What is the Long-run relationship between the Labor Income Share and the Relative Price of Investment? – Preliminary

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Abstract

Using data from the United States, co-integration tests reveals that the labor income share and the relative price of investment are most likely not co-integrated. However, co-variation tests indicates that the time series share a common $I(1)$ component. This result has important implication as it suggest that investment-specific technological progress – which is considered as the driving force of the long-run behavior of the relative price of investment – may have played a great deal in the recent decline of the secular trend of the labor income share.

Keywords: Growth, Investment-specific technological change, Labor share, Time series, Unit root, Cointegration. *JEL codes*: E01, E22, C32, O47.

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1 Introduction

A stylized fact in macroeconomics, emphasized by Kaldor (1957), is that the share of national income received by labor and capital are roughly constant over long periods of time. However, the labor share has declined significantly since the early 1980s in most advanced and emerging economies. Several recent studies have attempted to provide an explanation to justify this sudden structural break, and the bulk of studies emphasize the role of either technological progress or globalization. Karabarbounis and Neiman (2013), for instance, argue that a large part of the decline in the trend of the labor share is associated with the decline in the relative price of investment goods a phenomenon often ascribed to investment-specific technological progress due to advances in information technology and the computer age. Using a model of the labor share, they estimate that a 25 percent decline in the relative price on investment goods since 1975 explains roughly half of the 5 percentage point decline in the global labor share.

In this paper, I adopt a different, yet complementary, approach to evaluate the long-run relationship between the labor share and the relative price of investment in the United States. Specifically, I conduct an empirical analysis of the univariate and joint long-run properties of the labor share and the relative price of investment through the use of unit roots and co-integration tests. It is quite imperative to note that the exercise in this paper is not attempting to answer the question about the source of the decline in the labor share. The purpose of the analysis is to simply understand the extent to which the labor income share and the relative price of investment co-move at long horizons. The existence of any co-movement is not a foregone conclusion, but only suggestive that investment-specific technological innovations which drives the long-run behavior of the relative price of investment may have played a role in the decline in the secular trend of the labor income share.

Therefore, I first perform units roots tests using U.S. data over the period 1975-I to 2009-I and find that both of these time series contain a stochastic nonstationary component. This finding can be fulfilled either by assuming that each series process contains an independent stochastic trend or by assuming that the two series share a single stochastic trend. I allow the data to inform us about which of these two modeling strategies is empirically more compelling, and then perform cointegration tests on the labor share and the relative price of investment goods. I find that the two series appear to share a common stochastic trend; however, the result is quite sensitive to the specification of the cointegration relation. Specifically, the Johansen's trace test reveals that the labor share and the relative price of investment are co-integrated when the co-integrating relation of the data generating process is assumed to contain an intercept, and there are no trends in the associated data series. When I consider the case of a linear trend in the data series, the test rejects the null of the existence of a co-integration relationship between the two series.

Since the evidence from co-integration tests points to the fact that the labor share and the relative price of investment are most likely not co-integrated, I attempt to assess whether the two series have orthogonal non-stationary components or a common component without necessarily being co-integrated. Consequently, I perform a simple test in the spirit of Cochrane and Sbordone (1988) to determine the long-run co-variation of the labor income share and the relative price of investment. The results are unequivocal: the two series co-vary at long horizons indicating that the labor share and the relative price of investment share a common $I(1)$ without necessarily being co-integrated.

Overall, these results do not paint a definitive picture about the long-run relationship between the labor income share and the relative price of investment. They illustrate the difficulty associated with making clear statement about whether the two series are driven by a common component: a finding that would provide solid evidence for the argument that the trend component of the labor share, which has decreased for the past 30 years, is driven by investment-specific technological change or technological innovations that are embodied in capital units. However, it is also important to note that the lack of co-integration between the two series does not invalidate the explanation that technological changes play an important role in the secular trend of the labor share. It is quite possible that other factors such as globalization or profits shares in combination with technological innovations impacted the long-run behavior of the share and contributed to the decline in its trend.

