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An Analysis of the Effectiveness of Japanese Monetary Policy Through a Statistical Mathematical Approach: a Simultaneous Equations Model (SEM)

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Abstract

In this paper, the authors offer a policy analysis about the problem of the effectiveness of the Japanese monetary policy in contrasting the last three main crises that the country has experienced from the 1990s to today: that of the Lost decade, that of 2008 and that caused by the pandemic of COVID-19. To this end, they present a small equilibrium model consisting of a system of simultaneous equations (SEM) identified by solving the consumption optimization problem of the representative household and the profit optimization problem of the representative firm. The SEM was estimated using the three-stage least squares method (3SLS) quarterly historical series, at constant prices, in the sample period Q1 1994 - Q2 2020. The result achieved by the authors is that the monetary policy has been inadequate to stimulate the per capita GDP growth rate, the private consumption, the investment, the actual inflation and the expected inflation.

JEL classification numbers: C30, C40, C51, C60, E51.
Keywords: Mathematical and statistical methods, Mathematical applications for Economics, Japanese monetary policy, Quantitative easing, Simultaneous equations model.

1. Introduction

Since 1991, Japan has experienced three main economic crises: that of the Lost decade, that of 2008 and that due to the Covid-19 pandemic. The issue of the adequacy of the interventions of political decision-makers to contrast these crises,

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in particular of the monetary policy, have long been at the center of the academic debate.

The first criticisms of Japanese monetary policy were advanced, in fact, starting from the end of the 90s, precisely in reference to the measures adopted by the Bank of Japan (BOJ) to respond to the crisis of the Lost decade. In this period, in fact, an interesting debate which sees Bernanke, Blanchard, Krugman and Ueda as the main protagonists developed.

Bernanke (1999) analyzing the Call rate, the Prime short-term and long term rate and the percentage change in the monetary base, argues that between 1991 and 1994, the period in which the real estate and equity bubble that triggered the recession burst, the BOJ would have been more restrictive than was appropriate.

Ueda (1999) suggests that the BOJ should have strengthened monetary stimulus by purchasing commercial paper, corporate bonds and asset-backed securities under repurchase agreements or, alternatively, by accepting such assets as collateral for its financing operations.

Blanchard (2000) addresses the problem raised previously by Krugman (1998), namely how to influence the market expectations and how to increase the inflation at the Zero Lower Bound (ZLB). The solution that he proposes to the Japanese central bank consists in giving up setting an inflation target and in increasing the high powered money by about 20% and in not committing not to reduce this monetary aggregate in the future through contractionary market operations.

Interesting is, also, the contribution of Shioji (2003), who analyzes the reduction of the monetary multiplier and identifies the cause in the worsening of the soundness of commercial banks and in the Zero Interest Rate Policy (ZIRP).

Leigh (2009), on the other hand, proposes an alternative view to that of all the authors cited above. In fact, in one of his contributions he denies, through the estimation of a structural model, the thesis according to which the responsibility for the bursting of the bubble in the early 90s should be attributed to the errors committed by the BOJ and explains that, instead, this phenomenon was caused by a series of adverse shocks that occurred during that period.

Since 2013, the criticisms have focused on the monetary policy conducted under Abenomics, the program designed to boost the Japanese economy after the 2008 crisis and divided into "three arrows": expansionary fiscal policy, expansionary monetary policy (QQE and NIRP) and structural reforms.

De Michelis and Iacovello (2016) demonstrate, through a new-Keynesian DSGE model, that some progress has been made in combating deflation with Abenomics, although the achievement of the 2% inflation target remains far off.

Młodawska-Bronowska (2019) finds that Abenomics has only led to an increase in the monetary base and not a recovery in the inflation.

Koeda (2019) uses the SVAR methodology to estimate the effect of the Quantitative and Qualitative Easing (QQE) by checking for the Effective Lower Bound (ELB) on the nominal interest rate and discovers that, since 2013, this monetary stimulus has proved useful in simultaneously increasing the GDP and the inflation.

Ferrentino and Vota (2019) also utilize a SVAR model to study the effectiveness of

Abenomics between 2013 and 2016 and they find that the monetary impulses, unlike fiscal ones, have given unsatisfactory results.

Fukuda (2018) states that, unlike Quantitative and qualitative easing (QQE), the Negative Interest Rate Policy (NIRP) has damaged the Japanese economy because it has induced many domestic investors to transfer their capital to other Asian countries, benefiting mainly the stock market.

