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Abstract

We study a model of secular stagnation, income and wealth distribution, and employment in the classical-Marxian (CM) tradition, with the purpose of drawing a contrast with established neoclassical accounts of the topic (Piketty, 2014; Gordon, 2015). In these explanations, which assume full employment of labor at all times, an exogenous reduction in the growth rate g increases the difference with the endogenous rate of return to capital r. The capital-income ratio rises and, if the elasticity of substitution is above one, the wage share falls. Our explanation does not presuppose full employment, and features a crucial tension between profit-driven capital accumulation and wage-driven labor-augmenting technical change: both these features are defining for CM economics and have been emphasized in recent heterodox macro literature. Institutional or technological shocks that lower the wage share initially foster capital accumulation —which is profit-driven— and increase wealth inequality. However, the effect on long-run growth is negative, because a reduction in the wage share lessens the incentives by firms to introduce labor-saving innovation, which is wage-driven. The capital-income ratio must rise in order to restore balanced growth and stabilize employment in the long run; and the increase in wealth inequality is permanent. The ultimate effect on long-run employment depends on the relative strength of the response of technical change vs. real wage growth to labor market institutions: we identify a simple condition that delivers either a wage-led or a profit-led long-run employment regime. We then test the model using time-series data for the US (1960-2019): impulse responses from VECM estimators lend support to the main predictions of our model, and point to the employment-population ratio being wage-led.

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1 Introduction

The publication of Thomas Piketty's *Capital in the XXI Century* (Piketty, 2014) revived the interest of the mainstream of the economics profession in questions of distribution of income and wealth. The combination of path-breaking data work on the historical increase in the capital-income ratio and the top wealth share —the latter occurring after the 1980s— and the use of the familiar Solow (1956) growth model to provide a comprehensive understanding of rising inequality and stagnation made a lasting mark both in the profession and the public. A complementary argument is made in Gordon (2015), who used basically the same modeling framework but emphasized the forces at play that may have contributed to the growth slowdown, i.e., a reduction in g.

The combined neoclassical argument is now part of the economics toolbox: an exogenous reduction in the growth rate of the economy—be that because of declining fertility, the exhaustion of path-breaking scientific discoveries, 'diminishing returns' to information and communication technology, the decline in new startups, a decline in net investment—increases the difference $r - g$, between the rate of return to wealth and the growth rate of income: the implication is that the capital-income ratio rises. Factor substitution along a neoclassical production function provides a link from the capital-income ratio to the functional distribution of income: provided that the elasticity of substitution between capital and labor be higher than one, a rise in the capital-income ratio determines an increase in the share of profits and consequently a reduction in the wage share. These "Piketty-Gordon" facts have been widely documented in the literature: see Petach and Tavani (2021) for a recent illustration and discussion.

This paper aims to present an alternative viewpoint that builds on decades of work and debates between heterodox economists. Scholars working in the classical-Marxian (CM) tradition, in the post-Keynesian (PK) tradition and in the Sraffian supermultiplier (SSM) tradition have been concerned with questions of distribution for a long time before Piketty's blockbuster tome. PK authors especially have produced important work that challenges the causal account by neoclassical economists introducing the question of the distribution of wealth (Pasinetti, 1962) in established demand-driven growth models in the neo-Kaleckian and neo-Goodwinian tradition (Ederer and Rehm, 2020a,b; Taylor et al., 2020). The key issue in this literature is the relationship between the distribution of wealth and the distributional features of aggregate demand. On the other hand, recent important contributions to the secular stagnation debate from the SSM perspective can be found in Serrano et al. (2020); Di Bucchianico (2021a,b): the main difference is that in both neo-Kaleckian and neo-Goodwinian models long-run aggregate demand is endogenous to distribution; while in the SSM models this is not the case.

Our goal is to present a complementary heterodox argument that, without denying the importance of aggregate demand for growth and distribution, operates at the same level of abstraction of Piketty and Gordon, namely that the economy is constrained by supply forces and profit-driven accumulation in the long-run. This is a first reason why our approach is grounded in the CM tradition: the assumption of Say's law holding in the long-run and the notion that capital accumulation is ultimately constrained by profits are common in Ricardo and Smith, and in recent and contemporary work in the Marxian tradition (see for example Harris, 1978; Marglin, 1984; Duménil and Lévy, 2000; Foley et al., 2019).[1] Differently from neoclassical economics, we take seriously the Cambridge critique of capital theory that refuted the notion of instantaneous factor substitution along an aggregate production function (Cohen and Harcourt, 2003; Felipe and McCombie, 2013) and focus instead of the CM viewpoint that "capital-labor substitution" is in fact the result of *biased technological change* (Foley et al., 2019, Ch.7-9) that is driven by the firm-level incentives to introduce labor-augmenting innovations to respond to increases in the wage share (Hicks, 1932; Kennedy, 1964; von Weiszacker, 1966; Drandakis and Phelps, 1966; Foley, 2003; Julius, 2005; Zamparelli, 2015). This is another reason why our contribution is rooted in CM economics: the notion that labor-augmenting technical change is a "weapon" in the capital-labor conflict, and that therefore the distribution of income between wages and profits influences and responds to technological progress is already present in Marx (1894) but also features prominently in Shah and Desai (1981) and Julius (2005). Finally, unlike neoclassical economics and despite our acceptance of Say's law, we do not presuppose that the economy always operates at full employment of labor in the long run. This is another element that our argument has in common with the CM framework, where there is no mechanism guaranteeing that wage flexibility will clear the labor market: this implication arises from the fact that long-run factor shares depend on induced technical progress—and are therefore endogenous, but for different reasons than in the neoclassical model—and not on capital-labor substitution along a neoclassical production function.

Our argument goes as follows. Consider the long-run "Harrodian" balanced growth condition $g = \gamma + n$, where g is the accumulation rate, and γ and n are respectively the growth rate of labor productivity and the growth rate of the labor force. The long-run accumulation rate depends on the profit rate, equal to the income-capital ratio u times the profit share. Institutional changes —especially globalization (Kiefer and Rada, 2015), trade liberalization (Dube and Reddy, 2014),

[1] Of course, both Malthus and Marx famously disputed the validity of Say's law; nevertheless it is customary in the heterodox literature to refer to "classical" to those models where savings and investment are always equal by assumption. (See the relevant chapters in Blecker and Setterfield, 2019; Foley et al., 2019).

declining workers' bargaining power and unionization (Tavani, 2012, 2013; Farber et al., 2021), but also financialization (Hein, 2013; Hein and Dodig, 2014; Hein, 2019)— that occurred since the 1980s have put downward pressure on the labor share and upward pressure on the profit share.[2] The falling share of labor lessens the incentives on behalf of firms to introduce labor-augmenting innovations, which in turn depresses the long-run growth rate of the economy. Moreover, it increases the wealth share of households whose incomes are mostly made up of profits ("capitalists"), given the reduction in the funds available for savings and wealth accumulation by wage-earning households ("workers"). On the other hand, the decline in the share of wages puts pressure on capital accumulation, which is profit-driven: but the long-run growth rate, which is tied up to labor productivity growth through the Kennedy-Weiszacker induced technical change channel, has fallen. Restoring balanced growth requires a decline in the income-capital ratio u (or equivalently an increase in the capital-income ratio, as in Piketty and Gordon).

The final portion of our argument concerns the economy's long run employment rate. The balanced growth condition $g = \gamma + n$ guarantees that the economy operates with constant unemployment in the long run; but the steady-state employment rate is endogenous, and its response to changes in income shares is ambiguous because it depends on the forces at play both in the labor market and the bias of technological progress. In the theoretical model we present below, and with a nod to the familiar terminology in neo-Kaleckian economics, we identify both the possibility of a *wage-led* and a *profit-led* employment regime, depending on a simple condition on two parameters representing the response of technological change vs. real wage growth to labor market institutions.

Given the theoretical ambiguity in the response of the long-run employment rate to labor-crushing institutions, we finally carry an empirical test of our argument using time-series data for the United States (1960-2019). First, we estimate a vector error-correction model (VECM) using the income-capital ratio, the top 1% wealth share, the wage share, and the employment-population ratio to account for the endogeneity of all four variables of interest; then, we 'run an experiment' on the model, using impulse responses to inspect the response of the income-capital ratio, the top wealth share, and the prime-age employment-population to a negative one-standard deviation shock to the wage share. We find empirical support for our theory: an adverse shock to the wage share produces a long-run decline in the income-capital ratio and a long-run increase in the top wealth share. Moreover, the employment-population ratio declines, thus pointing to the U.S. employment regime being wage-led over the period under consideration.[3]

[2] Our model concerns the real side of the economy only, and as such cannot explain the role of financialization in the decline of the labor share. We report financialization as one of the causes of such decline for completeness.

[3] Stockhammer (2008) argues that the Goodwin model in fact implies an exogenous long-run employment rate that closely mirrors the textbook 'natural' rate of unemployment. Despite ours being a model of the supply side, and

Thus, the main contribution of this paper is to present a simple but comprehensive account of supply-side secular stagnation in the CM tradition. Our model combines insights from several strands of the heterodox literature, such as the Pasinetti theorem, the Kennedy-Weiszacker theory of biased technical change as opposed to factor substitution, and the distributive conflict at the heart of the Goodwin model into a unified thought framework that can be used to inform a progressive policy agenda aimed at ameliorating the conditions of working people. To our knowledge, this is the first paper that considers the simultaneous effects of shocks that affect the distribution of income on the distribution of wealth, the income-capital ratio, and the employment rate. Our argument is similar to the neo-Kaleckian viewpoint that the functional distribution of income comes first, and not last, in the causal links between the forces producing stagnation and inequality in the Neoliberal era. The main difference is that these causal links hold true even in an economy that is assumed to be supply-constrained. As such, the point of our contribution is also in part *rhetorical*, in that we show that a progressive role for redistributive policies in fostering growth while reducing inequality arises through the effect of such policies on the potential growth path of an economy.[4] In this regard, we find even more striking the empirical finding that the U.S. employment-population ratio appears to be wage-led in the long run: it implies that labor-friendly institutional changes aimed at reversing the decline of the wage share will have progressive supply-side effects on fostering growth and reducing inequality without necessarily being detrimental to employment.

