Secular stagnation, R&D, public investment and monetary policy: a global-model perspective

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Secular stagnation, R&D, and policies

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Abstract

We evaluate the global macroeconomic effects of cross-country coordinated fiscal and monetary policies to counterbalance secular stagnation by simulating a five-region New Keynesian model of the world economy, calibrated to the United States (US), the euro area (EA), Japan (JP), China (CH), and the rest of the world (RW). The model includes investment in research and development (R&D) as a key factor affecting global growth. Our main findings are as follows. First, unfavorable technology developments may have played a nontrivial role in the global growth slowdown. Second, secular stagnation can be more effectively counterbalanced by coordinating global fiscal and monetary measures encouraging R&D accumulation. Third, these coordinated measures provide a larger welfare gain relative to a unilateral fiscal expansion.

Keywords: DSGE modeling, secular stagnation, public investment, monetary policy.

JEL classifications: E43; E44; E52; E58.

...there is much we can still do to reverse the aggregate productivity slowdown and dispel pessimism about our future.

Mario Draghi, President of the European Central Bank.[1]

1 Introduction

The relatively slow recovery of the U.S. (US) economy from the recent financial crisis has resurrected interest in Hansen's secular stagnation hypothesis (see Hansen 1939). According to this hypothesis, industrialized economies show an increasing propensity to save and a decreasing propensity to invest, resulting in excess savings and depressed demand. This, in turn, determines low economic growth, inflation, and interest rates. This theory has been brought back to center stage by Summers (2014, 2015), who has emphasized two potential mechanisms: the increased propensity to save driven by the ageing of population and the technological innovation which has led to a decline in the relative price of capital goods (see Eichengreen 2015). A different version of the hypothesis, put forward notably by Gordon (2015), focuses on the supply side. It argues that the great inventions spurring massive productivity increases have, for the most part, already come to fruition; thus, a return to more moderate growth rates is inevitable.

The secular stagnation phenomenon is not confined to the US economy. Figure 1 reports US and euro-area (EA) GDP growth and interest rates over the past four decades. Both variables clearly display a downward trend.[2] Therefore, appraising the secular stagnation hypothesis and exploring its main implications is a worthwile exercise in a global context.

Several policy measures have been suggested to reinvigorate economic growth. One of them is a coordinated increase in public infrastructure investment in the major industrialized countries. An increase in public investment would support long-run growth and offset the excess of global savings with respect to total investment. It would stimulate aggregate demand and favor capital accumulation, especially in conjunction with an accommodative monetary policy stance. Given

[1] Draghi (2017).

[2] As emphasized by Eggertsson et al. (2016), the average long-term interest rates all over the industrial world are now lower than they were a few years ago, in the immediate aftermath of the crisis, and financial markets suggest that inflation and real interest rates are expected to persistently remain at rather low levels not only in the US but also in Europe and Japan. According to The World Bank (2018), long-term global growth forecasts are stabilizing at levels well below those expected a decade earlier and well below current growth rates.

the “global” dimension of the proposed policy measures, it is key to evaluate their domestic and international effects and the possible benefits of cross-country coordination.

We follow this “global” approach in this paper. By simulating a large-scale multi-country New Keynesian model, we evaluate how an increase in public infrastructure investment in the main advanced economies affects global growth and welfare under alternative monetary policy stances. The most crucial aspect of this approach is that we fully endogenize long-run global growth via research and development (R&D) accumulation, consistent with the supply-side view of secular stagnation. This allows us to (1) replicate the secular stagnation phenomenon and (2) to assess the macroeconomic and welfare effects of increasing public infrastructure investment in the short and long run. We further elaborate on the impact of different combinations of monetary policy stances and international coordination settings. To the best of our knowledge, the novelty of this paper relies in: (a) the quantitative assessments of the supply-side version of the secular stagnation hypothesis, along with the possible counter-setting policy measures at international level; and (b) the development of a multi-country New Keynesian model of the global economy featuring endogenous growth.

In the model, the world economy is composed of five blocs, calibrated to the main global investors in R&D – EA, US, China (CH), Japan (JP) – and the residual “rest of the world” region (RW). R&D is endogenously accumulated in the tradable sectors of US, EA, JP, and CH. The labor input is affected by a global technology trend, whose growth rate positively depends on global R&D accumulation. The latter is a new feature for models of this type. R&D affects the growth rate of the world economy in both the short and the long run. In the long run, the world economy follows a balanced growth path, driven by the growth rate of global labor-augmenting technology. Public infrastructure investment is accumulated into public capital that makes privately provided capital, labor, and R&D more productive. Thus, following an increase in public investment, firms have an incentive to increase their demand for those inputs, particularly for R&D. The increase in R&D favors labor-augmenting technological progress. It consequently affects global growth and interest rate along the steady-state balanced growth path.

We simulate the following scenarios. Initially, we design a secular stagnation scenario, in which the long-run growth rate of labor-augmenting technology permanently decreases because of a negative shock to global R&D investment efficiency. This shock is meant to capture the reduced capability to convert investment into the stock of R&D, consistent with evidence in Bloom et al. (2017). Starting from this new (long-run) "secular-stagnation steady state", we then simulate a permanent increase in public infrastructure investment by 1% of GDP; first in the US only, and then in US, EA, JP and CH. In both cases we make two alternative assumptions on the monetary policy stance in the region that implements the fiscal policy intervention: (i) the central bank follows the Taylor rule; (ii) the central bank announces to keep the policy rate constant at the initial steady-state level for two years, thus enacting forward guidance (FG).[3] Finally, we quantify welfare gains from international policy coordination.

Our main conclusions are threefold. First, unfavorable technology developments may have played a nontrivial role in the global growth slowdown. Second, the stagnation can be effectively counterbalanced by coordinating global fiscal and monetary measures encouraging R&D accumulation. Third, coordinated measures provide a larger welfare gain relative to a unilateral fiscal expansion.

Our paper provides two unique contributions to the existing literature on secular stagnation. First, building on Gordon (2015), we provide an estimate of the relevance of the global technology slowdown as a determinant of secular stagnation. Other papers have mainly focused on factors affecting aggregate demand (Summers 2014, 2015). One exception is Benigno and Fornaro (2018), that builds a New Keynesian closed-economy model where pessimistic expectations can permanently reduce productivity growth. In a departure from them, we build an open-economy multi-country model and rely on a fundamental shock (to the efficiency of R&D investment), based on evidence provided by Bloom et al. (2017). We also build on the estimates provided by Bianchi et al. (2019) within a closed-economy New Keynesian framework. Our second novel contribution is to estimate the quantitative effects of cross-country expansionary fiscal and monetary measures on global growth. Eggertsson et al. (2016) provide a theoretical analysis of this issue. Our analysis provides a quantitative assessment of one of their main conclusions, namely that cross-country coordination is crucial in escaping secular stagnation.

The paper is organized in four sections and a conclusion. Section 2 briefly provides an

[3]All scenarios are simulated under perfect foresight, so that households and firms perfectly anticipate the future path of R&D investment efficiency and policy measures.

overview and key features of the model and defines the calibration.[4] Section 3 describes the simulated scenarios. Section 4 reports the results. Section 5 concludes.