The rest of the paper is structured as follows. In the next section, I discuss the issues related to the measurement of the labor income share data series and establish some facts about the behavior of the share in the United Sates. Then, in section 2, I present the results of the statistical analysis of the univariate and joint long-run properties of the labor income share and the relative price of investment and discuss the implications of such results. Section 3 concludes the paper.

2 Measurement

Conceptually, the share is obtained by dividing the compensation of employees by gross value added, where gross value added is the sum of the following components: compensation of employees, corporate profits, rental income, net interest income, proprietors' income, indirect taxes less subsidies, and depreciation. At first glance, the computation seems straightforward. However, there has been a debate concerning the apportionment of proprietors' income (and the accounting of the government sector). Proprietors' income includes both labor and capital components and a concise decomposition is fundamentally ambiguous. For the baseline specification, I follow the established methodology outlined in Gomme and Rupert (2004) and classify the compensation of employees as unambiguous labor income (UL), corporate profits, rental income, net interest income, and depreciation as unambiguous capital income (UK). I then compute the labor share as the ratio of unambiguous labor income to the sum of unambiguous labor income and unambiguous capital income.[1] I also consider, as an alternative, the approach in Cooley and Prescott (1995) and Rios-Rull and Santaeulàlia-Llopis (2009) who assume that the ratio of unambiguous capital income to unambiguous income equals the ratio of ambiguous capital income to ambiguous income. One final alternative which circumvents the issues related to the apportionment of proprietors' income is to focus on the labor share within the corporate sector. This measure is defined as corporate compensations to employees divided by the gross value added of the corporate sector[2]. The computation of the labor income share within the corporate sector is the approach adopted

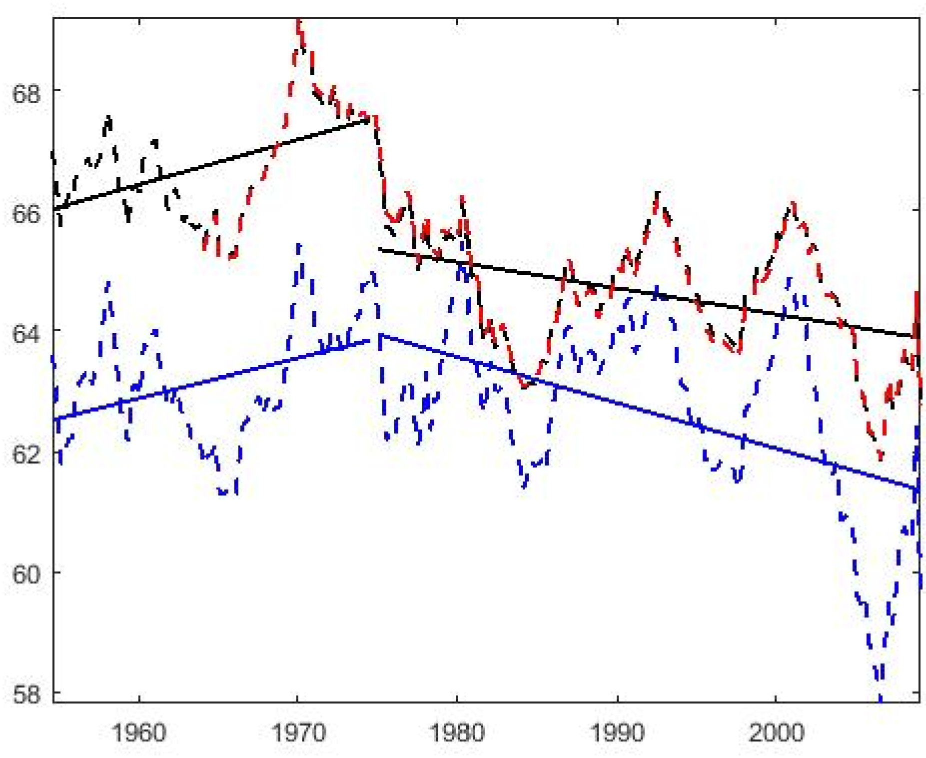
[1] I would like to thank Maggie Jacobson from the Federal Reserve Bank of Cleveland for providing some help with the construction of the series.