2 Secular Stagnation: Related Literature

The observation that an economy may experience low economic growth and high unemployment for long periods is well-routed in the history of economics. Alvin Hansen (Hansen, 1939) coined the concept of secular stagnation to express his preoccupation with grim U.S. growth prospects and slow recovery after the Great Depression due to, among other reasons, a shortage of impetus of opportunities and new investments. Since then, the world has changed significantly. Changes in demography, financial development, changes in income distribution between labor income and capital income, and technology have played a crucial role in the composition of employment, real wages, and productivity, impacting economic growth and unemployment.

despite the modeling of the labor market follows the Goodwin dynamics, the fact that the long-run employment rate is endogenous to distribution implies that there is no natural rate of unemployment.

[4] It goes without saying that this does not imply that we believe that, in fact, demand is not relevant for the potential growth and distribution path of an economy. As examples of an analysis of the role of aggregate demand in classical-Marxian models of growth and distribution, see Petach and Tavani (2019); Tavani and Petach (2021); Petach and Tavani (2022).

Several theories have emerged to explain the possibility of prolonged stagnation. The literature is vast, but we will focus on demand-side and supply-side secular stagnation from a mainstream standpoint and the countering post-Keynesian perspective for this analysis. Beginning with the demand-side mainstream explanation, Summers (2014a,b) has revamped the term secular stagnation to explain the growth slowdown in advanced economies such as the United States, Europe, and Japan during the last three decades. Summers's explanation is rooted in the loanable funds theory and amounts to a situation where demand and supply for savings translate into a negative equilibrium real interest rate. Under this scenario, the zero lower bound on the nominal interest rate is the relevant constraint on the policy contributing to economic stagnation. According to Summers (2015), the low equilibrium occurs due to decreased investment demand and an increased supply of savings. He argues that the former is explained by slow population growth in the more developed countries, a decline in the relative price of capital goods, and the problem of cutting-edge technology companies dealing with excess cash. The latter is explained, according to Summers, by large reserves accumulated in developing countries, an increase in propensity to save due to higher inequality, more rigorous collateral requirements due to financial crisis, and the increased costs of financial intermediation. Therefore, Summers (2015) alludes to an "inverse Say's law" where lack of demand leads to a lack of supply.

While Summers concludes that secular stagnation occurs when the desired level of savings exceeds the level of investment and monetary policy is constrained by the zero lower bound, Gordon (2015) and Pagano and Sbracia (2018) discuss that secular stagnation can also be explained through the supply side. These authors focus more on potential real GDP growth, labor productivity growth, and aggregate hours of work as significant variables to explain secular stagnation. (Gordon, 2015) argues that slow productivity growth in the past decade is due to three main reasons: (a) the business methods and installed capacity in the "dot.com" era characterized by meaningful productivity growth have faced diminishing returns; (b) the decline in net investment ratio to capital stock and the decrease in the information and communication technologies price deflator; and (c) the fall in the rate of new business start-ups. The Gordon account of secular stagnation is complementary to that presented by Piketty (2014), where an exogenous reduction in the growth rate g is responsible for the increase in the capital-income ratio and the falling wage share through high elasticity of substitution between capital and labor. Another supply-side argument hinges on the role played by an aging population (Hansen, 1939; Gordon, 2015, 2016). The idea is that an aging population reduces the size of the labor force and productivity and generates higher savings relative to investment. A contrary perspective can be found in Acemoglu and Restrepo (2017). They not only find no evidence of a negative association between changes in age structure and GDP per capita changes but a positive and robust relationship in some econometric specifications. They show that countries with higher shares of aging populations are the ones that adopted more industrial robots.

However, they recognize that they cannot establish causality between these two variables nor that the adoption of robots is necessarily the channel that offsets the potential adverse effect of population aging on economic growth. Therefore, these authors suggest that one possible explanation for the positive relationship mentioned above is that "technology adjusts to undo this potential negative effect." Indeed, Acemoglu (2010) shows that labor scarcity leads to the adoption of automation processes that increase aggregate output when technology is strongly labor-saving but discourages technological advances when technology is strongly labor complementary.

Heterodox perspectives on the issue have questioned the notion of a natural interest rate that equalizes investment and savings in the loanable funds market at full employment levels (Wicksell, 1898; Keynes, 1930) well as the money neutrality proposition. In this vein, Palley (2018, 2019) presents the *investment saturation* hypothesis as a critique of the zero lower bound economics. Palley asserts that negative nominal interest rates, even if feasible, might be unable to resolve the problem of unemployment due to demand shortages. If a negative nominal interest rate does not consistently achieve full employment, the zero lower bound will not cause Keynesian unemployment and stagnation. Palley's main point is that investment could become unresponsive to a lower interest rate if the returns on non-reproduced assets —fiat money, land, minerals, precious metals, rent streams from firms, and intellectual property— dominate the return to investment. The reason is that lower interest rates may result in bidding up the price of non-reproduced assets rather than increasing investment. In other words, since non-reproduced assets compete with investment projects, the interest rate is not necessarily set by the demand and supply forces in a loanable funds market but by the Keynesian liquidity preference. Thus, the link between the interest rate and the savings-investment equilibrium could be broken. Similarly, Taylor (2017), using a national account decomposition for the United States, shows that the loanable funds theory is inconsistent with real-world data. According to Taylor, saving is mostly a residual quantity; moreover, higher interest rates might reduce saving "by forcing business to increase financial transfers to other sectors." Based on U.S. data, Taylor also demonstrates that the private sector's decisions are not very sensitive to interest rates.

A different branch of heterodox explanations draws from the Kaleckian and Steindlian tradition, according to which the rise of financialization is a significant factor in depressing the economy (Hein, 2013; Hein and Dodig, 2014; Hein, 2019). The first main channel found empirically in this literature is the decline in the labor share of income, especially low-income households, which directly affects overall consumption. These arguments build on contributions to the neo-Kaleckian model by Amitava Dutt (and especially Dutt, 1984, 2006). The second one is the bias to favor short-run profits in the non-financial sector (see also Davis, 2016, 2017, 2018) that incentivizes financial investment at the expense of real investments. Hein rejects the idea of a single interest downward-sloping capital demand curve that, together with a supply of loanable funds curve in a more-than-one-good economy, clears the capital market at full employment level through a natural interest rate. Additionally, he argues that savings adjust to investment through income growth and changes in capacity utilization. This author also emphasizes the importance of social classes and the role of institutions in secular stagnation. In this latter respect, our perspective is similar.

The Harrodian approach has also been used to analyze the factors behind secular stagnation from a post-Keynesian viewpoint. Skott (2016) argues that public debt is not a problem in itself; however, it can be a significant burden for the economy when it reaches excessive levels. In that sense, one of the main points of Skott's contributions is to show a causal relation running from low economic growth to high public debt. Hence, fiscal policy —functional finance à la Lerner (1943)— must play an essential role in making the economy tend to full employment and avoid secular stagnation. Also, Skott supports the importance of more equitable income distribution since the higher the degree of inequality, the more elevated the public debt-GDP ratio.

From a structural Keynesian perspective, Palley (2012) alleges that stagnation in growth and wages and the Great Recession of 2008 are rooted in the neoliberal system and the growth model adopted in the late 1970s and early 1980s. According to Palley, even when financial deregulation played a crucial role in the Great Recession, the cause was the slow recovery and fragile expansion after mid-2001 due to the trade deficit that displaced domestic production and jobs and the acceleration of offshoring that closed local factories in the U.S. The weak exit from that recession caused the Federal Reserve to lower rates to 1% in mid-2003, which triggered the housing price bubble a couple of years later.

Palley (2012) also argues that before 1980, the US economy was characterized by a robust aggregate demand sustained by rising wages growing with productivity, which significantly contributed to full employment. However, after 1980, the new growth model abandoned the commitment to full employment as inflationary, weakening the link between wages and productivity and substituting wage growth as the engine of demand growth for a rising indebtedness and asset price inflation model.

While our paper focuses on a supply-side perspective, our argument is complementary to the contributions focusing on demand forces to explain complex phenomena like secular stagnation. For instance, Storm (2017) argues that the decline in total factor productivity, significantly explained by labor productivity growth -between 73% to 88%, is influenced by demand factors. Storm asserts that an unsatisfactory demand is, in turn, the consequence of a dualistic growth of the American economy with a "stagnant " sector that acts as an employer of last resort and a "dynamic" sector that loses jobs. On the other hand, Kiefer et al. (2020) present a measure of potential output that builds on the interaction between capacity utilization —that is, aggregate demand— and income shares, and show that the decline in US potential output, which predates the Great Recession of 2008, coincides with the decline in the labor share of income. Finally, our analysis draws conclusions regarding profit-led income-capital ratio vis. a vis. wage-led labor productivity growth dynamics that are somewhat similar to Palley (2013).

Our contribution draws from recent developments in the classical-Marxian tradition to offer an account of secular stagnation that, like Piketty and Gordon, emphasizes the role played by real —as opposed to financial— variables and supply forces. Our aim is not to deny the importance of financial factors and demand: rather, the goal is to present a perspective on the problem that operates at the same level of abstraction as the neoclassical explanations but is complementary to the post-Keynesian, Kaleckian, and Sraffian viewpoints.

3 Model: Setup

We consider a one-sector closed economy without government. Time is continuous, and the total population is assumed constant and normalized to one for simplicity. We also assume away capital depreciation as well as household debt. Finally, given that the model is one-sector, we normalize the price of the single good produced in the economy to one throughout.

3.1 Production, Income Distribution, and Wealth Accumulation

The economy is populated by two types of households. "Workers" (denoted by the superscript w in what follows) supply labor services inelastically to firms, earn both labor and capital income, consume and save. "Capitalists" (denoted by the superscript c) own capital stock, earn only profit incomes, consume and save. For the sake of simplicity, assume that neither type of capital depreciates. Output per worker y, homogeneous with capital stock, is produced using fixed proportions of capital per-worker $k \equiv k^c + k^w$ and labor: $y = \min\{A, uk\}$, where u denotes the output-capital ratio, endogenous to the model, and A is the stock of labor-augmenting technology, also endogenously growing over time. Let r be the uniform rate of return on capital, endogenous to the model but given to each household: both types of households are price-taking in goods and factor markets.