2 The model

2.1 Overview

We build and simulate a five-region New Keynesian model of the world economy, calibrated to US, EA, JP, CH, and RW.[5] In each country households consume, invest in physical capital and riskless one-period bonds, and supply labor. Households in the US, EA, JP, and CH can invest also in R&D.

On the production side, there are perfectly competitive firms that produce final nontradable (consumption and investment) goods and monopolistic firms that produce intermediate goods. The final goods are sold domestically and are produced by combining all available intermediate goods, using a constant-elasticity-of-substitution (CES) production function. The resulting bundles may have different composition.

The model has two rather novel features. First, following Bianchi et al. (2019), endogenous accumulation of R&D. Second, public investment in infrastructure in each region. Specifically, both intermediate tradable and nontradable goods are produced according to a sector-specific Cobb-Douglas technology that uses private capital, labor (both supplied by domestic households), and public capital. The labor input is subject to a global technological trend, which depends positively on the accumulated stock of global R&D. Firms in intermediate tradable sectors in the US, EA, JP, and CH optimally demand R&D in the domestic perfectly competitive market. R&D is supplied by domestic households that accumulate it over time by optimally choosing the amount of investment. Importantly, we assume the existence of an "efficiency" shock that affects the accumulation process of R&D.[6] Moreover, there are R&D spillovers on the other sectors and to other countries. The remaining features of the model are in line with standard open-economy

[4] For a complete and detailed description of the model, see the Online Appendix. See also Pesenti (2008) for a similar model setup without endogenous growth.

[5] In each region, size refers to the overall population and to the number of firms operating in each sector.

[6] See Anzoategui et al. (in press).

New Keynesian models.[7]

2.2 Production, R&D, long-run growth and interest rate

The production function of the generic firm f^{US} in the US intermediate tradable sector is

$$Y_{T,t}^{US}\left(f^{US}\right)=\left(K_{T,t}^{US,P}\left(f^{US}\right)\right)^{\alpha_{1T}}\left(TREND_{t}^{US}\left(f^{US}\right)L_{T,t}^{US}\left(f^{US}\right)\right)^{\alpha_{2T}}\left(K_{t-1}^{US,G}\right)^{1-\alpha_{1T}-\alpha_{2T}}, \tag{1}$$

where $K_{T,t}^{US,P}\left(f^{US}\right)$ is private capital, $K_{t-1}^{US,G}$ public capital, and $L_{T,t}^{US}\left(f^{US}\right)$ labor. The parameters $0<\alpha_{1T},\alpha_{2T}<1$, $\alpha_{1T}+\alpha_{2T}<1$, are the weights on private capital and labor, respectively. The labor-augmenting technology shock specific to the generic US firm f, $TREND^{US}\left(f^{US}\right)$, is

$$\begin{aligned} TREND_{t}^{US}\left(f^{US}\right) &= A\left(\left(R\&D_{t}^{US}\left(f^{US}\right)\right)^{\eta^{US}}\left(R\&D_{t}^{US}\right)^{1-\eta^{US}}\right)^{\gamma^{US}}\times \\ &\quad \left(R\&D_{t}^{EA}\right)^{\gamma^{EA}}\times\left(R\&D_{t}^{JP}\right)^{\gamma^{JP}}\times\left(R\&D_{t}^{CH}\right)^{1-\gamma^{US}-\gamma^{EA}-\gamma^{JP}},\forall f^{US}, \end{aligned} \tag{2}$$

where $A>0$ is a scaling parameter, $R\&D^{US}\left(f^{US}\right)$ is the US firm f^{US}'s stock of R&D, while the aggregate stock of R&D in the US is

$$R\&D^{US} = \int_{0}^{n^{US}} R\&D_{t}^{US}\left(f^{US}\right)df^{US}, \tag{3}$$

where $0<n^{US}<1$ is the number of firms in the US tradable sector. Similar equations hold for EA, JP, and CH.[8]

The $TREND^{US}\left(f^{US}\right)$ is positively affected by the stock of R&D optimally chosen by the generic firms f in the US, EA, JP, and CH intermediate tradable sectors. When choosing the optimal $R\&D\left(f\right)$, the generic firm f^{US} takes into account its direct contribution to $TREND^{US}\left(f^{US}\right)$ (measured by the parameter η, $0<\eta<1$). The parameters γ measure the

[7] We also include adjustment costs on real and nominal variables, ensuring that consumption, production, and prices react in a gradual way to a shock. On the real side, habit formation and quadratic costs delay the adjustment of households consumption and investment (in private capital and in R&D), respectively. On the nominal side, quadratic costs make wages and prices sticky (see Rotemberg 1982). Finally, in each country there are a Taylor-type monetary policy rule and a fiscal rule that stabilizes public debt as a % of domestic GDP.

[8] The number of firms in EA, JP, and CH tradable sectors is $0<n^{EA},n^{JP},n^{CH}<1$, respectively, 1 is the size of the world economy and $n^{US}+n^{EA}+n^{JP}+n^{CH}<1$.

elasticity of $TREND^{US}(f)$ to country-specific R&D ($0 < \gamma^{US}, \gamma^{EA}, \gamma^{JP} < 1$, $\gamma^{US}+\gamma^{EA}+\gamma^{JP} < 1$). The generic US firm f^{US} optimally demands capital, labor, and R&D (all of them are supplied by domestic households), taking as given prices, the stock of public capital (accumulated by domestic government), the R&D accumulated by other (domestic and foreign) individual firms, and the aggregate R&D in each domestic and foreign sector.[9]

A similar trend (and production function) holds for every firm in EA (and JP, CH, and RW):

$$\begin{aligned} TREND_t^{EA}\left(f^{EA}\right) &= A\left(\left(R\&D_t^{EA}\left(f^{EA}\right)\right)^{\eta^{EA}}\left(R\&D_t^{EA}\right)^{1-\eta^{EA}}\right)^{\gamma^{EA}} \times \\ &\quad \left(R\&D_t^{US}\right)^{\gamma^{US}} \times \left(R\&D_t^{JP}\right)^{\gamma^{JP}} \times \left(R\&D_t^{CH}\right)^{1-\gamma^{US}-\gamma^{EA}-\gamma^{JP}}. \end{aligned} \tag{4}$$

As we consider a symmetric equilibrium, in which all firms belonging to the same sector make the same choices, $TREND_t^{US}\left(f^{US}\right)$ will end up being the same for every US firm. The same is true for every firm in EA, JP, CH, and RW (even if RW firms are assumed to not invest in R&D).[10] Thus, $TREND_t^{US}\left(f^{US}\right)$ will be equal to all trends in other regions. This implies that there is a (common) global trend of labor-augmenting technology $TREND_t^{world}$, i.e., in the symmetric equilibrium the trend is common across all firms producing intermediate tradable and nontradable goods in all regions of the global economy,

$$TREND_t^{US} = TREND_t^{EA} = TREND_t^{JP} = TREND_t^{CH} = TREND_t^{RW} = TREND_t^{world}. \tag{5}$$

Following Bianchi et al. (2019), the US R&D is accumulated by the generic US household i according to

$$R\&D_t(i) = \left(1-\delta_{R\&D}\right) R\&D_{t-1}(i) + Z_{I_{R\&D,t}}\left(1-\frac{\psi_{R\&D}}{2}\left(\frac{I_{R\&D,t}(i)}{I_{R\&D,t-1}(i)}-gr_t\right)\right)^2 I_{R\&D,t}(i), \tag{6}$$

where we have dropped the "US" superscript for simplicity. The parameter $0 < \delta_{R\&D} < 1$ is

[9] Firms do not demand public capital and there is no price or tariff paid for its use.