Kondo et al. (2020) study the impact of Abenomics on the national stock market focusing on the demanded quantity of securities, while that on prices had already been previously analyzed by Fukuda (2015). They arrive at three main results: the first is that, at the beginning of Abenomics, there was a consistent increase in the quantity of shares demanded only by foreign investors, the second is that, in the two years following the start of Abenomics, the change in foreign investment in Japan depended mainly on foreign factors and not in domestic ones, the third is that Abenomics have had an impact on the expectations of foreign investors only until 2014.

The literature produced on the effectiveness of the forward guidance of the BOJ, deserves particular attention and it should be assessed considering that the country is close to the zero lower bound (ZLB).

Japan adopted the forward guidance at the ZLB for the first time in 1999, namely during the period of the ZIRP and strengthened it since 2013 just through the NIRP. The economists of the national government and of the Bank of Japan (BOJ) have often spoken out favorably on forward guidance. Many independent scholars, instead, oppose to this view and show greater caution (and in some cases even skepticism). The contributions of these scholars, in most cases, evaluate the Japanese forward guidance precisely at zero lower bound (ZLB) and model the process of forming operators' expectations formulating appropriate hypotheses about the rationality of the latter and about the structure of the shocks at the natural interest rate.

Katagiri (2016), an authoritative member of the BOJ board, present the results of a quantitative analysis carried out through a non-linear new Keynesian model and explain that the Japanese forward guidance is able to influence the formation process of the agents' inflation expectations and, therefore, it is suitable to cope with the deflation and the reduction of the GDP growth rate.

Levin et al. (2010) conduct a study on the major global economies (including also Japan) using a new Keynesian model. The conclusion of the study of these researchers is that the effectiveness of the forward guidance should be assessed considering the elasticity of the demand at the interest rate, but that in general it depends on the size and on the persistence of the shocks: it is useful in the case of a small persistent shock of the natural interest rate, instead it is not useful in the case of large and very persistent shock of the natural interest rate.

Filardo and Hofmann (2014) perform an analysis on the forward guidance at the ZLB for United Kingdom, for euro area, for USA and for Japan and, regarding the latter, they concentrate on the forward guidance implemented in October 2010 in the context of Comprehensive monetary easing (CME), and on the forward

guidance of 2013. They conclude that in the first case the effect on future interest rates was very small, while in the second case it was almost null, although the 10-years bond yield has significantly decreased.
Particularly interesting, in the Filardo's and Hofmann's research, are the estimations of the volatility of the short term expected interest rate at the ZLB in the periods in that the forward guidance is explicit and also the estimations of the realized volatility of the short term expected interest rate at the ZLB in the periods in that forward guidance is not operative (or anyway not explicitly conducted). What can be noted in Filardo's and Hofmann's paper is that among all the economies considered, the Japanese one is the only one in which the two estimated values are almost coincident both over a one-year time horizon, both over a two-year time horizon, and both over a five-year time horizon. This result puts further into question the usefulness of the Japanese forward guidance. In any case, the two authors admit the objective difficulty in expressing an exhaustive evaluation of the forward guidance because, in the two periods, the announcements on the BOJ's interest rates overlapped those relating to the securities purchase programs.
As can be deduced from this brief review, the judgments on the outcomes of the monetary policy in the last thirty years have been, almost unanimously, negative.
In effect, even through a simple empirical analysis, it can be easily understood that all the interventions implemented in this period have not allowed the country to leave its state of low growth and low inflation.
To this end, the underlying [Figure 1] shows the real GDP growth rate and the inflation rate at the Consumer Price Index (CPI) from the second quarter of 1994 to the first quarter of 2020:

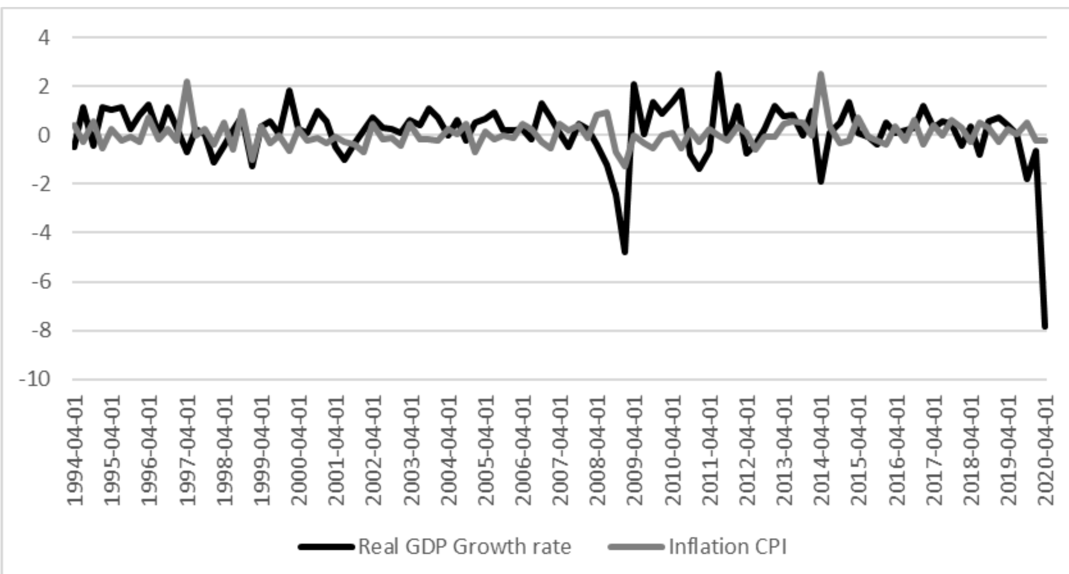

Figure 1. Real GDP growth rate and CPI inflation. Source: author's elaboration on FRED quarterly data.

As may be seen, the real GDP growth rate shows an appreciable acceleration at the end of the 90s, a W-shaped trend between 2007 and 2013 and a sharp fall in the first quarter of 2020, while it stagnates in the remaining periods.
The inflation generally remains around zero, alternating small positive variations with small negative variations. It is important to note that it reaches the target of 2% only in the second quarter of 1997 and in the second quarter of 2014, while it collapses after the third quarter of 2014, when there is an increase in the consuption tax rate from 5% to 8%.
In the graph above, however, it is difficult to identify clear trend lines due to the high variability of the data. To remedy to this problem, the compound quarterly growth rate of real GDP and the compound quarterly growth rate of the CPI (inflation) were calculated in the same previous sample period. These measures clean up the two variables of their respective volatilities, offering a better representation, just like in the following [Figure 2]:

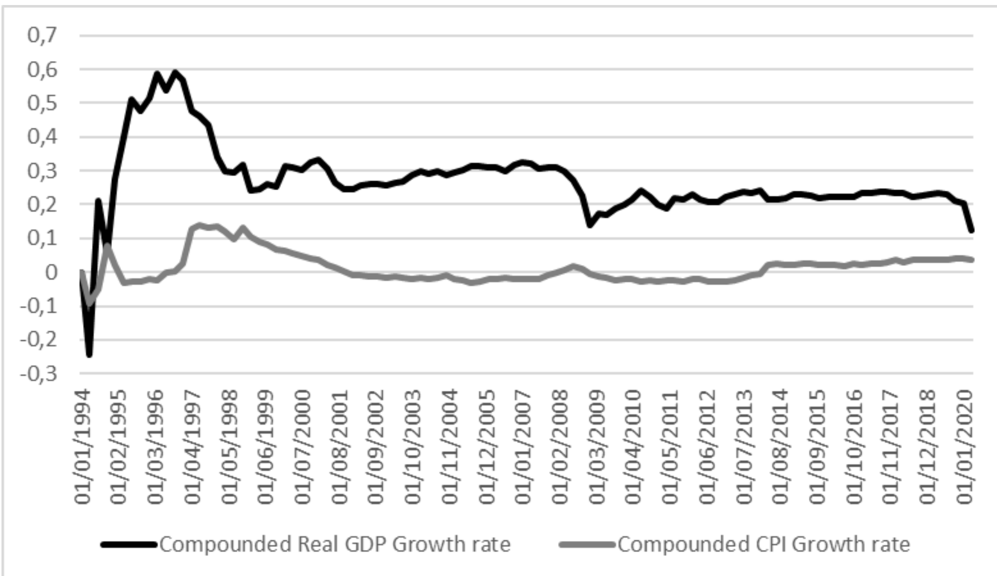

Figure 2. Real GDP compounded growth rate and Compounded CPI growth rate. Source: author's elaboration on FRED quarterly data.

From this second figure, it is clear that both the real GDP growth rate and the inflation become stagnant between the end of the 90s and the early 2000s.
Understanding the causes of the failure of Japanese monetary policy initiatives is a difficult challenge, that requires an appropriate quantitative approach and a careful ability to analyze the results.

2. Research aims

The aim of this paper is to offer a policy analysis about a very controversial and debated issue, namely the effectiveness of the Japanese monetary policy, defined, in this manuscript, as the ability of the conventional and of the unconventional operations to influence the real per capita GDP growth rate, the actual inflation and the expected inflation, in the period between the beginning of the Lost Decade crisis and the crisis due to the Covid-19 pandemic.