Through their savings, workers participate in the accumulation of capital in the economy (Pasinetti, 1962). The introduction of workers' savings in a CM model is motivated both by theoretical and empirical reasons. At the theoretical level, Michl (2009) has motivated saving by workers justified through life-cycle considerations. From an empirical standpoint, the analysis by Saez and Zucman

(2016) has shown that the saving rate for bottom 90% of wealth owners in the US averages 5% per year between the 1930s and the Great Recession. Let the workers' propensity to save, constant throughout, be denoted by $s^w \in (0,1)$. Importantly for the analysis, not all workers will be employed at any given point in time: the number of employed workers is equal to labor demand by firms which, due to the Leontief production technology, is not elastic to the wage. This implies that movements in the real wage are not enough to clear the labor market. The employment rate in the economy is $e \equiv uk/A$ (recall that the labor force is normalized to one). Therefore, total workers' savings, in turn, equal to workers' investment in new capital stock $\dot{k}^w$, is:

$$\dot{k}^w = s^w \left[\frac{w}{A} uk + rk^w \right] \tag{1}$$

Next, denote the capitalists' share of wealth by $\phi \equiv k^c/(k^c + k^w) \in [0,1]$ so that $k^c = \phi k$. Letting the labor share (endogenous in the model) be denoted by $\omega \equiv w/A$, simple algebra delivers the workers' accumulation rate as:

$$g^w \equiv \frac{\dot{k}^w}{k^w} = s^w u \left[\frac{\omega}{1-\phi} + (1-\omega) \right] \tag{2}$$

On the other hand, capitalist households only earn profit income out of the capital they own. With a constant propensity to save $s^c \in (0,1)$, the capitalists' accumulation rate satisfies the usual Cambridge equation:

$$g^c = s^c r = s^c u(1-\omega) \tag{3}$$

Using equations (2) and (3), the economy-wide accumulation rate will be a weighted average of the growth rates of capital stock for the two types of households:

$$\begin{aligned} g &= \phi g^c + (1-\phi) g^w \\ &= u \left[s^w + \phi(1-\omega)(s^c - s^w) \right] \end{aligned} \tag{4}$$

Equation (4) emphasizes the profit-driven nature of capital accumulation, even with worker saving. Indeed, everything else equal the economy's accumulation rate decreases in the wage share, and increases in the profit share.

Two clarifications are in order before moving on. First, the classical political economists often reasoned in terms of an institutionally given, "conventional" *real wage*, also given low growth rates in pre-industrial economies. In growing economies, a fixed real wage coupled with rising labor productivity implies a uniformly falling wage share. For this reason, Foley et al. (2019) present a modification of the basic classical one-sector model that features a conventional *wage share*, providing a model closure that is more appropriate under growing labor productivity growth. Here, however, the wage share is not fixed exogenously, but responds endogenously to the interaction between technological factors i.e. the bias of technical change (Kennedy, 1964; von Weiszacker, 1966, described below), as well as institutional factors affecting the real wage (Tavani, 2012, 2013).[5] Second, we assume Say's law to hold at all times, which means that we rule out any behavioral explanation for investment demand as independent of the supply of savings in the economy. This is common in the classical-Marxian literature (see the relevant chapters in Harris, 1978; Marglin, 1984; Blecker and Setterfield, 2019; Foley et al., 2019), but importantly it does not necessarily require the existence of a banking sector where loanable funds are traded with the real interest rate playing the role of equilibrating saving and investment. Here, the long-run rate of return to capital is determined endogenously but residually from the accounting relation $r = u(1 - \omega)$, given the income-capital ratio u, and the share of profits $1 - \omega$, but markedly *not* from a saving-investment equilibrating mechanism. As such, and similarly to many benchmark models of the real side, in our model there is no banking sector and investment is passive: whatever sources of funds are available from savings, they are automatically accumulated in the form of new capital. Once again, one of our goals in this paper is to show that secular stagnation can emerge from labor-crushing distributional changes —and not from exogenous reductions in the growth rate like in neoclassical accounts— even accepting the premises of a supply-constrained economy in the long run.

3.2 Technical Change: the Induced Innovation Hypothesis

We turn now to specify the evolution of technology through induced innovation. Following Kennedy (1964); Drandakis and Phelps (1966); Funk (2002); Julius (2005); Zamparelli (2015), we suppose that firms have access to a menu of technological improvements that potentially can increase both the output-capital ratio (at a rate χ) and labor productivity (at a rate γ). However, there are trade-offs between improving along one technological dimension versus the other. Such trade-offs are summarized by a twice-continuously differentiable, strictly decreasing, strictly concave *innovation possibility frontier* (Kennedy, 1964, IPF henceforth), which can be written in an explicit form as:[6]

$$\gamma = f(\chi), \ \ f_\chi < 0, f_{\chi\chi} < 0 \tag{5}$$

Firms choose a profile of technological improvements to maximize the rate of reduction in unit costs, or equivalently the rate of change in the profit rate, subject to the constraint given by the IPF (see Julius, 2005; Tavani, 2012): as discussed in Sasaki (2008) and Tavani and Zamparelli (2017),

[5]Note also that we will be closing the model with a Goodwin (1967) Phillips curve: this is enough to determine the time-path of the real wage given initial conditions. See Section 3.4.

[6]Strict concavity of the IPF synthetically captures the increasing difficulty in adopting factor-augmenting technologies (Funk, 2002), and is mathematically convenient because it will lead to an interior solution of the firm's problem.

this is in fact equivalent to the classical choice of technique criterion one can find, for example, in Okishio (1961) that involves maximizing the profit rate at a given real wage.

As shown in Kennedy (1964); Julius (2005); Tavani (2012); Foley et al. (2019, Ch.7), the firm's program amounts to maximizing a weighted average of the growth rates of factor-augmenting technologies, the weight being the shares of labor and capital: $(1-\omega)\chi + \omega f(\chi)$. The solution, an implicit function defined by the first-order condition $-f_\chi = (1-\omega)/\omega$, yields a dependence on the relative growth rates of capital- and labor-augmenting technologies on factor shares, and in particular a direct (inverse) relation between labor (capital) productivity growth and the labor share.

We also assume an exogenous shift parameter, denoted by z, that affects the curvature and intercept of the IPF, and therefore the firm's choice of factor-augmenting technical change. In particular, we assume that the partial derivatives of factor-augmenting technologies are such that $\chi_z > 0, \gamma_z \geq 0$, which guarantees that the long-run labor share will be increasing in z. Moreover, following Petach and Tavani (2021); Rada et al. (2022) we interpret z as any policy or institutional variable positively affecting the labor share.[7] Thus, the growth rates of capital- and labor-augmenting technologies can be written as:

$$\chi = \chi(\omega; z); \quad \gamma = f[\chi(\omega; z)] \tag{6}$$

with $\chi_\omega < 0$, and correspondingly $\gamma_\omega > 0$.[8]

Observe that induced innovation in this framework plays a similar role to what would be factor substitution in a neoclassical aggregate production function: higher labor costs induce more labor-saving and less capital-saving technologies. However, and as noted already in the literature, capital-labor substitution occurs through technological progress and not diminishing marginal products. Importantly, the induced innovation hypothesis: (a) does not suffer from the well-known issues with aggregating across different capital goods highlighted in the Cambridge controversy,[9] and (b) does not imply that wage flexibility will clear the labor market, given that in every period the underlying technology is Leontief.

[7] Tavani (2012, 2013) has provided microeconomic foundations for this result that use the generalized Nash (1950) bargaining solution to determine the real wage at the firm level. In these models, z is explicitly derived as a combination of the workers' reservation wage, in turn influenced by labor market institutions such as unemployment compensations or minimum wages, and the workers' bargaining power. Our argument presents a simplified, reduced form version that shares the same conclusions but retains the familiar Goodwin (1967) real-wage Phillips curve and corresponding macroeconomic determination of real wages.

[8] See Rada et al. (2022) for a discussion of the above assumption for both Classical and Keynesian models of growth and distribution.

[9] Kennedy (1973) shows that, unlike neoclassical factor substitution, induced bias in a model with differentiated capital goods is immune from the reswitching problem.

Hence, the evolution of the income-capital ratio is governed by induced innovation, and satisfies:

$$\dot{u} = \chi(\omega; z)u \tag{7}$$

To sharpen our conclusions, we postulate linear versions of both growth rates of factor-augmenting technologies that generalize the specifications by Petach and Tavani (2021):

$$\chi(\omega; z) = z - \beta\omega; \quad \gamma(\omega; z) = \alpha[z - \chi(\omega; z)] \tag{8}$$

The parameter α, describing the sensitivity of labor productivity growth to labor market institutions and the wage share, is crucial in what follows: see Section 4.

3.3 Dynamics: Wealth Distribution

Consider next the capitalist share of wealth ϕ. Its law of motion over time obeys the replicator equation:

$$\dot{\phi} = \phi(g^c - g) \tag{9}$$

which, using (3) and (2), gives after simple manipulation:

$$\dot{\phi} = \phi u \left[(1-\phi)(1-\omega)(s^c - s^w) - s^w\omega\right] \tag{10}$$

3.4 Dynamics: Income Shares and Employment Rate

To close the model, we follow Goodwin (1967) in specifying the interaction between the labor market and real wages. We assume that real wages follow a Phillips-style curve: $\dot{w}/w = f(e; z)$ with $f_e > 0, f_z > 0$. Given induced bias in technical change, the evolution of the labor share obeys:

$$\dot{\omega} = [f(e; z) - \gamma(\omega; z)]\,\omega \tag{11}$$

To characterize the steady state and policy implications in what follows, we assume a linear version of the Phillips curve: $f(e; z) = -\lambda + \delta e + \mu z$, with $\lambda > 0, \delta > 0, \mu > 0$. The Goodwin (1967) specification is obtained as a special case where $\mu = 0$.

Finally, the evolution of the employment rate is obtained by differentiation of its very definition. Given the assumed constancy of the labor force, we have that:

$$\dot{e} \;=\; (\chi + g - \gamma)e$$

$$= \quad \{\chi(\omega; z) + u\,[s^w + (1-\omega)\phi(s^c - s^w)] - \gamma(\omega; z)\}\, e \tag{12}$$

Equations (7), (10), (11), and (12) form a 4-dimensional dynamical system describing the growth and distribution path of this stylized economy. The endogenous variables are: (i) the functional distribution of income ω; (ii) the employment rate e; (iii) the distribution of wealth between the two classes ϕ, and (iv) the income-capital ratio u.

4 Steady State

We now turn to characterize the steady-state of the model. Start from equation (7): setting $\dot{u} = 0$ delivers the long-run labor share as

$$\omega_{ss} = \frac{z}{\beta} \tag{13}$$

increasing in the policy/institutional parameter z. In a graph with the employment rate e on the horizontal axis and the wage share ω on the vertical axis, the long-run labor share is a horizontal line at z/β: a positive (negative) shift in the institutional parameter z moves the long-run labor share up (down). See Figure 1.

Note further that the labor share evolves endogenously to its long-run value (13) to ensure a Harrod-neutral path of technological change where labor productivity grows but the income-capital ratio is constant (Kennedy, 1964; Drandakis and Phelps, 1966; Julius, 2005).