[10] Firms in the nontradable sector demand physical capital and labor supplied by domestic households, and take public capital and the (global common) labor-augmenting technology as given. They do not invest in R&D, in line with the empirical evidence. See Santacreu and Zhu (2018).

the depreciation rate; $\psi_{R\&D} > 0$ is a parameter measuring R&D investment adjustment costs; $I_{R\&D,t}$ is the investment in $R\&D$ (whose composition is assumed to be the same as that of private consumption); $Z_{I_{R\&D,t}}$ represents the shock to the marginal efficiency of R&D investment, and gr_t is the gross growth rate of the global labor-augmenting technology trend,

$$gr_t \equiv \frac{TREND_t^{world}}{TREND_{t-1}^{world}}. \tag{7}$$

Finally, along the long-run balanced growth path the global real (natural) interest rate RR is pinned down by the growth rate gr and the households' subjective discount factor $0 < \beta < 1$,

$$RR = \frac{gr}{\beta}. \tag{8}$$

2.3 Public capital and monetary policy

In each region fiscal authority exogenously chooses the amount of investment in infrastructure and, thus, the accumulation of public capital, K_t^G, according to

$$K_t^G = (1 - \delta_G) K_{t-1}^G + I_{G,t}, \tag{9}$$

where $0 < \delta_G < 1$ is the depreciation rate, and $I_{G,t}$ is public investment.[11]

In each country the central bank sets the policy rate R_t according to the Taylor rule

$$\left(\frac{R_t}{\bar{R}}\right)^4 = \left(\frac{R_{t-1}}{\bar{R}}\right)^{4\rho_R} \left(\frac{\Pi_{t,t-3}}{\bar{\Pi}^4}\right)^{(1-\rho_R)\rho_\pi} \left(\frac{GDP_t}{GDP_{t-1}}\right)^{(1-\rho_R)\rho_{GDP}}. \tag{10}$$

The parameter ρ_R $(0 < \rho_R < 1)$ captures inertia in interest-rate setting, while $\bar{R}$ represents the steady-state gross nominal policy rate. The parameters ρ_π and ρ_{GDP} are respectively the weights of the yearly CPI inflation rate $\Pi_{t,t-3} \equiv P_t/P_{t-4}$ (in deviation from the long-run constant target $\bar{\Pi}^4$) and the gross growth rate of the stationary (de-trended) component of GDP.[12] In some

[11]The government follows a fiscal rule defined on lump-sum taxes to bring the public debt in line with its long-run (steady-state) target and to stabilize its rate of change. We choose lump-sum taxes to stabilize public finances as they are non-distortionary and, thus, allow for a "clean" evaluation of the macroeconomic effects of public investment (thus, the level of public debt does not affect our results). See the Online Appendix.

[12]The stationary component of GDP in a given period is defined as the level of the gross domestic product divided by level of $TREND^{world}$ in the same period.

scenarios the central bank is assumed to keep the policy rate constant at its (initial) steady-state level for two years (forward guidance, FG).

2.4 Calibration

We match the empirical evidence on the pre-secular stagnation period (1970s-80s). Table 1 shows the great ratios for the five regions. Table 2 reports the trade matrix.[13]

The global growth rate is set to 2.8% in line with the evidence reported in Figure 1 and the one provided by the Conference Board (2015) on the growth rate of global TFP. The annualized real interest rate is 4.9%, in line with the evidence reported in Figure 1.

The parameters are calibrated to match these quantities and in line with the existing literature. Tables 3 to 6 report the (quarterly) calibration.

Table 3 shows the preference and technology parameters. Preferences are the same across households of different regions. We set the discount factor so that, given the steady-state worldwide growth rate, the (before-shock) steady-state annualized real interest rate is matched.

The intertemporal elasticity of substitution is set equal to 1.0, the habit parameter to 0.6, and the Frisch elasticity to 0.50. We further assume a depreciation rate of physical (public and private) capital and R&D of 0.025, consistently with an annual depreciation rate of 10%. About final goods, the degree of substitutability between domestic and imported tradables is higher than that between tradables and nontradables (2.5 vs 0.5). Concerning R&D technology, we set the scaling parameter to 0.75, the elasticity of $TREND^{world}$ to regional R&D, γ, to 0.30 in EA, 0.40 in US, 0.10 in CH and 0.20 in JP. The contribution of individual firms' R&D to $TREND^{world}$ (η) is set to 0.23 in the EA, 0.18 in the US, 0.42 in CH, and 0.35 in JP. These parameters are chosen so that the steady-state ratio of R&D investment to GDP matches aggregate data (see Table 1). The weight of domestic tradable goods in the consumption and investment tradable baskets is different across countries, to match multilateral import-to-GDP ratios. We then set the weights of bilateral imports to match the trade matrix.

Table 4 reports real and nominal rigidities. For real rigidities, parameters of the adjustment

[13] We rely on the United Nations' Commodity Trade Statistics (COMTRADE) data on each region's imports of consumer and capital goods, to derive the matrix delineating the pattern and composition of trade for all regions' exports and imports.

costs on investment changes are set to 4.5 in all countries, both for investment in physical capital and for investment in R&D. For nominal rigidities, we set the adjustment costs for wages to 600; for prices of domestic tradable and nontradable goods, to 600; for prices of imported goods, to 6.00.[14] Table 5 shows price and wage markup values. We identify the intermediate nontradable and tradable sectors in the model with the services and manufacturing sectors in the data, respectively. In each region the markup in the nontradable sector is assumed to be higher than that in the tradable sector and in the labor market.[15] Table 6 reports the parameters of the monetary policy rules (see equation 10). The interest rate reacts to the its lagged value (set to 0.87), inflation (1.7) and output growth (0.1).

3 Simulated scenarios

We initially design a secular-stagnation scenario, in which the long-run growth rate of the labor-augmenting technology permanently decreases (first scenario). Specifically, we simulate a negative shock, $Z_{I_{R\&D}}$, to the global R&D investment efficiency, i.e., to the capability to convert investment into (accumulated) stock of R&D (see equation 6). The size of the shock is such that the efficiency is permanently reduced to 90% of its initial level, which is in line with estimates provided by Bianchi et al. (2019). The persistent decline in R&D efficiency is documented, among others, by Bloom et al. (2017).