[2] The series are extracted from Line 1 and 4 of NIPA Table 1.14

in Karabarbounis and Neiman (2013); hence, it is useful to include it and compare how the results vary across the different measures.

The time series for the labor income share, computed under the above-mentioned assumptions, are plotted in Figure 1 for the time period 1954.III to 2009.I at a quarterly frequency along with the associated trends. The trends are estimated by fitting a linear trend to the data. I use 1974.III as the break point in the trend line in commensurate with the study in Karabarbounis and Neiman (2013) that establishes the decline of the share starting in 1975.I . Few observations can be made from the Figure. First, focusing on the dashed lines, there does not appears to be any noticeable difference between the two series computed using the approach in Gomme and Rupert (2004) and Cooley and Prescott (1995)(GR and CP hereafter). However, the labor income share within the corporate sector is smaller throughout the entire sample period. Next, in regards to the solid lines, we can note a clear decline in the trend of all series when comparing the two time periods. The decline is even larger in the share within the corporate sector.

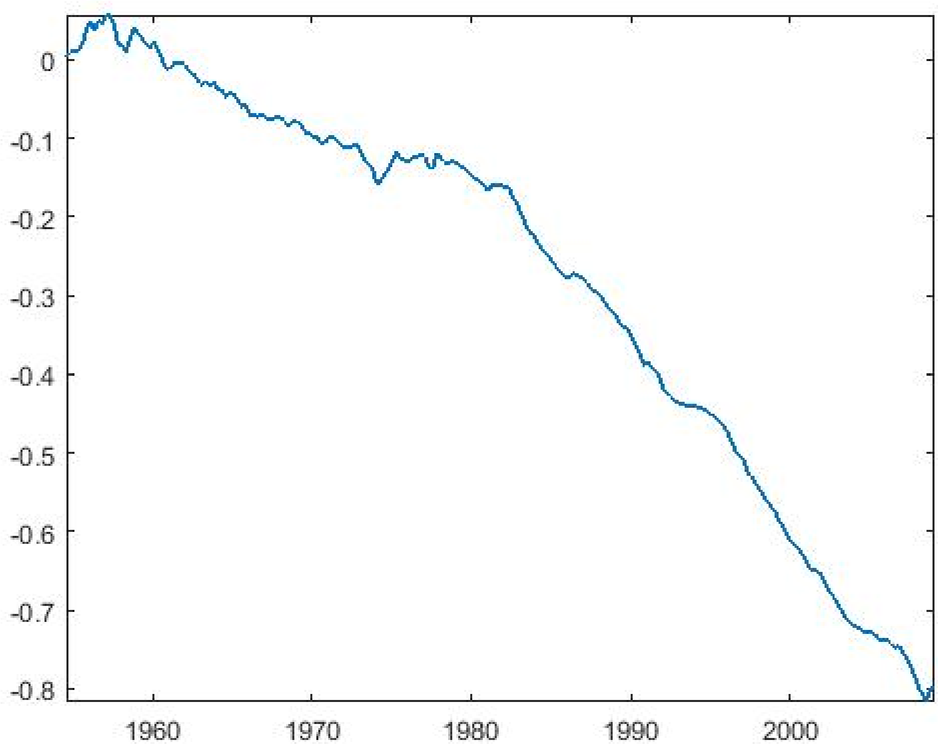
Figure 1: Labor Income Share, U.S 1954.III–2009.I



Notes: The labor share series within the corporate sector and following the approaches in Gomme and Rupert (2004) and Cooley and Prescott (1995) are represented by the blue, black and red dashed lines, respectively. The associated trend lines are graphed in solid lines

The relative price of investment goods corresponds to the ratio of the chain-weighted deflators for consumption and investment which is taken from Justiniano, Primiceri, and Tambalotti (2011). The data series is plotted in Figure 2, and it exhibits a clear downward trend.