Next, setting $\dot{\omega} = 0$ in equation (11) gives the employment nullcline

$$e(\omega; z) = \frac{\lambda + \alpha\beta\omega - \mu z}{\delta} \tag{14}$$

which is upward-sloping in the labor share everything else equal. However, a change in the policy variable z shifts the employment rate nullcline in the opposite direction, since $\partial e/\partial z = -\mu/\delta < 0$. In the (e, ω) plane in Figure 1, a decline in z shifts the employment nullcline down and right. Therefore, the ultimate effect on equilibrium employment depends on the relative magnitude of the response of income distribution to a policy change *vis à vis* the employment response. This is because both curves shift following a change in the policy variable z. In fact, once the employment equation is evaluated at the steady-state value for the labor share, it pins down the long-run employment rate as

$$e_{ss} = \frac{\lambda + (\alpha - \mu)z}{\delta} \tag{15}$$

and the effect of the labor market parameter z on employment depends on the sign of $\alpha - \mu$.[10] If $\alpha > \mu$, a positive shock to the wage share will increase the long-run employment rate: in a nod to the familiar terminology in demand-driven models, we will refer to this case as a wage-led employment regime in what follows. Conversely, if $\alpha < \mu$, the long-run employment rate responds negatively to shocks to the wage share: we will refer to this case as profit-led. The economic intuition has to do with the relative magnitude of the response of induced bias as opposed to labor market conflict to changes in labor institutions. The parameter α captures how strongly the firm's choice of the direction of technical change responds to an increase in the wage share; since the growth rate of labor productivity anchors the long-run growth rate of the economy, higher values of α imply that growth becomes wage-led to a higher extent. The parameter μ, on the other hand, captures how strong is the effect of labor market institutions on labor market conflict, as described by the real-wage Phillips curve. An increase in μ creates more pressure on real wage growth, which everything else equal depresses the profit-driven accumulation rate and employment. The relative magnitude of the two effects determines whether the accumulation response to labor market institutions is stronger or weaker than the technical change response and the ultimate effect of z on long-run employment.

Further, imposing $\dot{\phi} = 0$ in equation (10), we find the nullcline relating the distribution of wealth to factor shares:

$$1 - \phi(\omega) = \frac{s^w}{s^c - s^w}\left(\frac{\omega}{1-\omega}\right) \tag{16}$$

which captures that the capitalists' share of wealth and the labor share of income are inversely related, as it is intuitive. Substituting from (13) we find the long-run wealth distribution in terms of parameters only:

$$1 - \phi_{ss} = \frac{s^w}{s^c - s^w}\left(\frac{z}{\beta - z}\right) \tag{17}$$

Given that $1 - \phi_{ss}$ is the worker's wealth share, implies that a positive (negative) shock to the institutional parameter z will increase (decrease) the workers' share of wealth: an increase in the labor share increases the funds available to worker to accumulate capital stock and therefore increase their share in the economy's total wealth.

Finally, imposing a steady state in equation (12) gives the following nullcline relating the long-run output/capital ratio to the wage share and capitalist wealth share as follows:

$$u(\phi, \omega) = \frac{\alpha\beta\omega}{s^w + \phi(1-\omega)(s^c - s^w)} \tag{18}$$

Notice that the long-run income-capital ratio increases in the wage share and decreases in the cap-

[10] We also assume that $\delta > \lambda + (\alpha - \mu)z > 0$ so that the long-run employment rate is bounded above by one.

italist share of wealth. The economic intuition is the following: workers have a higher propensity to consume, which implies that an increase in their share of income results in more consumption demand. Such additional demand must be met by production, which implies that the output-capital ratio increases. Similarly, a higher capitalist wealth share increases the economy-wide saving-to-capital ratio in equation (4) above, and reduces total consumption-to-capital —and therefore the output-capital ratio u— everything else equal.

To find the long-run solution in terms of parameters only, plug in equations (13) and (17). After some algebra, we find:

$$u_{ss} = \frac{\alpha\beta z}{s^c(\beta - z)} \tag{19}$$

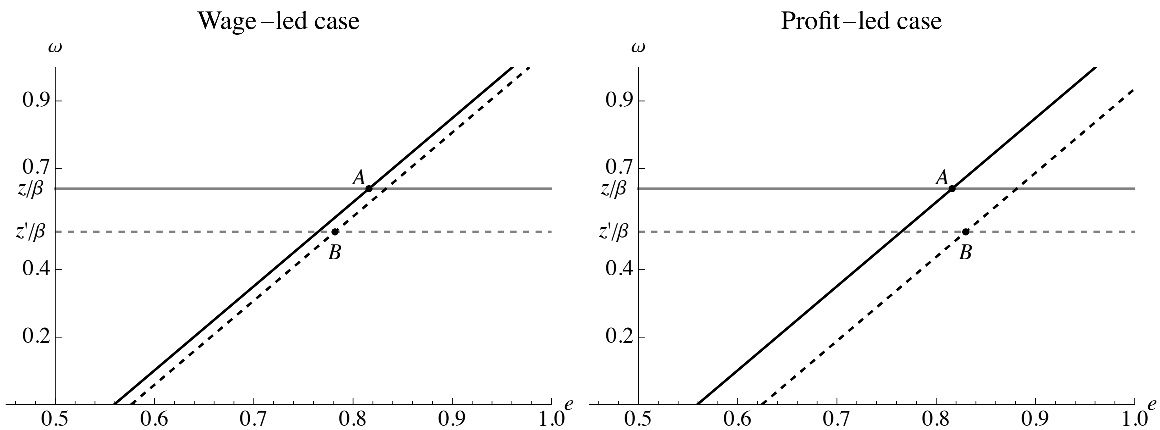
Thus, the long-run income-capital ratio is increasing in the policy variable z, while decreasing in the capitalist saving rate s^c. The similarity with the "paradox of costs" and the "paradox of thrift" in neo-Kaleckian economics is suggestive but misleading in this context. In a wage-led demand-driven model such as the neo-Kaleckian framework, redistribution toward wages or a lower saving rate both increase the income-capital ratio (aggregate demand) without harming accumulation. Conversely, the supply constraint is binding here, and both an decrease in the saving rate and an increase in the labor share of income via a positive shock to z will lead to an increase in the income-capital ratio, but at the expenses of short-run accumulation: there is no paradox of thrift. On the other hand, it is true that a version of the paradox of costs work in our model, but it operates through the adverse effect of labor-crushing shocks on the endogenous long-run growth rate, and not on aggregate demand.

4.1 Comparative Statics and Policy Implications

The model's main exogenous variables of interest are the parameter describing labor market institutions z and the two classes' propensity to save, s^c and s^w. We study the comparative statics effect of each variable in turn.

Start with a change in the institutional parameter z: it will produce a change of the same sign in the long-run wage share (equation 13), workers' wealth share (equation 17), the long-run growth rate of labor productivity (equation 8), and income-capital ratio (equation 19). As already noted, the ultimate effect on employment is ambiguous: it depends on whether the response of technical change to income distribution is stronger or weaker than the extent of labor market conflict on wage growth. Whenever $\alpha > \mu$, the long-run employment rate is wage-led and there is no tradeoff between long-run productivity growth and employment: a shift in labor market institutions that lowers z, and therefore is adverse to labor, reduces the long-run wage share, the growth rate of labor productivity, *and* employment. This scenario is displayed in the left panel of Figure 1. Conversely, If $\alpha < \mu$, long-run employment is profit-led: in this case, a capital-friendly shift in labor market institutions has a positive effect on long-run growth while a negative impact on long-run employment. This case is shown in the right panel of Figure 1.

Figure 1: The effect of a reduction in the labor market parameter z in the wage-led *vs.* profit-led steady-state



As argued in Petach and Tavani (2021), this simple model provides some interesting political economy insights on the secular stagnation and inequality that have plagued advanced economies, especially the United States, in the Neoliberal era. A shift toward labor-crushing institutions — because of globalization, trade liberalization, or the decline in workers' bargaining power and deunionization— which is responsible for the decline in the labor share, also has reduced the long-run growth rate of labor productivity because of the lessened incentives for firms to invest in labor-augmenting technologies. The decline in the labor share has in turn determined a reduction in the workers' wealth share, because labor income —the main source of income for workers— has declined as a share of total income, thus lowering the funds available to workers for wealth accumulation. A worsening of labor market institutions also has the ultimate effect of reducing the income-capital ratio (increasing the capital-income ratio) for the following reason. The decline in the labor share puts pressure on the capitalists' accumulation rate: because of the Pasinetti theorem, the capitalist accumulation rate $s^c u(1-\omega) = g^c$ is equal to the economy's growth rate g in balanced growth. However, the long run growth rate of labor productivity is wage-led, and has fallen. Restoring the balanced growth condition $g = \gamma(\omega)$ —which guarantees Harrodian stability in the labor-market— requires a decline in the long-run income-capital ratio. Finally, the ultimate effect on long-run employment can be either positive or negative, as described already and shown in Figure 1.

Next, consider the effect of the capitalist saving propensity s^c on the long run of the model.

Given that the long-run wage share only depends only on z, it will be unaffected by a change in the saving rate; so will steady-state employment. Conversely, a change in the capitalist saving rate will affect both the long-run capitalist share of wealth and the long-run income/capital ratio. Everything else equal, a higher capitalist propensity to save out of profits puts pressure on the capitalist accumulation rate, which increases their share (and reduces the workers' share) in total wealth. Given that the long-run wage share is unaffected by the change, labor productivity growth has not changed. Thus, the capital stock has grown more than income, which explains the reduction in the long-run income/capital ratio.

