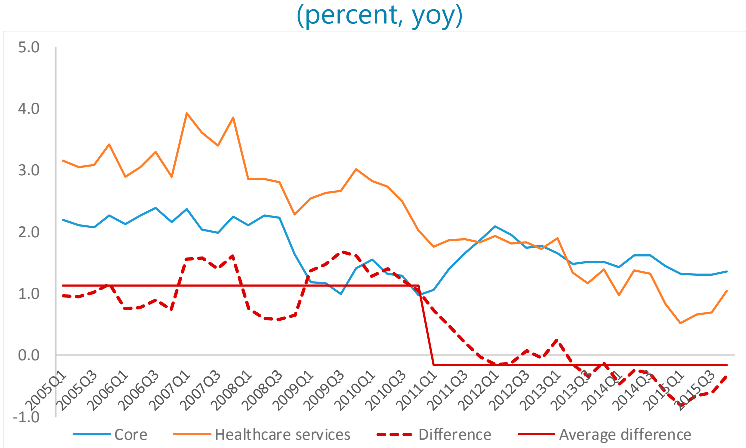
This appendix details the recent trends of healthcare services inflation and identifies the key drivers. This could help provide important insights in the modeling and projection of healthcare services inflation, which accounts for over three quarters of healthcare PCE.

Trends in healthcare service inflation

Historically, healthcare services inflation tends to be higher than overall core services inflation. This trend, however, changed around end-2010, as the gap narrowed and eventually flipped (Figure 18). Healthcare services inflation—relative to core inflation—has slowed down by on average about 1.3 percentage points when comparing the period before and after 2010. A similar pattern is also observed in CPI inflation, although understandably the relative slowdown is smaller as CPI only covers the consumer portion of healthcare costs.

Figure 18: GAP between PCE Core Inflation and Healthcare Services Inflation

(percent, yoy)



Source: Haver DLX databases.

Drivers of healthcare services inflation

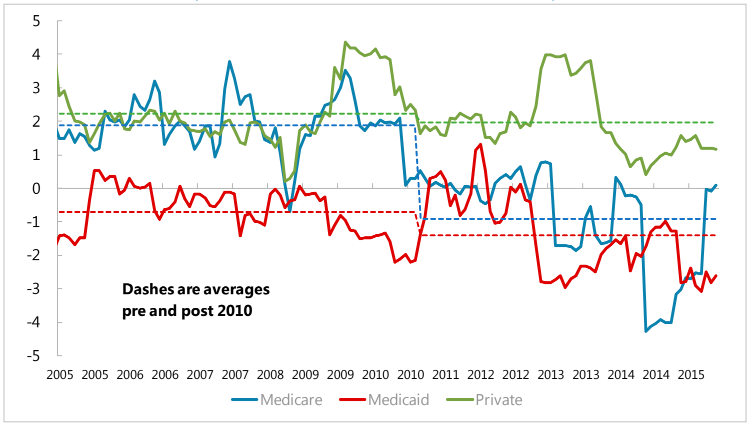
Understanding the drivers of the recent decline in healthcare services inflation could provide important insights on how healthcare inflation would evolve in the near future and how healthcare inflation should be modeled. Here we focus on the relative decline in healthcare services inflation and thus healthcare specific factors. This can be approached from examining factors that either affect output prices of healthcare services or input costs of health care services.

Public Payment Cuts

One key factor that has been discussed in the literature extensively is payment rate cuts by public health insurance programs such as Medicare and Medicaid. This includes the sequestration in April 2013, ongoing Medicare payment cuts through the implementation of Affordable Care Act (ACA) and other payment cuts in Medicare and Medicaid. Shifts in health insurance coverage under the ACA from private insurance and un-insurance to public insurance could also result in a reduction in average payment rates (Phillips, 2015; Clemens, Gottlieb and Shapiro, 2014). Phillips (2015) estimates that the total effect on healthcare inflation started at 0.14 percentage points in January 2012, peaked at 1¼ percentage points in

March 2015 and would gradually decline to 0.28 percentage points by the end of 2016. Consequently, the hospital PPI dropped substantially after 2010 for Medicare and to a less extent for Medicaid covered services (Figure 19).

Figure 19: Growth of Hospital PPI: Medicare, Medicaid and Private
(relative to PCE Core Inflation)



Source: Bureau of Labor Statistics.

Payment cuts in the public sector could also have implications for healthcare prices in the private sector. According to the "cost-shifting theory", public health insurance programs such as Medicare and Medicaid, by setting their payment rates relatively low, force healthcare providers to charge high payment rates to private insurers to maintain their profitability (Frakt, 2011). This implies that the effect of payment cuts in the public sector would be offset by price increases in the private sector. An alternative theory suggests that there is likely a positive link between payment rates by public insurance and payment rates by private insurance. When public insurance cut payment rates, private providers lose bargaining power in their negotiations with private insurance companies. Several recent studies provide evidence for the latter and suggest that reductions in public prices are leading to reductions in private prices (White, 2013; White and Wu, 2013 and Frakt, 2013).

