The Rise of Services and Balanced Growth in Theory and Data

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Abstract

When measured using NIPA conventions, a two-sector model of balanced growth and structural transformation can account for the mildly declining GDP growth rate, increasing share of services, and increasing real investment/GDP ratio observed in the post-war U.S. economy. These changes induce a decline of 36% in the marginal product of capital and of 5.4% in the real interest rate. By retaining the U.S. calibration, the process of structural transformation can also account, per-se, for cross-country differences in real investment/GDP ratios, which are comparable to those displayed by the U.S. along its growth path.

JEL Classification : E22; E24; E31; O41.

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vestment/GDP ratio, and the relative price manufacturing/services. The calibrated model replicates the data targets well. In addition, it predicts the following patterns over the period: i) a fall in the marginal product of capital of 36% in units of GDP and of 43% in units of aggregate consumption; ii) a decline in the real interest rates of 5% in terms of GDP units and 7% in terms of consumption units; and iii) a decline of the GDP growth rate from 2.29% per year to 1.93% per year from the beginning to the end of the sample period

technical change literature[3]. Hsieh and Klenow (2007) provide an excellent overview on the evidence that real investment rates increase with development while nominal investment rates display a at behavior.[4] Barro and Sala-i-Martn (2004, p. 13) argue that the Kaldor fact stating the constancy of the real interest rate \should be replaced by a tendency for returns to fall over some range as an economy develops". Caselli and Feyrer (2007) nd that the marginal product of capital (MPK), when appropriately measured, equalizes across countries. A key point by Caselli and Feyrer (2007) is that poor countries have a higher relative price of capital. So, when comparing MPKs across countries, this fact has to be taken into account. In our model, the same consideration applies along the theoretical balanced growth path. When measured in units of capital, the MPK is constant along the growth path, so that countries at di erent stages of development would display the same MPK. However, when measured in units of GDP (or aggregate consumption), the MPK declines because the relative price of capital declines along the growth path due to structural transformation. Put it di erently, in poor countries one has to give up a larger fraction of GDP to obtain one unit of capital. To compensate for the high price of investment, the return also has to be high, implying a larger MPK in poorer countries with respect to richer ones. Finally, the negative correlation between the growth rate of an economy and its stage of development is also well established in the large literature on income convergence[5]. Our model endogenously generates beta-convergenge, implying that a poorer economy grows faster than a richer one. However, in our case this is not the consequence of transitional dynamics but of structural transformation along the theoretical balanced growth path. While none of these facts is new, we rationalize them in the context of a single model that allows us to reconcile cross-country data and U.S. time series.

Given these qualitative predictions of the model, we ask how well it can account quantitatively for the cross-country evidence on investment rates. As discussed above, real investment rates correlate positively with income per-capita, while nominal investment rates display a at behavior. To analyze these di erences in a theory framework, one has to assume either that countries are on di erent balanced growth paths, or that countries are at di erent stages of a transitional dynamic pattern. The rst case is tractable, but requires to assume that countries di er in some deep parameter, while the second usually implies a strict relationship between investment rates and growth rates of output that is not always true. A two sector model of structural transformation represents a new tool to analyze these di erences: along a highly tractable balanced growth path in the theory, it predicts an increasing real investment

[3] See Greenwood, Hercowitz, and Krusell (1997) and subsequent work.
[4] See also Restuccia and Urrutia (2001).
[5] See, among many others, Barro and Sala-i-Martn (2004).

the real investment rate along the growth path.[6] Finally, Garca-Santana, Pijoan-Mas, and Villacorta (2016) nd that nominal investment rates display a hump shaped pattern with development. Our focus, however, is mainly on real investment rates, which increase with economic development.