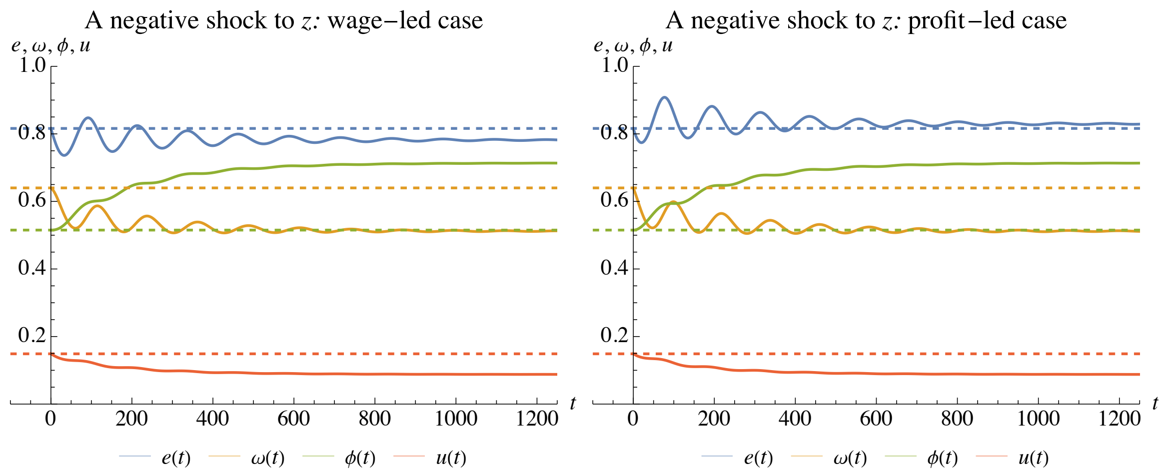
Finally, and perhaps strikingly, a change in the workers' saving rate s^w only influences the long-run distribution of wealth while leaving the steady-state value of every other endogenous variable unaltered. This is not surprising in light of the Pasinetti theorem. But, of course, there will be effects along the transitional dynamics: they are explored in the simulations below.

5 Transitional Dynamics and Numerical Simulations

A formal analysis of the local stability properties of the model's steady state is provided in Appendix A. Even though the model is stylized enough to be studied analytically, it is informative to carry a series of simulations exercises in order to showcase the adjustment dynamics following a shock to the parameters of interest, namely z, s^w, s^c. Notably, the simulations are meant to be illustrative of the qualitative properties of the dynamics and not to provide an exact representation of an economy's response to a series of shocks. In order to calibrate the two classes' saving rates, we follow Saez and Zucman (2016) and set the capitalists' saving rate equal to 35% and the workers' saving rate at around 7.5%. We fix z at 0.025 and internally calibrate β at .039 in order to obtain a steady state wage share of 64% in the baseline model. We then fix $\delta = 0.073$, in line with estimates of the slope of the Phillips curve for the United States, and $\alpha = 0.75$. In the wage-led model, μ is set at 0.25, and λ is internally calibrated to return a steady state prime-age employment/population ratio of about 80% —the pre-2008 value in the United States— in the baseline. In the profit-led model, $\mu = 0.95$, which requires recalibrating λ to match the steady state employment rate. All simulations assume that the economy is in steady-state at time zero when a shock to either parameter occurs.

In the first simulation, we reduce the labor market parameter z by 5% in both the wage-led and profit-led models. A visual representation of the simultaneous shifts in the wage share and employment nullclines (equations 13 and 14) corresponding to the two cases is already represented in Figure 1, obtained using the calibration described above. The actual transitional dynamics are displayed in Figure 2, where the shocked trajectories are displayed as solid lines while the baseline trajectory are shown as dashed lines. The comparison illustrates a critical implication of the model: income shares, the wealth distribution, and the income-capital ratio converge to the same values in both the profit-led and the wage-led model, while of course, the trajectory and the ultimate value of employment depend on whether it is wage-led or profit-led. The difference matters: in the wage-led case there is no trade-off between a labor-friendly change in income distribution and employment, while in the profit-led case such a trade-off does exist.

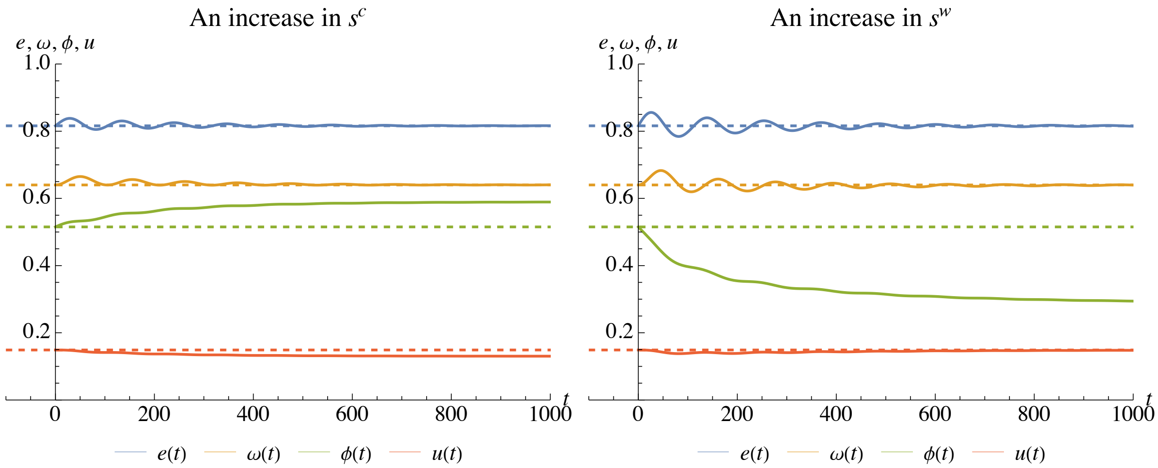
Figure 2: Simulations: a 5% time-zero reduction in z.



In the second set of simulations, displayed in Figure 3, we increase the capitalists' saving rate s^c by 5% at time zero (left panel), and the workers' saving rate by the same amount in the right panel. As already explained above, an increase in s^c reduces the income-capital ratio while it increases the long-run capitalist share of wealth; while an increase in s^w only affects the distribution of wealth (in favor of workers) in the long-run.

The comparative statics of reducing the capitalist saving rate offers an interesting comparison with a similar exercise in Michl and Tavani (2022). They use a reduced form technical progress function that depends on the growth rate of capital stock per capita and the wage share. They find that a reduction in the capitalist saving (which they call 'capitalization') rate will, in fact, lower long-run employment. The capital channel is precluded from operating by assumption in this paper, because technical progress responds only to income shares via induced technical change and is invariant to capital accumulation.

Figure 3: Simulations: a 5% time-zero increase in capitalists' and workers' saving rates.



6 Wealth Redistribution

Zamparelli (2017) has shown that, in a neoclassical economy with high elasticity of substitution between capital and labor, tax policy can be used to implement any wealth distribution among the two classes. The same is true here, despite the fixed-coefficients technology in production. Let us introduce a government that taxes capitalists' profit incomes proportionally at a rate τ and rebates the proceedings to workers in the form of subsidies. The capitalists' and workers' accumulation rates modify as follows:

$$g^c = s^c u(1-\omega)(1-\tau) \quad (20)$$

$$\begin{aligned} g^w &= s^w \frac{uwk/A + rk^w + \tau r k^c}{k^w} \\ &= s^w \frac{u}{1-\phi}\left[1-\phi(1-\omega)(1-\tau)\right] \end{aligned} \quad (21)$$

After factoring terms, the evolution of the capitalist wealth share modifies to:

$$\dot{\phi} = \phi u \left\{ s^c(1-\omega)(1-\phi)(1-\tau) - s^w[1-\phi(1-\omega)(1-\tau)] \right\} \quad (22)$$

Next, using the steady-state wage share from equation (13), the two-class equilibrium delivers the following capitalist wealth share as a function of the tax rate:

$$\phi_{ss}(\tau) = \frac{s^c(\beta - z)(1-\tau) - s^w \beta}{(\beta - z)(1-\tau)(s^c - s^w)} \quad (23)$$

which reduces to (17) for $\tau = 0$ as in the baseline model. Now, the government can fix the tax rate in order to implement the desired distribution of wealth, given the two classes' saving propensities and the parameters determining the long-run share of labor. Differentiating with respect to τ, we find that, intuitively, the long-run capitalist wealth share decreases in the tax rate:

$$\frac{\partial \phi_{ss}}{\partial \tau} = -\frac{s^w \beta(\beta - z)(s^c - s^w)}{[(\beta - z)(1-\tau)(s^c - s^w)]^2} < 0$$

Finally, the tax rate τ^* that implements the long-run wealth distribution targeted by the policy-maker ϕ^* is simply

$$\tau^* = 1 - \frac{s^w \beta}{(\beta - z)[s^c - \phi^*(s^c - s^w)]} \tag{24}$$

Petach and Tavani (2021) have provided some back-of-the-envelope calculations about various tax rates necessary to reduce wealth inequality in the United States. They have argued that both the effective corporate tax rate and the effective estate tax rate should be increased substantially to reduce the U.S. top wealth share to its value in 1978, the lowest since 1920s.

There is an important difference in policy implications with the neoclassical model, however: there, capital gains taxation will reduce wealth concentration and the capital-income ratio by reducing the difference $r - g$ and, with an elasticity of substitution higher than one, will increase the labor share. Here, capital gains taxation will reduce wealth concentration and lower the capital-income ratio (increase u in equation 16), *but will not have an effect on the labor share of income*. Therefore, our analysis implies that a tax on capital gains will certainly be effective at taming wealth inequality; but reversing the decline of the labor share requires specific policies aimed at strengthening the distributive position of the working class.

7 Empirical Evidence for the United States (1960-2019)

In addition to the numerical simulations, we performed an empirical exercise for the United States (1960-2019), using the following data: the income-capital ratio, the top 1% share of wealth, the employment-population ratio, and the labor share. We thus have an endogenous, four-variable, time-series system that we can estimate using standard econometric methods. We then run an 'experiment' on the estimated model. After estimating short- and long-run relations, we negatively shock the labor share by a one-standard deviation, and plot impulse-responses for the top wealth share, the income-capital ratio, and the employment-population ratio.[11]

The income-capital ratio is calculated by dividing the variable *cgdpo* by *cn* from Penn World Table 10.0.[12] The top 1% of net personal wealth is obtained from the World Inequality Database (WID). It must be said that the translation from the capitalist wealth share in the theoretical model to the top 1% wealth share is not straightforward: the notion of wealth in our model does not include financial wealth as already stated, while the WID calculations include financial appreciation. However, to our knowledge there are no measures of wealth inequality that are perfectly comparable with our theoretical capitalist wealth share; and earnings by the top 1% are mostly related to profits rather than wages. For these reasons, while imperfect, we believe that using the top 1% wealth share is useful toward an empirical validation of our model. The prime-age employment-population ratio (for workers of 25 to 54 years of age) is taken from the U.S. Bureau of Labor Statistics, and retrieved from Federal Reserve Economic Data (FRED). And the labor share is obtained from series *labsh* from Penn World Table 10.0. All these four variables are expressed in percentage points.

The main goal of the exercise is to evaluate the system's response to an exogenous negative shock to the wage share, which would correspond to a test of the main predictions of our theory against the available data. As a reminder, our theory leads to the testable implication that a negative shock to the wage share determines: (a) a decline in the income-capital ratio; (b) an increase in the top wealth share; (c) either a positive (profit-led) or negative (wage-led) response of employment.