Starting from the new steady state characterized by lower growth and lower interest rates, we simulate several scenarios to highlight the role of international policy coordination. We initially consider a permanent increase in US public infrastructure investment by 1% of (the secular-stagnation steady state) GDP under two alternative assumptions on the US monetary policy stance: (i) the US central bank always follows the Taylor rule (second scenario); (ii) alternatively, the US central bank announces to keep the policy rate constant at the initial level for two years, thus enacting FG in the short run (third scenario). The two key scenarios are then simulated. In one, public investment is permanently and simultaneously increased in US, EA,

[14]The value 600 for quadratic adjustment costs in prices is roughly equivalent to a four-quarter contract length under Calvo (1983) pricing, as highlighted, among others, by Faruqee et al. (2007). The value 6 for import price adjustment costs is consistent with a relatively quick pass-through of the nominal exchange rate to import prices.

[15]Our values are in line with other existing similar studies, such as Bayoumi et al. (2004), Faruqee et al. (2007), and Everaert and Schule (2008).

JP, and CH under a standard monetary policy stance (fourth scenario). In the other, the same increase in public investment occurs under a two-year FG in all the four regions (fifth scenario). The size of the public investment increase is equal to 1% of GDP, the same order of magnitude of the reduction in advanced economies' public investment observed in recent decades.[16] We first report the macroeconomic effects of permanently reducing the growth rate of the global labor-augmenting technology shock. Thereafter, we illustrate the welfare analysis, in order to provide a complete characterization of our results on policy coordination.

4 Results

4.1 Secular stagnation

Figure 2 reports the responses of the main macroeconomic variables to the negative shock to R&D accumulation.[17] Because of the lower R&D investment efficiency, firms decrease the growth rate of R&D investment relative to the before-shock long-run growth rate (i.e, the before-shock steady-state balanced growth path). Consistent with that, the global technology growth permanently decreases (in line with estimates provided by the Conference Board 2015). The nominal interest rate permanently declines as well. The decline is gradual, given the inertial term in the monetary policy rule. The GDP growth initially undershoots its new lower long-run value, because prices are sticky in the short run and the economy adjusts mainly through changes in the quantities. Inflation initially decreases and, thereafter, gradually returns to its initial baseline level. Consumption growth sharply declines on impact, in line with the increase in the ex-ante real interest rate (not reported). The lower consumption growth makes resources available for higher investment in physical capital, whose growth rate initially increases and, after around eight quarters, decreases below the baseline. The initial increase also reflects a substitution away from less efficient R&D. Hours worked initially decline (not reported), given the initial drop in labor-augmenting technology growth. Thereafter, they increase, in line with the (partial)

[16] See International Monetary Fund (2014). All scenarios are simulated under perfect foresight, so households and firms perfectly anticipate the future path of R&D investment efficiency and policy measures.

[17] In the charts we report the first 60 quarters to show long-run responses. Alternatively, 20 quarters are reported when the emphasis is on the short-run effects, typically when the accommodative monetary policy stance is considered.

recovery of the technology trend.[18]

US exports growth initially increases favored by the rise in investment in other countries (see below) and US imports growth persistently decreases, consistent with the lower growth in US aggregate demand. EA and JP exports growth initially increases, while CH and RW exports decrease. CH and RW import growth increases, while EA and JP import growth decreases. Consistent with the paths of exports and imports, the EA and JP currencies appreciate in real terms vis-à-vis the US dollar less than the CH and RW currencies do. The mechanism behind the different depreciations reflects differences in R&D. Specifically, the negative R&D shock affects US, EA, JP more than CH, given the chosen calibration (R&D has a lower weight in CH production), while RW does not invest in R&D by assumption. Thus, GDP growth decreases by relatively more in the US, EA, and JP. Because of the larger decrease in economic activity, prices decreases relatively more in these countries. This favors in the short and medium run a slightly larger decrease in their policy rates and, thus, the depreciation of their currencies vis-à-vis the CH and RW currencies. The favourable expenditure-switching effect benefits goods produced in US, EA, and JP.

As reported in Table 7, the slower R&D accumulation permanently reduces the growth of technology, which determines the long-run growth rate of the world economy. Thus, the latter converges to a new lower long-run balanced growth path, in which the annualized global growth rate is 1.9% (from 2.8%). Consistently, the global real interest rate decreases from 4.9% to 4.0%.

All in all, the negative shock to R&D allows us to partly replicate the main stylized facts associated with the secular stagnation, i.e., the permanent slowdown in global economic activity and the permanent reduction in the global interest rate, in line with the evidence reported in Figure 1.

4.2 Increase in US public investment under alternative assumptions on the monetary policy stance

Figures 3 and 4 present the responses of the main variables when the US permanently and unilaterally increases public investment by 1% of GDP starting from the secular-stagnation

[18]The real wage permanently increases (not reported).

steady state (the new baseline, which the world economy achieved at the end of the simulation reported in the previous section). The US fiscal expansion is either accompanied by an immediate increase in the US monetary policy rate (solid black line) or, alternatively, by a 2-year FG (dashed black line). The increase in US public investment induces US firms to increase R&D accumulation (see Figure 3). The global labor-augmenting technology growth initially decreases, given that other countries reduce R&D (see below). Thereafter, it permanently increases. Instead, global technology growth already increases in the short run in the case of 2-year FG, because keeping constant the nominal policy rate favours a larger fall in the short-term real interest rate (not reported but available upon request). The latter fosters higher US investment in R&D on impact.

As reported in Figure 4, US GDP growth increases in the short run, in particular in the case of 2-year FG. The US spillovers are slightly negative and quantitatively similar irrespective of the US monetary stance. EA and RW GDP growth rates decrease because their households save to finance the additional US growth rate induced by the higher US public investment. Thus, consumption and investment growth rates (not reported to save on space) initially decrease, inducing a fall in their import growth rates (not reported). In the case of accommodative US monetary policy (i.e. the 2-year FG) the euro and the RW currency appreciate relatively more in real terms vis-à-vis the US dollar, implying a slightly negative price-competitiveness effect on the EA and RW exports (not reported). However, the latter increase as much as under standard US monetary policy, because the appreciation is counterbalanced by the higher US aggregate demand.[19]

Overall, we find that in the short run the mix of permanent increase in US public investment and monetary policy accommodation can counterbalance the negative macroeconomic effects of secular stagnation on the US economy, while the other regions experience small negative spillovers.

In the long run the global growth rate exhibits a larger value than in the (initial) secular-stagnation steady-state. Consistent with that, the global (and common across countries) interest rate increases. As reported in Table 7, the global growth rate increases to 2.1% (from 1.9%), the interest rate to 4.2% (from 4.0%).

[19]Results for CH and JP closely mimic those for the EA. They are available upon request.

4.3 Simultaneous increase in US, EA, JP, and CH public investment

Figures 3 and 4 also report the responses of the US, EA, RW variables when US, EA, JP, and CH simultaneously raise public investment by 1% of GDP.[20] RW public investment is instead constant at its baseline level.