The remainder of the paper is organized as follows. Section 2 presents the data facts for the U.S. that motivate our work; in section 3 we present the model and in section 4 we show how measuring the model's equilibrium with NIPA methodology makes growth non-balanced. In section 5 we calibrate the model to U.S. data and use it as a measurement tool to assess the declines in the MPK, the real interest rate, and the growth rate of GDP induced by structural transformation. In section 6 we discuss the international evidence and use the model to assess how much structural transformation can explain cross-country di erences in investment rates. In section 7 we compare the predictions of our model with those of a model with investment-speci c technical change. In section 8 we conclude.

2 Stylized facts for the U.S.

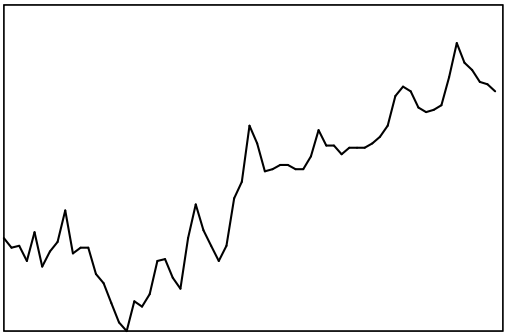
We present a set of facts that motivate our analysis and serve as quantitative targets for our model. Because of the need to match theory and data, we pay special attention to the measurement of variables in a way that is consistent with the two-sector model presented below. The key variables are the relative price of goods over services, the investment to GDP ratio measured in real terms, the capital-GDP ratio measured in real terms, and the nominal share of services consumption in total personal consumption expenditure. In the two-sector model below we assume that the manufacturing sector produces a good that can be used both for investment and for consumption of manufacturing. Thus, in the data we construct a price of goodswhich is a Fisher chain-weighted price index of consumption goods and gross domestic investment (GDI).[7]

The relative price goods/services is obtained from NIPA tables[8] as the price of goods (constructed as described above) relative to the price of services. The real GDI to GDP ratio is calculated as the ratio of real investment to real GDP. We de ate nominal GDI[9] using the sameprice of goodsused to construct the goods/services price ratio. Note that when

[6] Duernecker, Herrendorf, and Valentinyi (2017) also point out that the measurement of the model with NIPA methodology is key for the model to generate the slowdown in aggregate TFP. Moro (2015) shows

using the investment de ator from NIPA tables to de ate investment, the trend observed in the investment/GDP ratio is similar and statistically signi cant, but less pronounced.[10] This is discussed further below because replicating a measure of the investment-output ratio de ated by the investment price requires a three-sector model.[11] Finally, real GDP is given by nominal GDP de ated by the GDP de ator.

Additionally, we present evidence on the evolution of the capital-GDP ratio. We are interested in the ratio between the real capital stock and real GDP, i.e. where each nominal measure is de ated by its own price. Note that this di ers from the ratio of the two nominal measures as long as the relative price de ators for capital and GDP are di erent.