Appendix B shows that all the four variables are non-stationary in levels but stationary in first differences, even in the presence of possible structural breaks. Appendix C displays detailed trace and maximum eigenvalue tests for the Johansen cointegration test. We run this test without a linear deterministic trend in data, but with an intercept in the cointegrating equation. The trace and the maximum eigenvalue tests support that one cointegrating equation exists at a 5% significance level.

Based on the five information criteria in Appendix D, there is no consensus on the optimal lag length for the vector autoregressive (VAR) model. We, therefore, selected three lags for the vector error correction model (VECM) since it was the minimum number of lags to have no serial autocorrelation of residuals in our model. Since this is a cointegrated endogenous system, we run the following VECM with three lags and one cointegrating equation (see Table 1 for details on the

[11] Our estimation is a standard vector error-correction model (VECM) and does not allow for the time-varying regime of income-capital ratio and distribution in Carrillo-Maldonado and Nikiforos (2022). However, our conclusions are broadly in line with theirs.

[12] Both of these measures are calculated in real terms in the PWT, with *cgdpo* being real output from the supply side and *cn* being real capital stock (there is a separate price level for capital in the PWT). As such, our measure of the income-capital ratio is by construction removed from appreciation effects due to mere financial forces.

notation):

$$
\begin{aligned}
\Delta u_t &= \sigma_{u0} + \sum_{j=1}^{k-1} \tau_{uj} \Delta u_{t-j} + \sum_{j=1}^{k-1} \zeta_{uj} \Delta \phi_{t-j} + \sum_{j=1}^{k-1} \eta_{uj} \Delta e_{t-j} + \sum_{j=1}^{k-1} \psi_{uj} \Delta \omega_{t-j} + \xi_u ECT_u + \upsilon_t^u \\
\Delta \phi_t &= \sigma_{\phi 0} + \sum_{j=1}^{k-1} \tau_{\phi j} \Delta u_{t-j} + \sum_{j=1}^{k-1} \zeta_{\phi j} \Delta \phi_{t-j} + \sum_{j=1}^{k-1} \eta_{\phi j} \Delta e_{t-j} + \sum_{j=1}^{k-1} \psi_{\phi j} \Delta \omega_{t-j} + \xi_\phi ECT_\phi + \upsilon_t^\phi \\
\Delta e_t &= \sigma_{e0} + \sum_{j=1}^{k-1} \tau_{ej} \Delta u_{t-j} + \sum_{j=1}^{k-1} \zeta_{ej} \Delta \phi_{t-j} + \sum_{j=1}^{k-1} \eta_{ej} \Delta e_{t-j} + \sum_{j=1}^{k-1} \psi_{ej} \Delta \omega_{t-j} + \xi_e ECT_e + \upsilon_t^e \\
\Delta \omega_t &= \sigma_{\omega 0} + \sum_{j=1}^{k-1} \tau_{\omega j} \Delta u_{t-j} + \sum_{j=1}^{k-1} \zeta_{\omega j} \Delta \phi_{t-j} + \sum_{j=1}^{k-1} \eta_{\omega j} \Delta e_{t-j} + \sum_{j=1}^{k-1} \psi_{\omega j} \Delta \omega_{t-j} + \xi_\omega ECT_\omega + \upsilon_t^\omega
\end{aligned}
$$

Table 1: Notation of the VECM

Notation	Description
Δ	First-difference operator
σ_{i0}	Constant term of variable *i*
k	Optimal lag length for the VAR specification
ξ_i	Speed of adjustment parameter of variable *i*
ECT_{it}	Error correction term of variable *i*
υ_t^i	Disturbance or error term of variable *i*

Concerning the joint long-run effects, the error correction terms (ECTs) for the income-capital ratio, the top 1% wealth share, and labor share are negative and statistically significant (see Table 2). The system converges to equilibrium at a speed of 52.2%, 14.4%, and 24.9% annually when the three variables mentioned above are shocked, respectively. The ECT for employment-population ratio is not statistically significant (p-value = 0.19, not shown in the table), meaning that the employment-population ratio is weakly exogenous in the cointegrating relations.

Appendix E and Appendix F provide evidence of the absence of serial autocorrelation of residuals, and appendix G shows that residuals are homoskedastic. Appendix H demonstrates that the model is stable since the roots of the characteristic polynomial lie within the unit circle: this is equivalent to the eigenvalues in the Jacobian having negative real parts in the continuous-time theoretical model. In Appendix H three unit-roots are expected because we have four endogenous variables ($n = 4$) and one cointegrating equation ($CE = 1$). The number of unit-roots imposed by the VECM specification is equal to $n - CE = 3$.

7.1 Impulse-Responses

Figure 4 shows the responses of u, ϕ, and e to an orthogonal set of negative innovations in the residuals of the labor share ω. By using the generalized impulses specification, the innovations do not depend on the VECM ordering ignoring the correlations in the residuals (Pesaran and Shin, 1998).

In the impulse responses plotted in Figure 4, the effect of an exogenous negative shock to ω, which would be equivalent to an decrease in the policy parameter z in equation 13, does not die out over time but leads to new steady-state values for all three variables.[13] We use Hall's percentile bootstrap (Hall, 1992) with 1000 bootstrap repetitions to compute the confidence intervals for the IRF's. The impact on u is negative as expected from equation (19), and the effect on ϕ is positive, as implied by equation (17). The long-run effect on e could be either positive or negative in the theoretical model, depending on the relative magnitude of the parameters α and μ: our time-series exercise suggests that the employment regime in the United States over the period under consideration is wage-led. Note that, for the first three or four periods depending on the variable under consideration, the confidence intervals cross zero on the vertical axis. But statistical significance of the responses is achieved after at most four periods, consistent with the fact that our theoretical predictions pertain to the long run.

In Appendix I, we generate impulse-responses using Hall's studentized bootstrap (Hall, 1986) with 1000 bootstrap repetitions and 500 double bootstrap repetitions as a robustness check. These results confirm our findings in Figure 4.

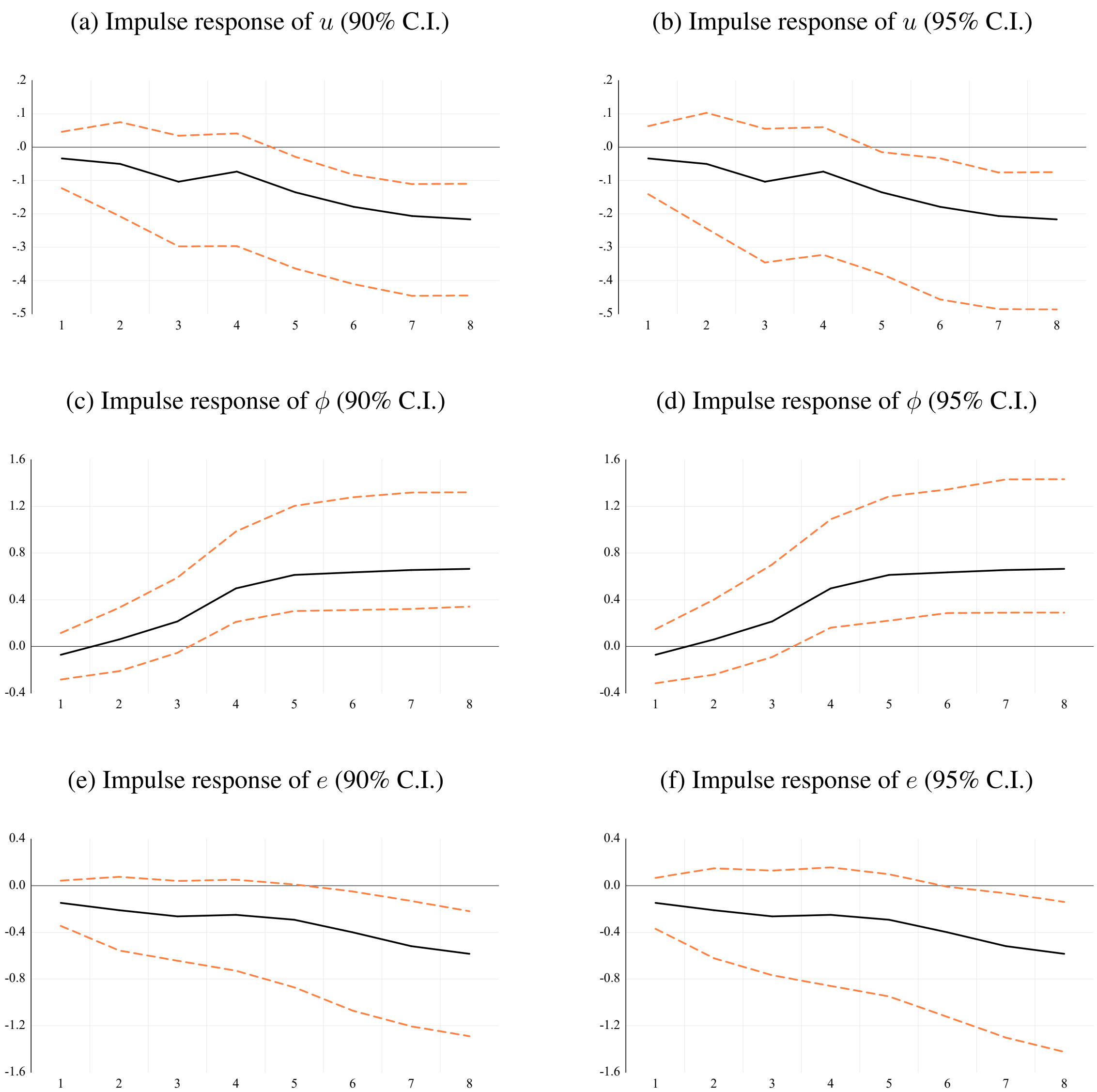
[13] Since we are working with annual data, one period corresponds to a year in the plots.