Figure 2: Relative price of investment, U.S 1954.III–2009.I



Notes: Relative price of investment computed by Justiniano, Primiceri, and Tambalotti (2011).

3 Empirical Analysis

In this section, I investigate the univariate and joint long-run properties of the labor share and the relative price of investment (RPI henceforth) for the period 1975.I to 2009.I. Specifically, I perform units roots tests, co-integration tests and co-variation tests in the spirit of Cochrane and Sbordone (1988) to determine whether each series contains a stochastic component and whether there exists a relationship between these stochastic components. As noted above, the relative price of investment goods corresponds to the ratio of the chain-weighted deflators for consumption and investment which is taken from Justiniano, Primiceri, and Tambalotti (2011). For the labor income share series, I use all three series as computed in the previous section.

3.1 Unit root tests

I carry out Augmented Dickey Fuller (ADF) tests that examine the null hypothesis that the logarithms of the labor income share and the relative price of investment have a unit root. The lag order is chosen based on the Schwartz and Hannah-Quinn criteria (SIC and HQ, respectively). The results of the tests are presented in Table 1, and they clearly indicate that the tests fail to reject the null hypothesis of the presence of a unit root in the series at the standard 5 percent confidence level.

An alternative to the ADF test is the Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) test that

Table 1: Testing the null hypothesis of the presence of a unit root.

Test	Variable	Lags (SIC and HQ)	Test Statistic	Critical Value	Reject Null
ADF	Log share GR	2	-1.5718	-2.8839	No
ADF	Log share CP	2	-1.7238	-2.8839	No
ADF	Log share corp. sect	2	-1.2932	-2.8839	No
ADF	Log RPI	2	1.0734	-2.8839	No

Note: ADF, SIC and HQ stands for Augmented Dickey Fuller test, Schwartz, and Hannah-Quinn, respectively. GR and CP correspond to the approaches discussed in Gomme and Rupert (2004) and Cooley and Prescott (1995). In all cases, the model includes a constant and no time trend.

evaluates the null hypothesis that the time series is stationary in levels. The lag length is still selected according to the SIC and the HQ criteria, and I allow for the possibility of a time trend in the series. The results are illustrated in Table 1, and they are consistent with those obtained from ADF tests: the KPSS reject the null hypothesis of stationarity in the logarithm of the labor income share and the relative price of investment.

Table 2: Testing the null hypothesis of stationarity.

Test	Variable	Lags (SIC and HQ)	Test Statistic	Critical Value	Reject Null
KPSS	Log share GR	2	0.3135	0.1460	Yes
KPSS	Log share CP	2	0.2803	0.1460	Yes
KPSS	Log share corp. sect	2	0.4349	0.1460	Yes
KPSS	Log RPI	2	0.7122	0.1460	Yes

Overall, stationarity tests are unequivocal in terms of the univariate properties of the labor income share and the relative price of investment: both time series contain a non-stationary stochastic component.

3.2 Co-integration between the labor income share and the relative price of investment

The results from the previous section clearly indicate that the time series of both the labor income share and the relative price of investment contain a non-stationary stochastic component. With that information at hand, the next goal is to determine the extent to which these two non-stochastic component might be co-integrated. Specifically, I perform the Johansen's trace test that evaluate the null hypothesis that there is no cointegration relationship between the two series. A rejection of this hypothesis would indicate that the labor income share and the relative price of investment are driven by a single stochastic component. Consistent with the previous section, I still select the lag length lag length according to the SIC and the HQ criteria. A final and crucial component of the test is the specification of the data generating process (DGP) for the co-integrated model as this step has great importance on the results of the test. In other words, should a deterministic term, constant or linear, be included in the DGP? Such decisions are usually guided by the underlying process of the variables which may or may not contain a drift term. Instead of relying of an eye test, I consider the cases with and without the addition of a deterministic term in the DGP. The results of the Johansen's trace tests are shown in Table 3.