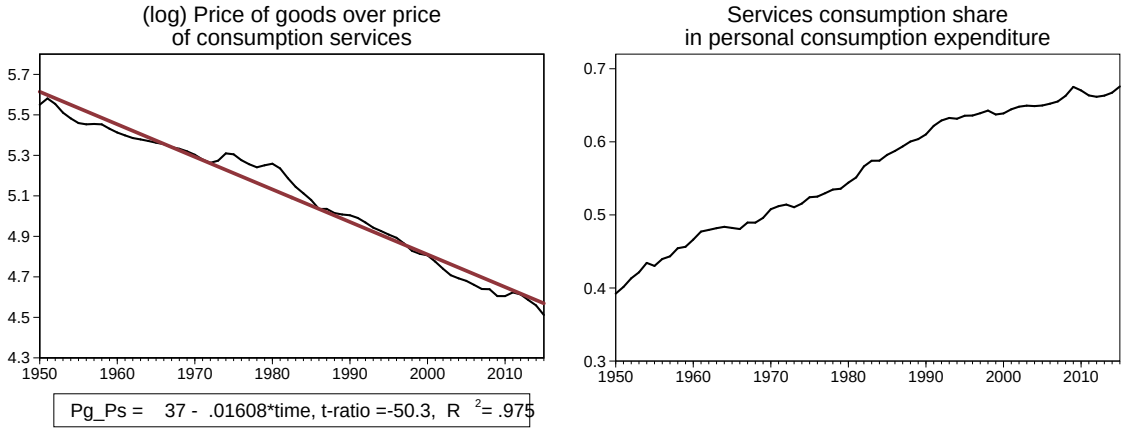


Figure 1: BLS capital-output ratio, Fernald capital-output ratio, real investment-output ratio, nominal investment-output ratio, price of goods relative to services consumption, and share of services consumption in total consumption expenditure. All variables in logs and with a tted linear trend except for consumption shares.

capital to GDP ratio. The former increases at a rate of 0.92% per year and the latter at a

wage. The budget constraint is

$$E_t + K_{t+1} = w_t + K_t(1 + r_t \quad); \tag{3}$$

where w_t is the wage rate, K_t is the amount of capital owned by the household, r_t is the (net) return on capital and is the depreciation rate. Thus, the problem of the household is to maximize (1) subject to (2) and (3).

The indirect utility function $V(p_{st}; p_{gt;} E_t)$ encompasses the static problem in which the household decides, given the level of consumption expenditure E_t, how much to spend in goods and services such that instantaneous utility is maximized and

$$E_t = p_{st} C_{st} + C_{gt};$$

holds, where C_{st} and C_{gt} are the optimal consumption levels of services and manufacturing.

3.2 Firms and Market Clearing

There are two representative rms in the economy operating in perfect competition. The rst rm produces the manufacturing good with technology

$$y_{gt} = k_{gt}(n_{gt} A_{gt})^{1} \quad ; \tag{4}$$

where k_{gt}, n_{gt} and A_{gt}^{1} are capital, labor and total factor productivity (TFP) of the goods producing rm. This output can be used to build the capital stock or as consumption of manufacturing.[12] The second rm produces services with technology

$$y_{st} = k_{st}(n_{st} A_{st})^{1} \quad ; \tag{5}$$

with k_{st}, n_{st} and A_{st}^{1} being capital, labor and TFP of the service producing rm. The output of this rm is used as services consumption.

The e ciency terms in the two sectors evolve according to

$$\frac{A_{st+1}}{A_{st}} = 1 + \quad _s; \tag{6}$$

$$\frac{A_{gt+1}}{A_{gt}} = 1 + \quad _g; \tag{7}$$

[12] In Appendix A we consider the case in which consumption of manufacturing and investment are produced in two di erent sectors.

where $_s$ and $_g$ are exogenous [redacted] assume that $_s$ < $_g$.

In equilibrium, all markets [redacted] d:

and

$$_g a^{+1}$$

by the sectoral price, is equal across sectors. However, the physical marginal product of

Use some amount of GDP, say y units, whose price is $P_{GDP;t}$ at time t, to purchase some capital such that $P_{GDP;t}\, y = P_{kt} K_t$ holds. The real return to capital at time t+1 is r_{t+1}, so the investor has, at $t+1$, $P_{kt+1} K_t (1 + r_t)$ or, by using the previous equality, $P_{kt+1} \frac{P_{GDP;t}\, y}{P_{kt}} (1 + r_t)$.

Table 1: Parameter Values

	A_{g1}	A_{s1}

Figure 2: Model versus Data.

very difficult to detect such trend decline in the data. Using state space models allowing for a change in the long-run growth rate of GDP, however, Antolín-Díaz, Drechsel, and Petrella (2017) find that there is a slow moving fall in the growth rate of real GDP in the U.S.[15] They report a fall from an estimated long-run growth of 3.5% in the 1950s to 2% in recent years (a decline of almost 43%). Their estimates correspond to real GDP growth and are not in per-capita terms. Given the decline in the rate of population growth of about 1 percentage point (1.7% in the 1950s to 0.7% in the current decade) this implies a decline in the rate of growth of per capita GDP of around 28%.