Compared to the case in which the US is the only country to increase public investment (black lines), the increase in global public investment induces firms to increase R&D at a faster rate in the medium and long run (red lines). Thus, there is a larger permanent increase in the labor-augmenting technology (Figure 3).

The US experiences a slower pace of GDP growth in the short run, compared to the case in which it is the only region to expand public infrastructure spending (compare red and black lines in Figure 4, respectively). The result is due to lower global savings available to finance the US expansion. Thus, the US economy relies now more on its own savings, which translates into a stronger fall in US consumption growth in the short run (not reported) and a correspondingly lower inflation rate. The latter determines a smaller increase of the monetary policy rate in the short run. In the short run the US export growth (not reported) increases by more than in the case of a US-only expansion, favored by the increase in global demand, while US import growth (not reported) increases by less, because of the lower increase in US aggregate demand. Compared to the case in which public investment increases only in the US, EA GDP growth now rises more in the short run (see Figure 4). There is no negative short-run spillover on the growth rate of economic activity. In the short run the EA output growth benefits from the increase in global public investment. The implementation of FG in the regions where public investment is simultaneously raised (US, EA, JP and CH) enhances the expansionary short-term effects. Finally, the RW experiences a larger decrease in the very short-run growth rate (thus, a negative spillover), because it has to finance the other regions' expansion. The stronger world aggregate demand also determines on average higher global interest rates both in the short (except for the RW, not reported) and in the long run, due to the stronger global growth rate induced by higher R&D accumulation, activated by the global fiscal stimulus, (thus, R&D accumulation increases not only in the US but also in EA, CH, and JP.

[20]Results for CH and JP are similar to those for the EA. They are not reported to save on space and are available upon request.

As reported in Table 7, in the long run the global (including the RW) growth and interest rate permanently increase to 2.4% and 4.5% from 1.9% and 4.0%, respectively).

Overall, the simultaneous cross-country increase in public investment favors global activity both in the short and long run, because of the positive effects on R&D. Short-run economic activity in the countries implementing the fiscal measures further benefits from an accommodative global monetary policy stance. Our results do confirm, as advocated by Eggertsson et al. (2016), that cross-country coordination is key for favoring an exit from secular stagnation.

4.4 Welfare analysis

Welfare effects of the simulated scenarios are calculated as consumption equivalent, i.e., the constant percentage amount by which in each country the representative households' quarterly consumption in the secular stagnation balanced growth path must be adjusted upward or downward each quarter in perpetuity to make lifetime utility equal to that attained in the simulations featuring a public investment increase.[21]

Results are reported in Table 8. Compared to the secular stagnation balanced growth path, in the case of an increase in public investment in the US under standard monetary policy, each region has a welfare gain equal to around 8%. The gain is due to the permanently higher consumption growth rate in each region, which is made possible by the (permanently) higher global productivity growth, common to all regions and positively affected by the increase in worldwide R&D following the increase in US public consumption. Intuitively, the world economy moves to a balanced growth path which is steeper than the secular stagnation path. This benefits consumption and thus utility.

Welfare gains are larger in the case of a simultaneous increase in US, EA, CH, and JP public investment. The corresponding consumption equivalent is equal to 23%. The reason is

[21] The expected utility function of each region's representative household is given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\log \left(\left(C_t - b_c C_{t-1} \right) (1 + \Delta) \right) - \frac{1}{1+\zeta} L_t^{1+\zeta} \right), \tag{11}$$

where E_0 is the expectation operator at time 0, $0 < \beta < 1$ is the discount factor, $\zeta > 0$ is the inverse of the Frisch elasticity, C is consumption, and L is labor. The term $0 < b_c < 1$ measures external consumption habit and Δ is the corresponding consumption equivalent term. See Leith et al. (2012) for the computation of consumption equivalents in a New Keynesian model with external habit in consumption.

that the larger increase in public investment generates, through higher worldwide R&D, faster consumption growth in the new balanced growth path.

Finally, in both cases an accommodative stance of monetary policy favors further improvement in welfare, by counterbalancing the initial crowding-out effect of higher public investment on consumption. Welfare gains are, however, rather modest, because the immediate increase in public investment to the new long-run level induces a rather quick transition of the global economy to the new balanced growth path.

Overall, results suggest that the simulated policy measures do significantly improve global welfare.

5 Conclusions

This paper addresses the secular stagnation hypothesis from a global supply-side perspective. We show that unfavorable technology developments may have played a nontrivial role in the observed global growth slowdown. According to our results, secular stagnation can be effectively counterbalanced by coordinating global fiscal and monetary measures which encourage R&D accumulation. Further, cross-country coordinated measures provide a much larger welfare gain compared to a fiscal expansion implemented in only one country. The analysis can be extended in several directions. For example, one can consider global fiscal measures that directly address the shock that generates secular stagnation in this paper – R&D efficiency – such as tax breaks or subsidies. Alternatively, one can focus on other possible determinants of secular stagnation, like demographic factors. We leave these issues for future research.

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The World Bank (2018) Box 1.1. Long-term Growth Prospects: Downgraded No More? Global Economic Prospects 8.

Table 1: Great ratios (% of GDP)

	EA	US	CH	JP	RW
Private consumption	54.0	54.0	51.0	54.0	52.0
Private investment in physical capital	21.0	21.0	25.0	21.0	25.0
Private investment in R&D	1.8	1.8	0.9	1.8	−−
Public consumption	20.0	20.0	20.0	20.0	20.0
Public investment	3.0	3.0	3.0	3.0	3.0
Imports	15.0	13.0	22.0	18.0	13.0
Consumption goods	9.0	7.0	11.0	13.0	6.0
Investment goods	7.0	6.0	11.0	5.0	8.0
Share of world GDP	18.0	20.0	14.0	6.0	41.0

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 2: International linkages (% of GDP)

	EA	US	CH	JP	RW
Imported consumption goods from					
EA	...	1.3	1.7	1.1	1.7
US	1.9	...	2.0	1.3	1.4
CH	1.5	1.3	...	1.9	2.0
JP	0.5	0.4	1.3	...	0.5
RW	5.0	4.1	6.1	9.0	...
Imported investment goods from					
EA	...	1.0	1.6	0.4	2.4
US	1.4	...	1.9	0.5	1.9
CH	1.1	1.0	...	0.7	2.8
JP	0.4	0.4	1.3	...	0.6
RW	3.7	3.3	5.9	3.7	...