Table 3: Johansen's trace test for co-integration.

Null hypothesis	Alternative hypothesis	Deterministic trend	Lags	Share variable	p-value
$r = 0$	$r > 0$	No	2	GR	0.0016
$r = 0$	$r > 0$	Yes	2	GR	0.7912
$r = 0$	$r > 0$	No	2	CP	0.0010
$r = 0$	$r > 0$	Yes	2	CP	0.7395
$r = 0$	$r > 0$	No	2	corp. sect	0.0013
$r = 0$	$r > 0$	Yes	2	corp. sect	0.3561

Note: The co-integration tests are performed on the logarithms of the relative price of investment and the three measures of the labor income share. The sample period is 1975.I to 2009.I. The variable r denotes the number of co-integrating vectors. GR and CP correspond to the approaches discussed in Gomme and Rupert (2004) and Cooley and Prescott (1995) to compute the labor income share, and corp. sect. corresponds to the labor income share in the corporate sector.

The co-integration results portray are inconclusive. When a deterministic term is included, the null hypothesis of zero co-integrating vector is rejected at the standard 5 percent confidence level for all three measures of the labor income share. However, the test fails to reject the null hypothesis of zero co-integrating vector when a deterministic trend is considered. The model with no deterministic term is typically appropriate for non-trending data with non-zero mean while the model with a deterministic term is suitable for linear-trending data with non-zero mean. It is possible to make an argument that the labor income share may not have a clear trend based on studies that have questioned the validity of the declining "trend" in the series.[3], but it would be very hard to justify the non-existence of a trend in the relative price of investment as illustrated in Figure 2. Consequently, we cannot affirm that the model without the deterministic trend is the most preferred specification. Therefore, it is impossible to claim with certainty that the labor income share and the relative price of investment are driven by a single stochastic component.

Given this lack of clear co-integrating relationship, are we to assume that the non-stationary stochastic component of each series are orthogonal to each other or is it possible for the two series to still share a common component but not be co-integrated? I evaluate this possibility in the next section.

3.3 Co-variation between the labor income share and the relative price of investment

Before it can be concluded that the non-stationary component of the labor income share and the relative price of investment are orthogonal to each other, I adopt a simple approach to determine whether the two series, while not being co-integrated, may share a common $I(1)$ component. Much of the discussion that follows is borrowed from Benati (2013).[4] The approach, which is proposed by Cochrane and Sbordone

[3]Elsby, Hobijn, Sahin (2013

[4]I would like to thank Luca Benati for sharing the codes to implement this approach.

(1988), search for a statistically significant extent of c-variation between the labor income share's and the relative price of investment's long-horizon differences. The basis of this approach is that whatever may happen at short-to-medium run horizons for two non-stationary series that are suspected to be related in the long-run but are not co-integrated , the two series' long-horizon differences should exhibit a statistically significant extent of co-variation. Specifically, consider the two $I(1)$ processes $y_{1,t}$ and $y_{1,t}$, defined as

$$y_{1,t} = \alpha_1 z_t + \beta_1 x_{1,t} + \gamma_1 s_{1,t} \tag{1}$$

$$y_{2,t} = \alpha_2 z_t + \beta_2 x_{2,t} + \gamma_2 s_{2,t} \tag{2}$$

where $z_t = z_{t-1} + u_t$ is the common non-stationary component; $x_{i,t} = x_{i,t-1} + v_{i,t}$, $i = 1, 2$, are idiosyncratic non-stationary components; and $s_{i,t} = \rho_i s_{i,t-1} + \epsilon_t$, $i = 1, 2$, with $|\rho_i| < 1$ are idiosyncratic, but correlated $I(0)$ components. The four shocks – u_t, $v_{1,t}$, $v_{2,t}$ and ϵ_t – are uncorrelated both contemporaneously, and at all leads and lags, with variances σ_u^2, σ_{v1}^2, σ_{v2}^2 and σ_ϵ^2, respectively. Finally, α_i's, β_i's and γ_i's are parameters. This DGP captures the notion of two $I(1)$ processes which are not co-integrated, but share a common random-walk component, the z_t.