Figure 4 reports the MPK, the real interest rate and GDP growth implied by the model. The left panel of Figure 4 shows that the MPK declines by 36% over the period considered

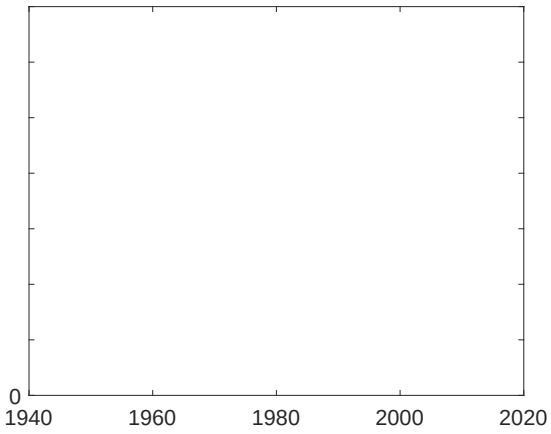


Figure 3: GDP: Model versus linear trend.

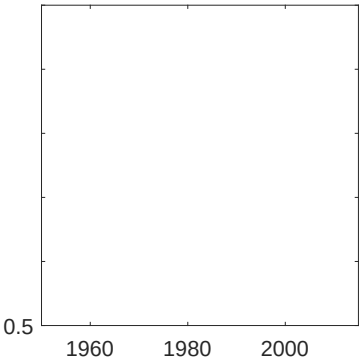


Figure 4: Model versus Data.

The middle panel of Figure 4 shows that while the e ect on the MPK is striking in magnitude, the corresponding e ect on the real interest rate is very contained. It goes from 7.42% to 7.04% in GDP units and from 7.27% to 6.80% in consumption units.[16] The di erence between the decline in the MPK and the real interest rate lies in the fact that, while the units of GDP obtained from an additional unit of capital decline strongly, the cost of buying that unit of capital also falls substantially. Finally, the third panel of Figure 4 shows the comparison between the decline in the real interest rate and the growth rate of GDP, when both are normalized to one in 1950. The growth rate of GDP declines faster than the real interest rate, regardless of the units the latter is measured in (i.e. GDP or consumption).

U.S. growth process, and allows to measure variables such as the MPK and the real interest rate that can be captured only using a theory framework. In the next section we bring the calibrated model to international evidence, and ask wheather the evolution of the real investment rate in the model is consistent with cross-country data.

6 Cross country evidence

In the previous section we show that the model of structural transformation measured with NIPA methodology ts well the growth experience of the U.S. both qualitatively and quantitatively. We note here that the model also ts qualitatively a set of cross-country facts documented in the literature on economic growth and development: i) the positive relationship of real investment rates with income levels (Barro (1991)); ii) the absence of correlation between nominal investment rates and income levels (Hsieh and Klenow (2007)); iii) a declining real interest rate with income levels (Barro and Sala-i-Martn (2004, p. 13)); iv) the absence of correlation between the marginal product of capital in units of capital and income levels (Caselli and Feyrer (2007)); v) beta-convergenge, that is, a poorer economy grow faster than a richer one (Barro and Sala-i-Martn (2004)).

Given these qualitative predictions of the model, we ask how well the model can account quantitatively for the cross-country evidence on real investment rates. Our model implies that, as the share of services increases, the investment to GDP ratio measured in real terms increases. Thus, we can use the model to compute how much of the cross-country di erences in real investment rates can be accounted for by an economy at di erent stages of structural transformation. To do this, we tie our hands by using the calibration of the previous section for the U.S. growth path. Thus, our exercise amounts to asking whether the U.S. growth experience produces an evolution of the real investment to GDP ratio that resembles the cross-country evidence.