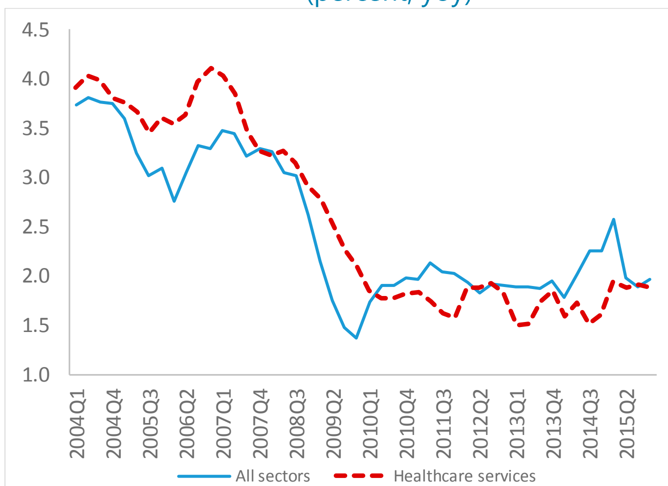
Input Costs

From the perspective of input costs, the growth of the employment cost index (ECI) for total compensation in healthcare services dropped substantially between 2007 and 2010 (Figure 20). Healthcare ECI growth appears to be strongly correlated with healthcare services inflation and this is confirmed in the regression analysis. Given that employment costs account for a large share of healthcare services output and employment costs are more inflationary in the healthcare sector because of the relative low productivity growth, the recent trends in the growth of ECI could potentially explain a large share of the relative decline in healthcare services inflation:

- A common reduction in ECI growth of 2 percentage points for all sectors thus would lead to a reduction in the gap between the healthcare services and core inflation of about 0.4 percentage points, assuming labor productivity stays unchanged during the short period of time.

- Growth of the healthcare ECI relative to the growth of overall ECI has in fact slowed by on average an additional 0.6 percentage points, which would translate into another reduction of 0.3 percentage points in the gap between healthcare services and core inflation.

Figure 20: Growth of ECI: All Sectors vs. Healthcare Services
(percent, yoy)



Source: Bureau of Labor Statistics, Bureau of Economic Analysis and IMF staff calculations.

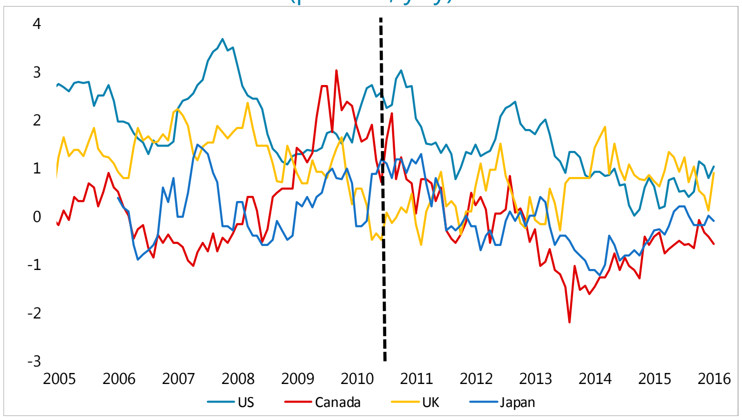
The gross operating surplus—which accounts for 8.2 percent of healthcare services in 2014—also appears to have declined in the healthcare sector relative to the rest of the economy since 2010 (as seen in Figure 10). A relative reduction of 0.5 percentage points between 2010 and 2014 in the gross operating surplus could imply a reduction in the gap between healthcare services and core inflation of a similar magnitude. Declines in the growth of the healthcare ECI and gross operating surplus together thus could potentially explain nearly all the decline in the gap between healthcare services and core inflation. Looking at the decline in the gap between healthcare services and core inflation from the input cost and output price perspectives do not mean that they are independent of each other. In fact, they are likely to be closely linked as some of the declines in the growth of healthcare ECI and gross operating surplus could well be the result of payment cuts by public health insurance programs.

International Comparisons

The narrowing in the gap between core inflation and healthcare inflation does not appear to be unique to the United States and a similar pattern is also seen in other developed countries such as Canada, Japan and the United Kingdom, suggesting that some common factors may be affecting many countries although the extent differs (Figure 21). An obvious candidate is the economic slowdown and slowdown in healthcare spending growth after the onset of global financial crisis in 2007 (Morgan and Astolfi, 2013), which could have driven down both ECI growth in the general economy and the healthcare sector and also healthcare services prices through weaker demand.

Figure 21: Gap between CPI Core and Healthcare inflation: Cross-country Comparison

(percent, yoy)



Source: Country statistics.

APPENDIX II. VARIABLE DEFINITIONS

The data in this paper are publically available and come from the following sources: the Bureau of Economic Analysis; the Bureau of Labor Statistics; Haver Analytics; and the IMF's World Economic Outlook Database. In Table 11, we report the definition of all the variables used in this paper.