Based on equations (1)-(2), there are two sources of co-variation between $y_{1,t}$ and $y_{2,t}$: the common random walk component and the two $I(0)$ processes, which are driven by the common shock ϵ_t. Hence, at long horizons co-variation between $y_{1,t}$ and $y_{2,t}$ will be dominated bythe common random walk component whereas the relative importance of the extent of co-variation originating from the two correlated $I(0)$ processes will asymptotically go to zero.

Formally, it can be shown that the k-horizon differences for the two processes are given by

$$y_{1,t+k} - y_{1,t} = \alpha_1 \sum_{j=1}^{k} u_{t+j} + \beta_1 \sum_{j=1}^{k} v_{1,t+j} + \gamma_1 \left[(\rho_1^k - 1) s_{1,t} + \sum_{j=1}^{k} \rho_1^{k-j} \epsilon_{t+j} \right] \tag{3}$$

$$y_{2,t+k} - y_{2,t} = \alpha_2 \sum_{j=1}^{k} u_{t+j} + \beta_2 \sum_{j=1}^{k} v_{2,t+j} + \gamma_2 \left[(\rho_2^k - 1) s_{2,t} + \sum_{j=1}^{k} \rho_2^{k-j} \epsilon_{t+j} \right] \tag{4}$$

which implies that the covariance between them is given by

$$E\left[(y_{1,t+k} - y_{1,t})(y_{2,t+k} - y_{2,t}) \right] = \alpha_1 \alpha_2 k \sigma_u^2 + \gamma_1 \gamma_2 \sigma_\epsilon^2 \frac{2 - (\rho_1^k + \rho_2^k)}{1 - \rho_1 \rho_2} \tag{5}$$

so that

$$\lim_{k \to \infty} \frac{E\left[(y_{1,t+k} - y_{1,t})(y_{2,t+k} - y_{2,t}) \right]}{k} = \alpha_1 \alpha_2 k \sigma_u^2 \tag{6}$$

thus implying that $(\frac{1}{k})$ times the co-variance between the two series' long horizon differences comes to be dominated by the common random walk component, and as a consequence, it is different from zero if and only iff the two series share a common $I(1)$ component.

Following Cochrane and Sbordone (1988), I estimate $(\frac{1}{k})$ times the co-variance between the two series' long horizon differences as

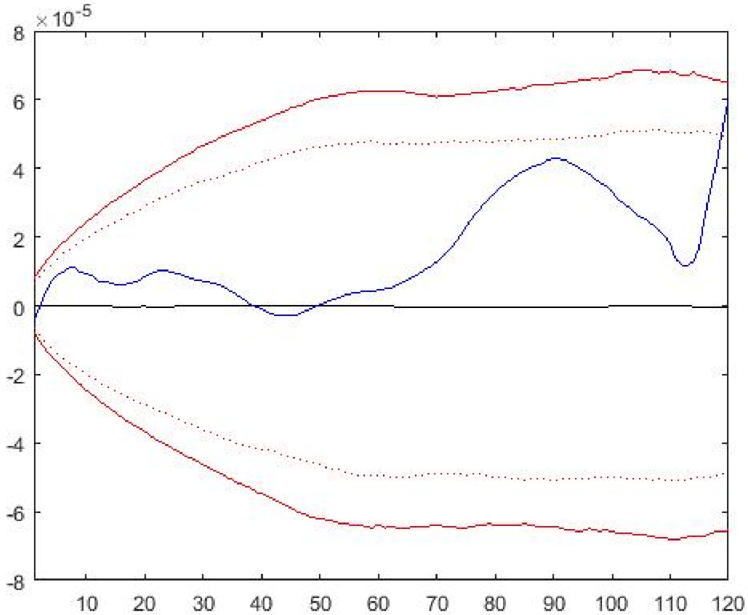
$$\frac{T}{k(T-k)(T-k+1)}\sum_{t=k}^{T}\left[(y_{1,t}-y_{1,t-k})-\frac{k}{T}(y_{1,T}-y_{1,0})\right]\left[(y_{2,t}-y_{2,t-k})-\frac{k}{T}(y_{2,T}-y_{2,0})\right] \quad (7)$$