We use data from the International Comparisons Program (ICP) used to construct the Penn World Tables for the years 1980, 1985, 1996, 2005 and 2011. We focus on these years as they contain the benchmark data with details on expenditure components measured in local currency (nominal) and in purchasing power parity (PPP) dollars (real). Appendix C describes in detail data sources and methodology. We construct data for the cross-section of countries for the real and nominal shares of investment in GDP, and the share of services in private consumption expenditures. In table 3 and gure 4 we report, for each year, the estimated elasticity of the real and nominal investment rates with respect to the share of services in private consumption.[17] Similar to the results in Hsieh and Klenow (2007), who

[17] We also provide estimates for all countries and years pooled. To account for di erent intercepts, in that

Table 3: Coe cient of PPP investment rates and domestic prices investment rates regressed on consumption share of services. All variables in logs.

year	PPP I/Y	Nominal I/Y	No. Observations

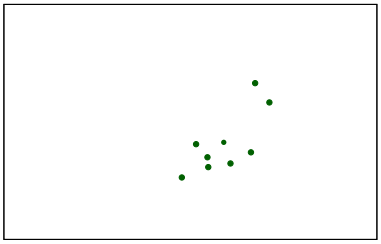


Figure 5: Investment to GDP ratio measured in PPP dollars (left column) and in nominal terms (right column) versus consumption share of services. Data from the International Comparisons Program, 1980, 1985, 1996, 2005, 2011. See Appendix C for construction.

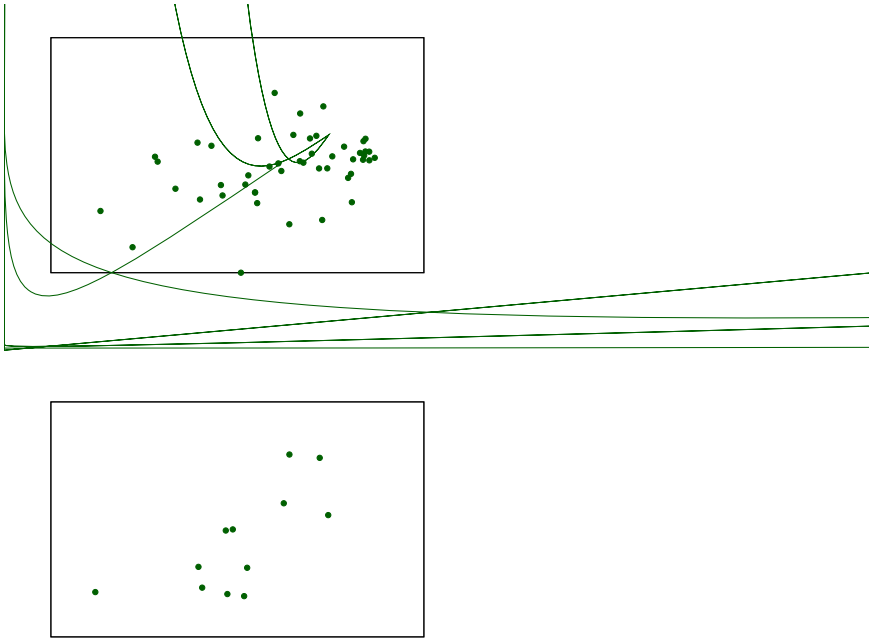


Figure 5: Continued

across countries and years in the data (0.10 for Tanzania in 1996). This implies that, given the growth rates of TFP in table 1 and starting from period 1 of the U.S. simulation, we need to project the model back by 38 periods. This exercise leaves us with 104 years of data for the arti cial economy with the same parameter values as the U.S. economy between 1950 and 2015. We then calculate the real investment to GDP ratio of this arti cial economy for the 104 periods and the corresponding average elasticity with respect to the consumption share of services.[19] This yields a model elasticity of 0.63. The average elasticity in table 3 for the ve years considered is 0.61. The elasticity obtained by pooling the data for all years is 0.56 (row \all years" in table 3). Figure 6 shows the scatter plot for all country-years and the log-linear t together with the model-implied log-linear t.[20] The two lines are virtually undistinguishable, showing a striking resemblance between the model and the cross-country elasticity of the real investment to GDP ratio with respect to the services share in consumption. Thus, even without resorting to transitional dynamics, the behavior of the structural transformation model, measured with NIPA conventions, can account well for the international evidence on real investment rates. This suggests that most countries experience

[19] The elasticity of the real investment rate to the share of services in consumption is given, period by period, by the percentage change in the rst variable divided by the percentage change in the second variable.