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 3: Households and firms behavior

	EA	US	CH	JP	RW
Households					
Subjective discount factor	0.995	0.995	0.995	0.995	0.995
Intertemporal elasticity of substitution	1.00	1.00	1.00	1.00	1.00
Habit persistence	0.60	0.60	0.60	0.60	0.60
Inverse of the Frisch elasticity of labor	2.00	2.00	2.00	2.00	2.00
Depreciation rate of capital	0.025	0.025	0.025	0.025	0.025
Depreciation rate of R&D	0.025	0.025	0.025	0.025	0.025
Final consumption goods					
Substitution btw domestic and imp. goods	2.50	2.50	2.50	2.50	2.50
Bias toward domestic goods	0.70	0.70	0.60	0.60	0.90
Substitution btw tradables and nontrad.	0.50	0.50	0.50	0.50	0.50
Bias toward tradable goods	0.50	0.50	0.50	0.50	0.50
Final investment goods					
Substitution btw domestic and imp. goods	2.50	2.50	2.50	2.50	2.50
Bias toward domestic goods	0.60	0.60	0.50	0.70	0.80
Substitution btw tradables and nontrad.	0.50	0.50	0.50	0.50	0.50
Bias toward tradable goods	0.90	0.90	0.90	0.90	0.90
Intermediate tradable goods					
Bias toward private capital	0.30	0.30	0.40	0.30	0.40
Bias toward public capital	0.10	0.10	0.10	0.10	0.10
Intermediate nontradable goods					
Bias toward private capital	0.30	0.30	0.30	0.30	0.30
Bias toward public capital	0.10	0.10	0.10	0.10	0.10
R&D technology					
Scaling parameter	0.75	0.75	0.75	0.75	–
Elasticity of trend to regional R&D	0.30	0.40	0.10	0.20	–
Contribution of firm R&D investment to trend	0.23	0.18	0.42	0.35	–

Note: EA=euro area; US=United States; CH=China; JP=Japan; RW=Rest of the world.

Table 4: Real and nominal rigidities

Real rigidities	
Investment adjustment	4.50
R&D Investment adjustment	4.50
Nominal Rigidities	
Households	
Wage stickiness	600
Manufacturing	
Price stickiness (domestically produced goods)	600
Price stickiness (imported goods)	6
Services	
Price stickiness	600

Note: in each region the corresponding parameter is set equal to the reported value.

Table 5: Gross price and wage markups

Manufacturing (tradables) price markup	1.20
Services (nontradables) price markup	1.30
Wage markup	1.20

Note: in each region the corresponding parameter is set equal to the reported value.

Table 6: Monetary policy rule

Interest rate inertia	0.87
Interest rate response to inflation gap	1.70
Interest rate response to output growth	0.10

Note: in each region the corresponding parameter is set equal to the reported value.

Table 7: Global fiscal stimulus

	gr	R
(1): Initial steady state	2.8	4.9
(2): Secular stagnation	1.9	4.0
difference (2)-(1)	-0.9	-0.9
(3): (2) + US pub. inv.	2.1	4.2
difference (3)-(2)	0.2	0.2
(4): (2) + global pub. inv.	2.4	4.5
difference (4)-(2)	0.5	0.5

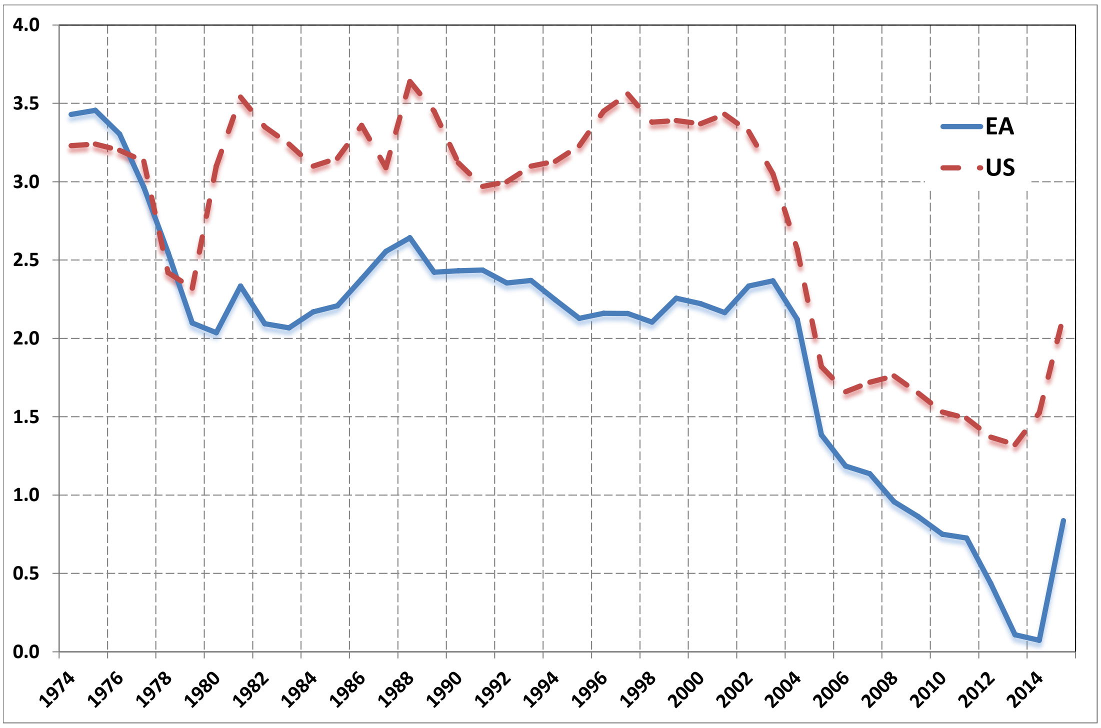
Note: gr is the long-run global growth rate, in annualized p.p.. Real interest rate (R) is in level (annualized p.p.).