where T is the sample length, and $\frac{(y_{1,T}-y_{1,0})}{T}$ and $\frac{(y_{2,T}-y_{2,0})}{T}$ are the estimated drifts in the two processes.

Figures 3 – 5 report the results of the estimator based on equation 7 at horizons up to 30 years ahead together with the median and the 90 percent and 95 percent coverage percentiles of the bootstrapped distribution of the estimator computed under the null hypothesis that the two processes follow orthogonal ARIMA(p,1,0) processes. The estimator is computed using the relative price of investment and either of the three series of the labor income share. The results based on the labor income share series computed using the GR and CP approaches suggest that the labor income share and the relative price of investment share a common $I(1)$ component. Specifically, the co-variance estimator exceeds the 90 percent and 95 percent coverage upper percentile of the bootstrapped distribution at all horizons beyond 60 and 70 quarters, respectively. However, the result are not mixed when we consider the labor share within the corporate sector: the co-variance estimator exceeds the 90 percent and 95 percent coverage upper percentile near the 120 quarters but it stays within the 95 percentile coverage of the bootstrapped distribution. Overall, the evidence appears to indicate that the relative price of investment and the labor income share share a common stochastic component at the 10 percent confidence level.

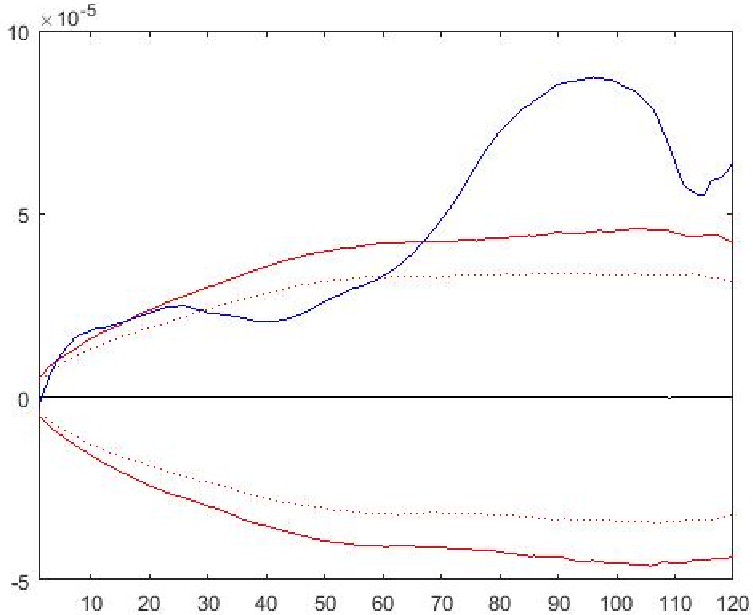
What are the implications of these results in regards to the decline of the secular trend of the labor income share? The direct answer is that the presence of a non-stationary stochastic component between the relative price of investment and the labor income share is only suggestive that investment-specific technological progress play an important role in the decline of the share if we assume that such technological progress is a dominant driving force of the relative price of investment. This assumption, in turn, is supported by a vast literature. In fact, under certain assumptions, the inverse of the relative price of investment equals the relative TFP of the investment sector where the latter could be defined as the investment-specific technology. Also, Basu, Fernald, Fisher, and Kimball (2013, Figure 2) find that the inverse of the relative price of investment and the relative TFP of the investment sector track each other fairly well over long periods of time. Therefore, it is impossible to rule out investment-specific technological progress as a major source of the break in the trend of the labor income share.