[20] The intercept of the model implied log-linear t in Figure 6 is chosen such that it crosses the data t line at the average value of the services shares.

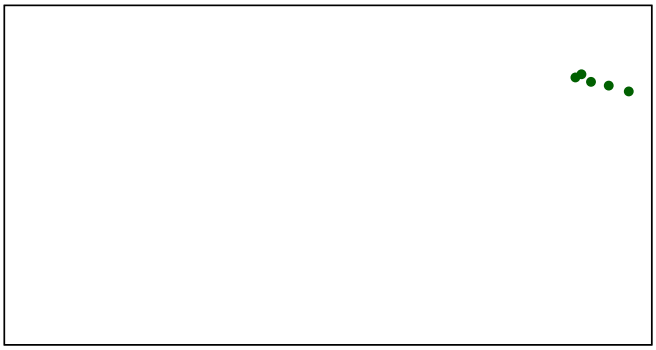


Figure 6: Cross country investment to GDP ratio in PPP dollars for all years v consumption share of services. The red line is the linear data t, and the blue line the t arising from the model calibration.

a growth process that resembles the one of the U.S.[21]

7 ISCT or Structural Transformation?

Given some common features, it is due discussing here the relationship of our results with those of the investment-speci c technical change (ISCT) literature. The model of structural change endogenously produces ISTC as the price of investment relative to aggregate

facts observed in the data: 1) structural transformation; 2) a decline in the growth rate of GDP; 3) an acceleration of ISTC. The first two facts apply to both a single country such as the U.S., and also at the cross-country level as discuseed above. The third fact has been recently documented by Samaniego and Sun (2016), who show that ISTC accelerates with the level of income. The model of structural transformation captures this acceleration due to the fact that the share of services in consumption increases over time, thus making the relative price of investment decline faster at higher income levels. Note that we make this comparison between models considering that both are measured with NIPA methodology, so the differences that we highlight do not depend on measurement issues.

Nevertheless, it is useful to analyze the performance of a structural transformation model that directly nests ISTC. To do so, Appendix A presents a structural transformation model where the investment good is produced by a third sector that differs from the sectors producing the consumption good and services. The quantitative performance of this model is also good. The three sector model performs remarkably well in fitting GDP growth and the evolution of the share of services. As in the two-sector model, it reproduces a growth of the investment-GDP ratio slightly smaller than in the data. The decline in the MPK in this case is 25% in terms of GDP and 32% in terms of aggregate consumption.

8 Conclusions

The time series properties of post-war U.S. economic growth are characterized by "unbalanced" growth features: the real investment-output and capital-output ratios display significant upward trends, whereas the rate of growth of per capita GDP displays a mild decline. We argue that a two sector model of structural transformation from manufacturing to services displaying "balanced" growth can account for these features. In this model, disp(S)1(.)-3(h)1(i)A

calibration arising from the model for the U.S. economy, we then ask the question whether our model can explain international cross-country evidence on real investment to output ratios. It does. The elasticity of the real investment-output ratio with respect to the share of services in consumption is 0.61 in the data. The elasticity arising from the model is 0.63. That is, we can interpret the well known fact that real investment-output ratios increase as economies develop as a consequence of economies being at di erent stages of structural transformation along the same growth path. It follows that the two-sector model of structural transformation represents a simple and very tractable tool that can be used to study the process of economic growth. In particular, to explain the long run evolution of real investment rates and capital-output ratios, it is not necesary to assume that di erent countries are on transitional dynamics converging asymptotically to a balanced growth path. The model does not even require to assume di erences in preferences, taxation, or other deep parameters to predict the correct cross-country di erences in investment rates. The key assumption to generate these di erences is a constant di erential TFP growth between the goods and the services sector along the growth path, something that is motivated by the well established constant decline of the relative price goods/services in U.S. data.