Table 11: Variable Definitions

Variable	Definition
Ch_prof_all	Year-over year change in: the operating margin in the overall economy in percent of total economy output.
Ch_prof_hlth	Year-over year change in: the operating margin in the health care sector in percent of total output of the health care services sector.
CorPCE_Gyoy	Growth rate of core PCE price index (PCE excluding food and energy).
CorPceGds_Gyoy	Growth rate of PCE price index for core goods (goods price index excluding food and energy goods prices).
CorPceSer_Gyoy	Growth rate of PCE price index for core services (services excluding energy services).
CorPceSerExcHH_Gyoy	Growth rate of PCE price index for core services excluding healthcare and housing.
ECI_hlth_Gyoy	Growth rate of the health care employment cost index.
HPI_PO_Gyoy	Growth rate of the FHFA house price index (purchase only).
I: 2003 (2)	A dummy variable that equals one in 2003-Q2, and zero otherwise.
I: 2009 (2)	A dummy variable that equals one in 2009-Q2, and zero otherwise.
ImNPRlagCor_gyoy	Growth rate of: nonpetroleum import prices relative to one-period-lag core PCE price index.
ImNPRLagCorgds_gyoy	Growth rate of: nonpetroleum import prices relative to one-period-lag core PCE goods price index.
ImNPRLagCorSer_gyoy	Growth rate of: nonpetroleum import prices relative to one-period-lag core PCE services price index.
ImNPRLagCorSerEHH_gyoy	Growth rate of: nonpetroleum import prices relative to one-period-lag core PCE services (excluding healthcare and housing) price index.
ImPNopet_Gyoy	Growth rate of the nonpetroleum import price index.
Inf_umexp_5to10yr	Long term inflation expectations as measured

	by the median forecast of inflation 5 to 10-years ahead, as reported in the University of Michigan Surveys of Consumers.
Inf_umexp1yr	Median 1-year-ahead inflation expectations, as reported in the University of Michigan Surveys of Consumers.
InfExp_LongTerm	Long term inflation expectations.
InfExpShortTerm	Short term inflation expectations.
Mor30yrReal_Mich	Real mortgage rates (in percent): 30-year nominal rates adjusted for expected long run inflation as measured in the University of Michigan Surveys of Consumers.
Mor30yrReal_SPF	Real mortgage rates (in percent): 30-year nominal rates adjusted for expected long run inflation as measured in the Survey of Professional Forecasters.
NEER_Gyoy	Growth rate of the nominal effective exchange rate of the dollar.
OilPRLagCor_gyoy	Growth rate of: the West Texas Intermediate oil price relative to one-period-lag core PCE price index.
OilPRLagCoreGds_gyoy	Growth rate of: the West Texas Intermediate oil price relative to one-period-lag core PCE goods price index.
OilPRLagCorSer_gyoy	Growth rate of: the West Texas Intermediate oil price relative to one-period-lag core PCE services price index.
OilPRLagCorSerEHH_gyoy	Growth rate of: the West Texas Intermediate oil price relative to one-period-lag core PCE services (excluding healthcare and housing) price index.
PCE_hlth_Gyoy	Growth rate of PCE price index for healthcare services.
PCE_HousSer_Gyoy	Growth rate of PCE price index for housing services.
PCE_pfexp10yr_JY	Long term inflation expectations as measured by the median forecast of long-run PCE inflation reported in the Survey of Professional Forecasters.
PCE_pfexp1yr_JY	Median 1-year-ahead PCE inflation expectations, as reported in reported in the Survey of Professional Forecasters.
Pop_Gyoy	Growth rate of civilian population.
PPI_CorNOImWt_M4_Rev_Gyoy	Growth rate of: Nonpetroleum import

	weighted core PPI for China, the Euro area, Mexico, and Canada. The PPIs exclude oil to the extent possible.
Pub_paymrnt_cut	A variable that captures the impact of public spending cuts on health services inflation.
RntP_HPI_PO	Rent to housing price ratio (in percent).
ROWyoyInfla	World's CPI inflation excluding the US. Countries' inflation data are aggregated using purchasing power parity weights.
ROWyoyInflExp1yr	Consensus forecast of one-year-ahead World's CPI inflation excluding the US. Countries' forecasts are aggregated using purchasing power parity weights.
Ugap_CBO	Unemployment gap (in percentage points) measured as the difference between the actual unemployment rate and the natural rate as estimated by the Congressional Budget Office.
Ugap_CBODumUgap_0.7	The CBO unemployment gap multiplied by a dummy variable that takes a value of zero except for one when the gap is less than or equal to -0.7 percentage points.
VacanRate_HomOwn	Homeowner vacancy rate: is vacant year-round housing units for sale only divided by (owner-occupied housing units + vacant year-round housing units sold but awaiting occupancy + vacant year-round housing units for sale only) multiplied by 100.
VacanRate_rent	Rental vacancy rate: is vacant year-round housing units for rent divided by (renter-occupied housing units + vacant year-round housing units rented but awaiting occupancy + vacant year-round housing units for rent) multiplied by 100.
Note: All growth rates are on a year-over-year basis and are in percent.	