Table 2: Vector error correction model with u, ϕ, e, and ω as endogenous variables

	Dependent variable							
		u		ϕ		e		ω
LR								
	ϕ	-0.2028***	u	-4.9309***	u	-36.52***	u	-2.0146***
		(0.0391)		(0.8388)		(7.6388)		(0.2911)
	e	-0.0033	e	0.0161	ϕ	62.16***	ϕ	0.4086***
		(0.0363)		(0.1458)		(12.0096)		(0.0932)
	ω	-0.4964***	ω	2.4476***	ω	152.15***	e	0.0066
		(0.0861)		(0.5918)		(35.83)		(0.0685)
	trend	-0.0735***	*trend*	0.3622***	*trend*	22.52***	*trend*	0.1480***
		(0.0164)		(0.1160)		(5.7813)		(0.0251)
	ECT	-0.5224***	ECT	-0.1436***	ECT	0.0014	ECT	-0.2485***
		(0.1893)		(0.0674)		(0.0010)		(0.1156)
SR								
	Δu_{t-1}	0.7467***	Δu_{t-1}	-0.8675*	Δu_{t-1}	1.3036***	Δu_{t-1}	0.8867***
		(0.2564)		(0.4504)		(0.4328)		(0.3155)
	Δu_{t-2}	0.2062	Δu_{t-2}	0.7599	Δu_{t-2}	-0.6327	Δu_{t-2}	0.3983
		(0.2999)		(0.5269)		(0.5063)		(0.3691)
	Δu_{t-3}	-0.2408	Δu_{t-3}	0.2516	Δu_{t-3}	-0.1483	Δu_{t-3}	-0.2751
		(0.2316)		(0.4068)		(0.3909)		(0.2850)
	$\Delta \phi_{t-1}$	0.0702	$\Delta \phi_{t-1}$	0.2145	$\Delta \phi_{t-1}$	-0.0089	$\Delta \phi_{t-1}$	0.0751
		(0.0819)		(0.1438)		(0.1382)		(0.1007)
	$\Delta \phi_{t-2}$	-0.0411	$\Delta \phi_{t-2}$	0.1779	$\Delta \phi_{t-2}$	0.0327	$\Delta \phi_{t-2}$	-0.0063
		(0.0789)		(0.1385)		(0.1331)		(0.0970)
	$\Delta \phi_{t-3}$	-0.1451*	$\Delta \phi_{t-3}$	-0.0224	$\Delta \phi_{t-3}$	-0.03403***	$\Delta \phi_{t-3}$	0.0325
		(0.0788)		(0.1385)		(0.1331)		(0.0970)
	Δe_{t-1}	-0.1577	Δe_{t-1}	0.0854	Δe_{t-1}	0.1320	Δe_{t-1}	-0.3686***
		(0.1422)		(0.2498)		(0.2400)		(0.1750)
	Δe_{t-2}	0.0852	Δe_{t-2}	-0.8894***	Δe_{t-2}	0.4536*	Δe_{t-2}	-0.1761
		(0.1525)		(0.2678)		(0.2574)		(0.1876)
	Δe_{t-3}	0.2587*	Δe_{t-3}	0.1798	Δe_{t-3}	0.0833	Δe_{t-3}	0.2737
		(0.1544)		(0.2712)		(0.2606)		(0.1900)
	$\Delta \omega_{t-1}$	-0.2223*	$\Delta \omega_{t-1}$	0.0604	$\Delta \omega_{t-1}$	-0.1924	$\Delta \omega_{t-1}$	0.2116
		(0.1286)		(0.2259)		(0.2171)		(0.1582)
	$\Delta \omega_{t-2}$	-0.1046	$\Delta \omega_{t-2}$	0.1973	$\Delta \omega_{t-2}$	-0.1291	$\Delta \omega_{t-2}$	0.2854*
		(0.1247)		(0.2190)		(0.2105)		(0.1534)
	$\Delta \omega_{t-3}$	-0.2572***	$\Delta \omega_{t-3}$	-0.2128	$\Delta \omega_{t-3}$	-0.3493	$\Delta \omega_{t-3}$	-0.0411
		(0.1254)		(0.2204)		(0.2118)		(0.1544)
	Constant	-0.0357	Constant	0.2173	Constant	0.0340	Constant	-0.0602
		(0.0817)		(0.1436)		(0.1380)		(0.1006)

Notes: LR stands for long-run, and SR for short-run. Standard error in parenthesis, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Figure 4: Generalized impulse responses of u, ϕ, and e to a negative one-SD innovation in ω using Hall's percentile bootstrap.



(a) Impulse response of u (90% C.I.)

(b) Impulse response of u (95% C.I.)

(c) Impulse response of ϕ (90% C.I.)

(d) Impulse response of ϕ (95% C.I.)

(e) Impulse response of e (90% C.I.)

(f) Impulse response of e (95% C.I.)

Note: Confidence intervals are calculated using Hall's percentile bootstrap with 1000 bootstrap repetitions.

8 Conclusion

This paper presented a simple but comprehensive model of secular stagnation, income and wealth distribution, and employment drawing from contemporary work in the classical-Marxian tradition, and extending Petach and Tavani (2021). Similarly to to the well-known neoclassical account (Piketty, 2014; Gordon, 2015), in our model the economy is constrained by supply-forces in the long run; however, rather than presupposing full employment, exogenous growth, and high elasticity of substitution between capital and labor, our framework emphasizes the preeminence of the functional distribution on both capital accumulation and technological change. The former is profit-driven, while the latter is conflict- (or wage-) driven by induced bias in technology (Kennedy, 1964; Shah and Desai, 1981; Julius, 2005; Zamparelli, 2015).

We argued that labor-suppressing institutional shocks initially foster capital accumulation g, which is profit-driven. However, in the long-run, the growth rate of the economy —which ultimately depends on labor-productivity growth γ, in turn related to income shares through induced bias— falls due to the lessened incentive to adopt labor-augmenting technologies, given that the labor share has fallen. Thus, the income-capital ratio must fall to restore the balanced growth condition $g = \gamma$.

We also emphasized the evolution of the distribution of wealth, revisiting the Pasinetti (1962) theorem that ties up to our argument through the inverse long-run relationship between the wage share and the top wealth share on the one hand, and between the top wealth share and the income-capital ratio on the other. Differently from previous contributions, we also explicitly studied the evolution of the employment rate and its relationship to the functional income distribution in the long run: we identified two forces at work in determining the ultimate response of employment to shocks to the wage share, namely the strength of the induced technical change channel as opposed to the pure labor-market conflict channel. Correspondingly, we were able to identify a wage-led and a profit-led employment regime in the long-run depending on the relative strength of the two channels.

Finally, we ran a time-series test of the model using U.S. data (1960-2019). In particular, our interest is in the response of the income-capital ratio, the top wealth share, and the employment-population ratio to an exogenous negative shock to the wage share. Our theoretical model appears to do reasonably well for the period under consideration. Following a negative one-standard-deviation shock to the wage share, the impulse-response functions display a long-run effect of the same sign on the income-capital ratio and an opposite-sign impact on the top wealth share. Both these effects are as expected from the theory. The long-run effect on employment appears to be the same sign of the shock to the wage share, thus suggesting that the long-run employment regime in the US has been wage-led over the sample period.

Importantly, our explanation of secular stagnation and inequality does not feature a role for aggregate demand but emphasizes technological (i.e., supply) forces. Our model features a long-run where growth is wage-led through technological change; and it features the possibility of a wage-led employment regime in the long run —similarly to the possibility of long-run wage-led economic activity (capacity utilization) in neo-Kaleckian economics— that appears to be supported by the empirical evidence pertaining to the period under consideration.

The main policy implication is that, even in a supply-constrained economy, labor-friendly redistribution policies that increase the labor share of income will reduce wealth inequality while at the same time increasing economic growth and long-run employment; while a tax on capital gains —which will be undoubtedly effective at reducing wealth inequality— may fall short at reversing the decline in the labor share, and therefore will have no effect on either the long-run employment rate or the growth rate.

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Appendices

A Stability analysis

Linearization of the dynamical system around the Pasinetti steady state where $\phi_{ss} \in (0,1)$ yields, independently of the sign of $\alpha - \mu$, a Jacobian matrix with the following sign structure:

$$\begin{bmatrix} \dot{u} \\ \dot{\phi} \\ \dot{\omega} \\ \dot{e} \end{bmatrix} = \begin{bmatrix} 0 & 0 & - & 0 \\ 0 & - & - & 0 \\ 0 & 0 & - & + \\ + & + & - & 0 \end{bmatrix} \begin{bmatrix} u - u_{ss} \\ \phi - \phi_{ss} \\ \omega - \omega_{ss} \\ e - e_{ss} \end{bmatrix}$$

with the following entries in the Jacobian matrix:

$$\begin{array}{lllllll}
J_{13} & = & \frac{\partial \dot{u}}{\partial \omega}|_{ss} & = & -\frac{\alpha \beta^2 z}{s^c(\beta - z)} & < & 0 \\
J_{22} & = & \frac{\partial \dot{\phi}}{\partial \phi}|_{ss} & = & -\frac{\alpha z}{s^c}\left[\frac{(s^c - s^w)(\beta - z) - s^w z}{\beta - z}\right] & < & 0 \\
J_{23} & = & \frac{\partial \dot{\phi}}{\partial \omega}|_{ss} & = & -\frac{(s^c - s^w)(\beta - z) - s^w z}{(s^c - s^w)(\beta - z)} \frac{\alpha \beta s^w z}{s^c(\beta - z)^2} & < & 0 \\
J_{33} & = & \frac{\partial \dot{\omega}}{\partial \omega}|_{ss} & = & -\alpha z & < & 0 \\
J_{34} & = & \frac{\partial \dot{\omega}}{\partial e}|_{ss} & = & \frac{\delta z}{\beta} & > & 0 \\
J_{41} & = & \frac{\partial \dot{e}}{\partial u}|_{ss} & = & \left[\frac{s^c(\beta - z)}{\beta}\right]\left[\frac{\lambda + (\alpha - \mu) z}{\delta}\right] & > & 0 \\
J_{42} & = & \frac{\partial \dot{e}}{\partial \phi}|_{ss} & = & \alpha z \left(\frac{s^c - s^w}{s^c}\right)\left[\frac{\lambda + (\alpha - \mu) z}{\delta}\right] & > & 0 \\
J_{43} & = & \frac{\partial \dot{e}}{\partial \omega}|_{ss} & = & -\beta\left\{(1 + \alpha) + \frac{\alpha z}{s^c(\beta - z)^2}\left[(s^c - s^w)(\beta - z) - s^w z\right]\right\}\left[\frac{\lambda + (\alpha - \mu) z}{\delta}\right] & < & 0
\end{array}$$

$$J_{11} = J_{12} = J_{14} = J_{21} = J_{24} = J_{31} = J_{32} = J_{44} = 0$$

For local stability, the eigenvalues of J_{ss} must have uniformly negative real parts. Petach and Tavani (2021) have already proven the local stability of the 3-dimensional subsystem in (u, ω, ϕ) under $\mu = 0$. Notice however that the terms in square brackets in J_{42} and J_{43} are nothing but the steady state employment rate, which is positive no matter whether $\alpha - \mu \gtreqless 0$, with the implication that all the signs in the Jacobian are unambiguous, no matter whether the model is wage-led or profit-led. Thus, it is sufficient to show that the fourth eigenvalue is negative. In order to do so, consider that the equations describing the evolution of u and ϕ do not communicate with the equation tracing the evolution of employment: the implication is that we can focus on the interaction between ω and e in the Jacobian, i.e, the submatrix formed by the entries $\begin{bmatrix} J_{33} & J_{34} \\ J_{43} & J_{44} \end{bmatrix}$ in the bottom right of the full Jacobian. Such minor has the following sign structure: $\begin{bmatrix} - & + \\ - & 0 \end{bmatrix}$ that delivers a negative trace and positive determinant, which implies that the fourth eigenvalue of J is negative as required.