Thus, on the one hand, our results suggest that one-sector growth models cannot account for a typical growth path that involves an increasing real investment-output ratio. On the other hand, they suggest that a two-sector model, when appropriately taken to the data, can account well for the time series evidence for the U.S. and for the international evidence on investment-output ratios. The measurement of the model with NIPA conventions is a key aspect of our approach, which is overlooked in most applications comparing multi-sector models to the data.

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Appendix

A A three sector model

In this appendix we extend the model to three sectors: a consumption good sector, a services sector and an investment sector. There are now three representative rms in the economy operating in perfect competition. The rst rm produces the manufacturing consumption good with technology

$$y_{gt} = k_{gt}(n_{gt}$$

Table 4: Parameter Values

					A_{g1}	A_{s1}	A_{l1}	$_g$	$_s$	$_l$
0.95	0.34	0.06	0.17	0.50	0.63	1	1	1	3.05%	0.62%	2.60%

Table 5: Data targets

Target	(1)	(2)	(3)	(4)	(5)	(6)
Data	2.12%	0.393	0.685	0.67%	-1.61%	-1.31%
Model	2.13%	0.390	0.685	0.46%	-1.61%	-1.31%

and

$$n_{gt} + n_{st} + n_{lt} = 1:$$

By normalizing TFP levels in the three sectors in the rst period to 1, we then need to calibrate three preference parameters, and se

Figure 7: Three-sector model versus Data.

Q^L

weighted average of the two. The bottomline is that the Fisher quantity index is independent of the numeraire.

The Fisher price index instead, is not independent of the numeraire. To see this we can proceed in two different ways, a direct one and an indirect one. The direct one requires constructing the Fisher price index using the NIPA formula. This is a weighted average of a Laspeyres and a Paasche price indices:

$$P_t^L = \frac{\sum p_t q_{t-1}}{\sum p_{t-1} q_{t-1}}$$

$$P_t^P = \frac{\sum p_t q_t}{\sum p_{t-1} q_t};$$

where again the sum is over the goods and services included in the bundle. The Fisher index is then given by a weighted average of Laspeyres and Paasche

$$P_t^F = \sqrt{P_t^L P_t^P}.$$

Consider the case of two goods. The Laspeyres is:

$$P_t^L = \frac{p_{1;t} q_{1;t-1} + p_{2;t} q_{2;t-1}}{p_{1;t-1} q_{1;t-1} + p_{2;t-1} q_{2;t-1}}. \tag{18}$$

It should be clear that this formula is not independent of the numeraire. To see this, consider that in (18) the numeraire each period is current dollars, as prices are expressed in dollar units. If instead, the numeraire each period is the price of good 1, equation (18) becomes

$$\tilde{P}_t^L = \frac{q_{1;t-1} + \frac{p_{2;t}}{p_{1;t}} q_{2;t-1}}{q_{1;t-1} + \frac{p_{2;t-1}}{p_{1;t-1}} q_{2;t-1}}. \tag{19}$$

Clearly

$$P_t^L \neq \tilde{P}_t^L.$$

The same argument can be made for the Paasche price index.

The other way to see this is to use the indirect method to construct the Fisher price index, that is dividing nominal GDP (i.e. in current dollars) by the Fisher index of real GDP computed above. Then

$$P_t^F = \frac{GDP_t}{Q_t^F}.$$

While real GDP Q_t^F is independent of the numeraire, nominal GDP, given by GDP_t in the formula, is not. For instance, if we express nominal GDP in units of apples instead of dollars,

separate rents out, we imputed rents according to the proportion of rents in total housing costs in 1996. The results without this imputation remain very similar and are available on request.

2011: services include health, transport, communication, recreation and culture, education, restaurants and hotels, miscellaneous goods and services. Housing expenditure is obtained as the di erence between \individual consumption expenditure by households" and \individual consumption expenditure by households without housing".