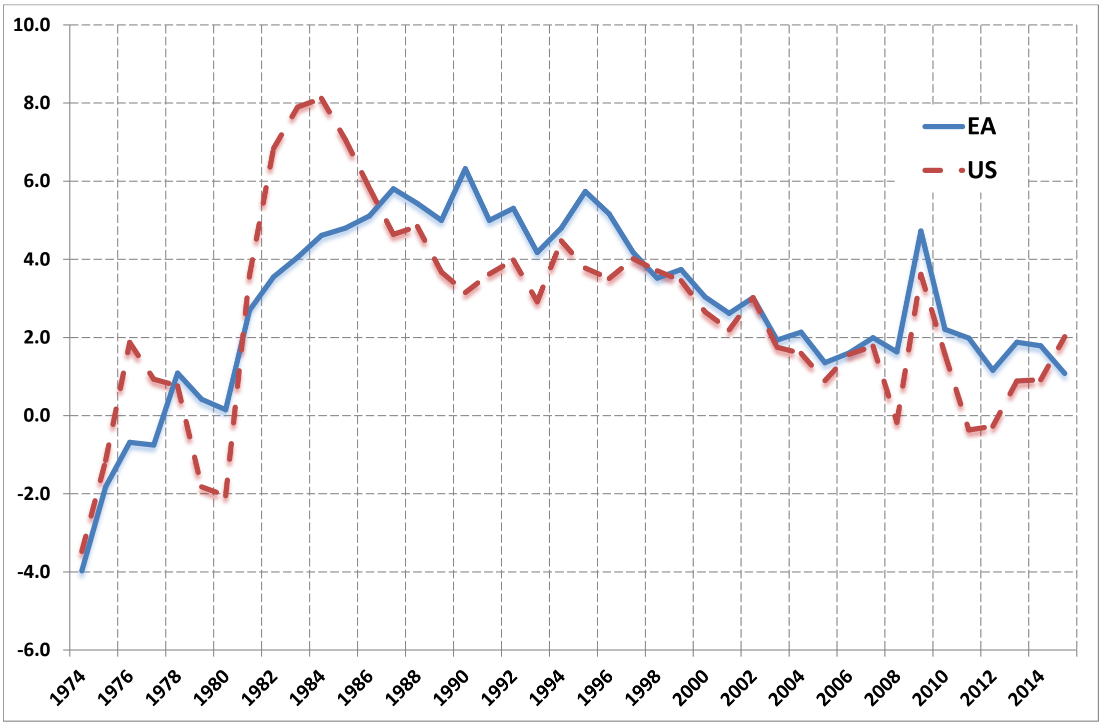
Table 8: Utility-based welfare analysis

	US pub. inv.	Global pub. inv.	US pub. inv. US FG	Global pub. inv. Global FG
US	8.93	22.76	8.93	22.81
EA	8.13	22.74	8.18	22.79
CH	8.08	22.37	8.13	22.42
JP	8.12	22.81	8.16	22.86
RW	10.25	24.15	10.30	24.22

Note: US=United States; EA=euro area; CH=China; JP=Japan; RW=Rest of the world. The welfare is expressed in % steady-state consumption equivalent, computed with respect to the secular stagnation balanced growth path. A positive value indicates a gain. FG: the monetary policy rate is kept constant in the initial two years of the simulation.

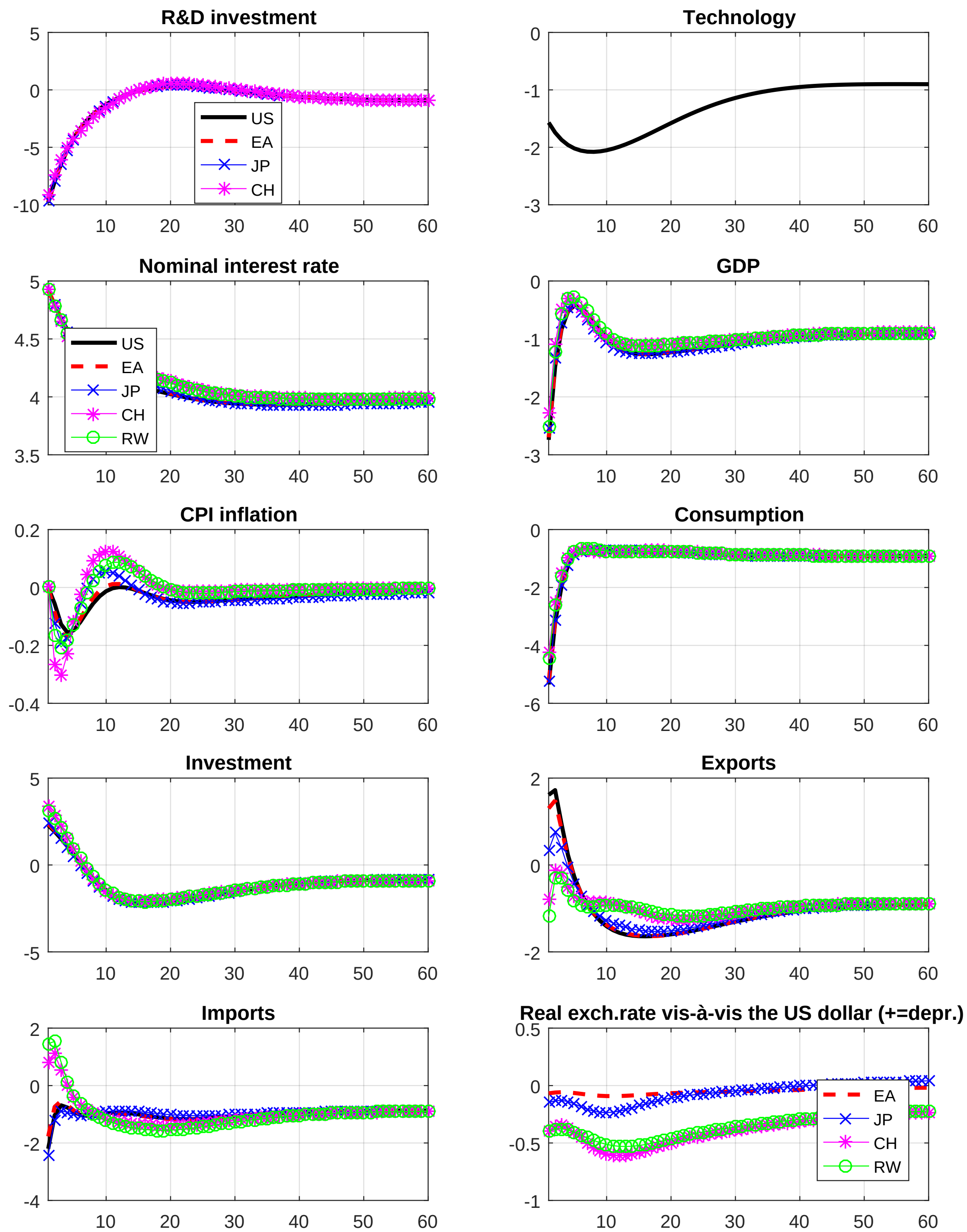
Figure 1: Secular stagnation. EA and US GDP and real interest rates