B Unit-root tests

Test	Specification	u	ϕ	e	ω	Δu	$\Delta\phi$	Δe	$\Delta\omega$
ADF	None	1.68	1.20	1.34	-0.89	-6.01***	-6.27***	-4.57***	-6.19***
	C	-0.82	-0.20	-2.07	-1.52	-6.24***	-6.34***	-4.83***	-6.18***
	C & *T*	-3.41*	-2.03	-2.08	-2.23	-6.18***	-6.53***	-4.94***	-6.13***
PP	None	2.07	1.02	1.71	-0.89	-5.86***	-6.26***	-4.49***	-6.20***
	C	-0.69	-0.16	-1.71	-1.75	-6.23***	-6.34***	-4.67***	-6.20***
	C & *T*	-2.75	-1.82	-1.25	-2.59	-6.14***	-6.52***	-4.66***	-6.14***
Breakpoint	*C*	-3.56	-2.49	-3.94	-3.21	-6.95***	-7.44***	-6.30***	-6.53***
	C & *T*: break: *C*	-4.43	-4.15	-4.06	-2.63	-7.00***	-7.74***	-6.55***	-6.66***
	C & *T*: break: *T*	-4.21	-4.24	-3.86	-2.42	-6.46***	-6.93***	-5.46***	-6.17***
	C & *T*: break: *C* & *T*	-4.47	-4.41	-4.07	-2.95	-7.01***	-7.78***	-5.96***	-6.78***

Notes: ADF: Augmented Dickey-Fuller, PP: Phillips-Perron, Breakpoint: unit-root test in the presence of a break. *C*: Constant, *T*: Trend. The null hypothesis is that the variable has a unit-root, while the alternative hypothesis is that the variable is stationary. The lag length for the ADF test is based on the Bayesian information criterion. The Barlett kernel is selected as the spectral estimation method with a bandwidth set by the Newey-West procedure for the PP unit-root test. Breakpoint unit-root tests use innovation outlier as its break type, the Dickey-Fuller mint-t as breakpoint selection, and the Bayesian information criterion is used to select their optimal lag length. Operator Δ before the name of the variables denotes that the variable is expressed in first-differences. *** $p < 0.01$, *$p < 0.10$.

C Johansen cointegration test

Hypothesized No. of cointegrating equations	Trace		Max. Eigenvalue	
	Statistic	Prob.	Statistic	Prob.
None	62.5563	0.0073	29.4754	0.0384
At most 1	33.0808	0.0830	18.5498	0.1540
At most 2	14.5311	0.2545	10.1313	0.3225
At most 3	4.3998	0.3558	4.3998	0.3558

Notes: The test does not allow a linear deterministic trend, but an intercept in the cointegrating equation.

D Model selection

Lag	Log L	LR	FPE	AIC	BIC	HQ
0	-421.15	N.A.	110.30	16.05	16.20	16.11
1	-157.98	477.23	0.0097	6.72	7.46*	7.00
2	-129.91	46.61*	0.0062	6.26	7.60	6.78*
3	-113.48	24.80	0.0063	6.24	8.18	6.99
4	-95.73	24.11	0.0062*	6.18	8.71	7.15
5	-77.94	21.48	0.0064	6.11*	9.23	7.31
6	-70.96	7.37	0.0103	6.45	10.17	7.88
7	-59.08	10.76	0.0149	6.61	10.92	8.27

Notes: * Indicates lag order selected by the criterion. L.R.: sequential modified L.R. test statistic (each test at a 5% level). FPE: Final prediction error. AIC: Akaike information criterion. BIC: Bayesian information criterion. HQ: Hannan-Quinn information criterion. Endogenous variables: output-capital ratio, top 1% wealth share, the share of labor compensation, and the employment-population ratio.

E VECM residual serial correlation LM tests

Lag	LRE stat.	df	Prob.	Rao F-stat.	df	Prob.
1	10.79	16	0.8222	0.66	(16, 107.6)	0.8231
2	7.71	16	0.9571	0.47	(16, 107.6)	0.9573
3	12.48	16	0.7102	0.77	(16, 107.6)	0.7114

Note: Null hypothesis: No serial correlation at lag h

Lag	LRE stat.	df	Prob.	Rao F-stat.	df	Prob.
1	10.79	16	0.8222	0.66	(16, 107.6)	0.8231
2	27.28	32	0.7043	0.84	(32, 115.9)	0.7102
3	37.32	48	0.8674	0.74	(48, 106.0)	0.8770

Note: Null hypothesis: No serial correlation at lags 1 to h

F VECM residual correlation Portmanteau tests

Lags	Q-statistic	Prob.	Adj. Q-stat.	Prob.	df
1	2.28	-	2.32	-	-
2	4.62	-	4.75	-	-
3	9.63	-	10.05	-	-
4	28.05	0.5155	29.87	0.4203	29
5	40.40	0.6669	43.44	0.5381	45
6	50.41	0.8314	54.65	0.7039	61

Notes: Null hypothesis: No residual autocorrelation up to lag h. Tests are valid only for lags larger than the VECM lag order.

G VECM White heteroskedasticity tests

Chi-square stat.	Degrees of freedom	Prob.
244.72	260	0.7435

Notes: The null hypotheses are no heteroskedasticity. White heteroskedasicity test does not include cross terms.

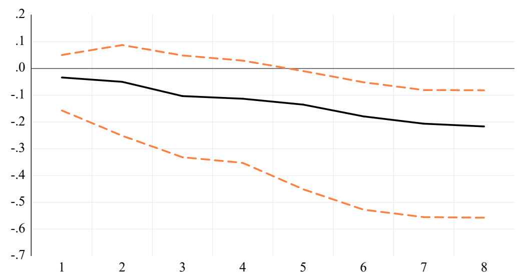
H Roots of the characteristic polynomial of the VECM

Root	Modulus
1.0000	1.0000
1.0000 - 3.60e - 16 i	1.0000
1.0000 + 3.60e - 16 i	1.0000
0.6520 - 0.4764 i	0.8075
0.6520 + 0.4764 i	0.8075
-0.6263 - 0.4125 i	0.7499
-0.6263 + 0.4125 i	0.7499
0.6666 - 0.0379 i	0.6677
0.6666 + 0.0379 i	0.6677
0.3404 - 0.5488 i	0.6459
0.3404 + 0.5488 i	0.6459
-0.6437	0.6437
0.2034 - 0.5389 i	0.5760
0.2034 + 0.5389 i	0.5760
-0.2199 - 0.2128 i	0.3060
-0.2199 + 0.2128 i	0.3060

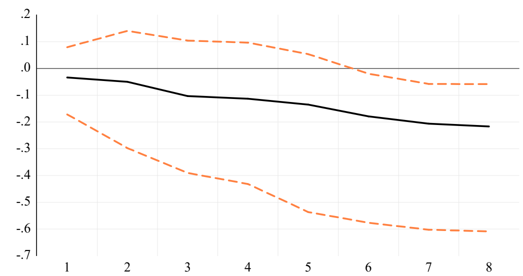
Note: VECM specification imposes three unit-roots.

I Generalized impulse responses of u, ϕ, and e to a negative innovation in ω using Hall's studentized bootstrap.

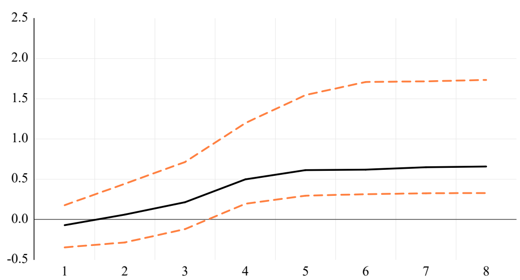
(a) Impulse Response of u (90% C.I)



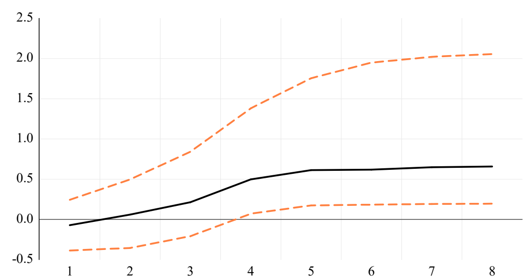
(b) Impyulse Response of u (95% C.I.)



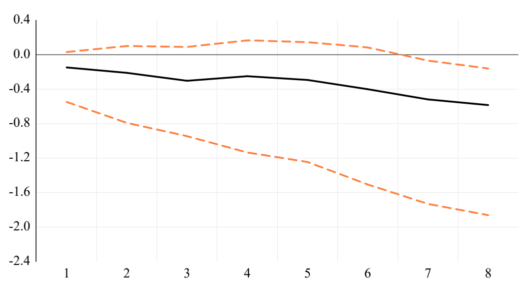
(c) Impulse Response of ϕ (90% C.I)



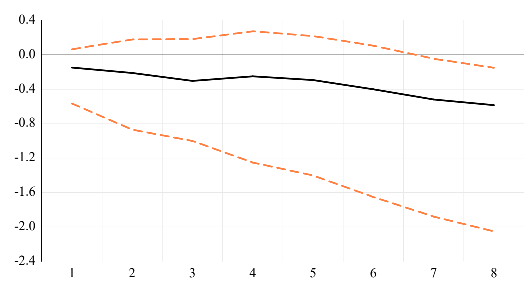
(d) Impyulse Response of ϕ (95% C.I.)



(e) Impulse Response of e (90% C.I)



(f) Impyulse Response of e (95% C.I.)



Note: Confidence intervals are calculated using Hall's studentized bootstrap with 1000 bootstrap repetitions and 500 double bootstrap repetitions.