Figure 3: Co-variance estimator



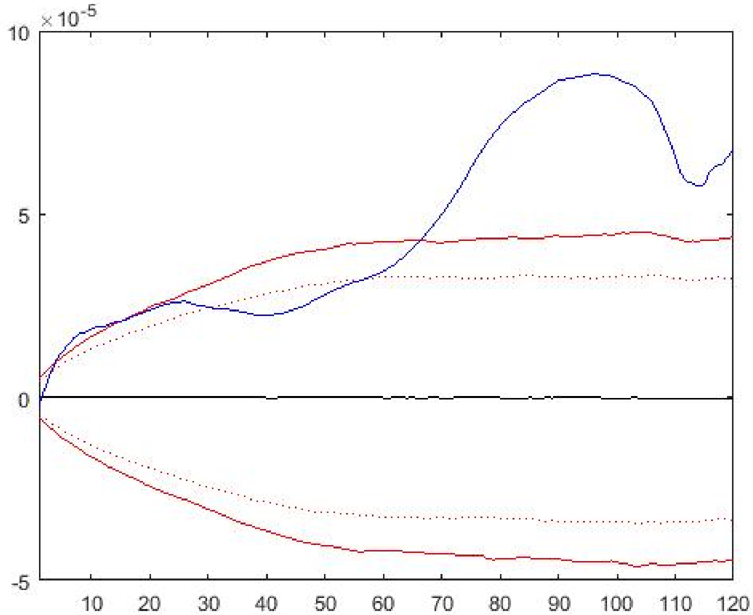
Notes: The solid blue line represents the simple estimates of $\frac{1}{k}$ times the covariance between the long horizon differences of the relative price of investment and the labor income share within the corporate sector. The solid black line, the dashed red line and the solid red line represents the median and the 90 percent and 95 percent coverage percentiles, respectively, of the bootstrapped distribution of the estimator computed under the null hypothesis that the two processes follow orthogonal ARIMA(p,1,0) processes.

Figure 4: Co-variance estimator



Notes: The solid blue line represents the simple estimates of $\frac{1}{k}$ times the covariance between the long horizon differences of the relative price of investment and the labor income share computed according to the approach in Gomme and Rupert (2004). The solid black line, the dashed red line and the solid red line represents the median and the 90 percent and 95 percent coverage percentiles, respectively, of the bootstrapped distribution of the estimator computed under the null hypothesis that the two processes follow orthogonal ARIMA(p,1,0) processes.

Figure 5: Co-variance estimator



Notes: The solid blue line represents the simple estimates of $\frac{1}{k}$ times the covariance between the long horizon differences of the relative price of investment and the labor income share computed according to the approach in Cooley and Prescott (1995). The solid black line, the dashed red line and the solid red line represents the median and the 90 percent and 95 percent coverage percentiles, respectively, of the bootstrapped distribution of the estimator computed under the null hypothesis that the two processes follow orthogonal ARIMA(p,1,0) processes.

4 Conclusion

In this paper, I conduct an empirical analysis of the univariate and joint long-run properties of the labor income share and the relative price of investment. Using U.S. data from 1975.I to 2009.I, I perform unit root and co-integration tests and find that while both series contain a non-stationary stochastic component $I(1)$, the respective component are not co-integrated. However, a simple test in the spirit of Cochrane and Sbordone (1988) reveals that, although the two series are not co-integrated, they share a common $I(1)$ component. This result is important because it lends support to the recent claim that investment-specific technological progress – which has been demonstrated to be the driving force of the long-run behavior of the relative price of investment – played a major role in the decline of the labor income share.

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