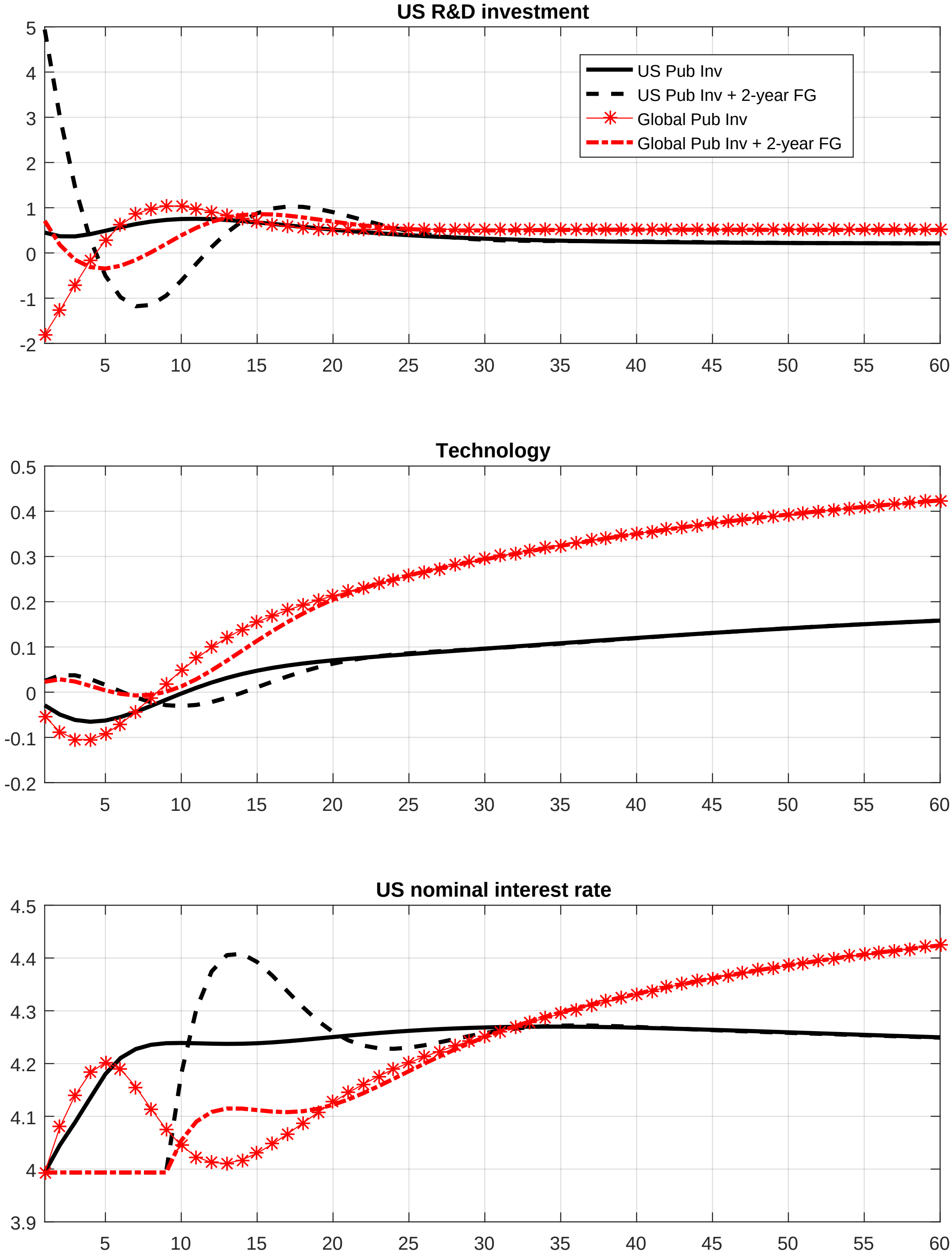
Note. GDP in real terms. Ten-year centered moving averages of annual growth rates, % points. Interest rates on ten-year government bonds, % points. Sources: St. Louis Fed FRED and Area Wide Model Dataset. EA= euro area; US= United States.

Figure 2: Secular stagnation. Technology and global variables



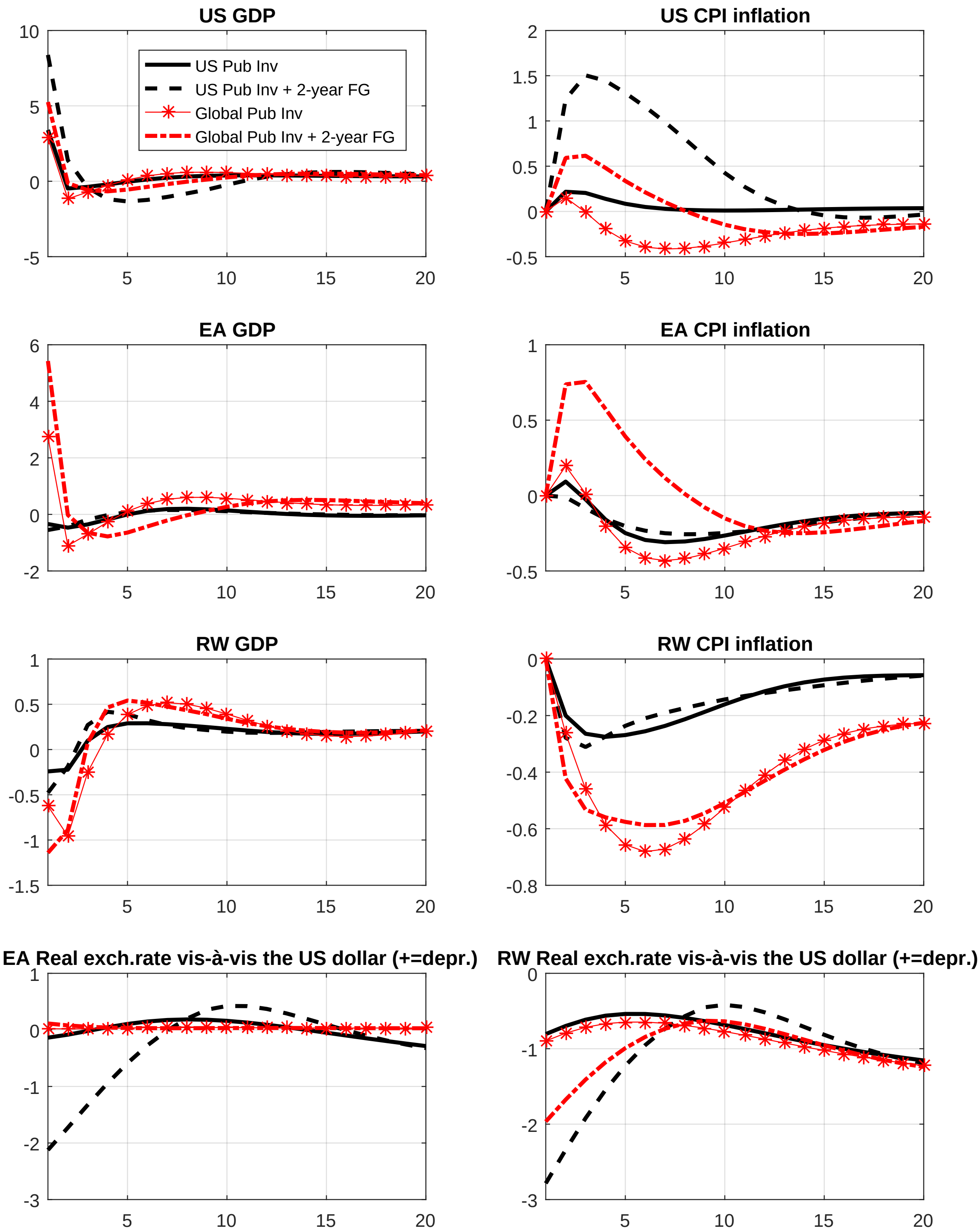
Note. Horizontal axis: quarters; vertical axis: R&D investment, labor-augmenting technology, real GDP and its components are reported in growth rates, annualized p.p. deviations from the pre-secular-stagnation steady state; nominal interest rate as annualized p.p.; CPI inflation as annualized p.p. deviations; real exchange rate as % deviations.

Figure 3: Secular stagnation, public inv. and monetary stance. US variables



Note. Horizontal axis: quarters; vertical axis: R&D investment and labor-augmenting technology growth rates reported as annualized p.p. deviations from the secular-stagnation steady state; nominal interest rate as annualized p.p..

Figure 4: Secular stagnation, public inv. and monetary stance. Global variables



Note. Horizontal axis: quarters; vertical axis: real GDP and its components' growth rates as annualized p.p. deviations from the secular-stagnation steady state; CPI inflation as annualized p.p. deviations; real exchange rate as % deviations.