For this purpose, the authors present a small equilibrium model consisting of a system of simultaneous equations whose solution is identified by solving the profit optimization problem of the firm and the consumption optimization problem of the household.

The small equilibrium models, such as the one presented in this paper and as Christiano, Eichenbaum and Trabandt (2018) pointed out, have the merit of emphasizing different subsets of the economy. The subset on which the authors focus their attention is the capital goods market.

The intuition behind the small equilibrium model presented by the authors is that the monetary policy can affect the real per capita GDP growth rate thanks to the reduction in the investment cost. In fact, a reduction in the reference rate set by the central bank (the basic discount and loan rate in the Japanese case) and an increase in the money supply should encourage the access of private firms to the credit market and incentivise the government to increase investments. In other words, monetary policy can stimulate the physical capital accumulation process and, consequently, the real GDP growth rate.

The choice of a model of simultaneous equations (*Structural Equation Models or SEM*) is due to the fact that these models are now widely applied in many fields of the social sciences. In particular, in the macroeconomics, SEMs are frequently used both for positive analysis purposes and, as in this case, for normative analysis purposes and, over time, they have become increasingly advanced tools, thanks to the development of identification and estimation strategies.

These models represent, in fact, a multivariate statistical analysis technique that allows to verify hypotheses about the influence of a set of variables on others and, therefore, they allow to explain complex phenomena using a limited number of indicators.

The idea behind the structural equation models is to define the causal connections existing between a set of variables, starting from the detection of some directly observable variables, usually defined as "known variables" or "indicators".

After describing their theoretical model, the authors also present its estimation, carried out with the three-stage least squares method (3SLS), using quarterly historical data, in the sample period Q1 1994 - Q2 2020 and at constant prices.

The result they reach, is that the monetary policy has not proved useful in achieving the optimal per capita investment level for the Japanese economy and that its impact on the per capita consumption, on the actual inflation and on the expected inflation, has been very unsatisfactory.

The main innovation of this manuscript consists, in fact, in demonstrating that the monetary policy is ineffective in favoring the real per capita GDP growth rate, the private consumption, the investment, the actual inflation and the inflation expectations. The obtained results offer a critical view of the Bank of Japan's work and allow the formulation of some important economic policy prescriptions.
The paper is organized as follows. In the section 1, an introduction about the topic of the manuscript has been inserted, while, in the section 2, the research aims are illustrated and the main results are summarized. In the section 3, the small equilibrium model is presented and in the section 4, the SEM representing the small equilibrium model is estimated. Finally, in the section 5, the conclusions are drawn and an economic policy proposal, based on the results of the estimated model, is brought forward. The last part contains a detailed bibliography.

3. The theoretical model

In this section, the authors present their theoretical model, obtained by imposing an equilibrium condition and formulating appropriate hypotheses regarding the production function, the cost of physical capital, the physical capital accumulation process, the utility function of the household, the expected inflation and the actual inflation. In this regard, the authors consider the following Cobb-Douglas production function of the representative firm:

$$y_t = A_t k_t^{1-\alpha} \tag{1}$$

with:

$$A_t = A\, e^{\lambda t} \tag{2}$$

and where y_t is the real GDP per capita, A_t is the total factor productivity, k_t is the per capita physical capital at constant prices and $\alpha, \lambda > 0$ are constants. This particular specification for Japan has already been used in previous contributions (Tonogi, 2017; Lin, 2002).
The per capita physical capital accumulation process is described by the following relationship:

$$k_{t+1} = I_t^{PC} + (1-\delta)k_t \tag{3}$$

where $I_t^{PC} = k_t - k_{t-1}$ is the current per capita investment at constant prices and δ is the depreciation rate of physical capital between time $t-1$ and time t.

The authors assume also that the demand function and the supply function of physical capital have the following expressions:

$$S_t = p_t + \eta_1 r_t^{CB} - \eta_2 M_{3,t} + \eta_3 G_t + \eta_4 D_t + \eta_5 b_t + \varepsilon_t^b \qquad (4)$$

$$I_t^T = \psi_1 M_{3,t} - \psi_2 r_t^{CB} - \psi_3 G_t - \psi_4 D_t - p_t - \psi_5 b_t + \varepsilon_t^b \qquad (5)$$

where I_t^T is the aggregate investment (demand for physical capital at current time), K_t is the physical capital (physical capital supply at current time), r_t^{CB} is the basic discount and loan rate set by the Bank of Japan, $M_{3,t}$ is the monetary base, p_t is the physical capital price, G_t is the government expenditure, D_t is the government debt and b_t is the interbank call money market rate. The latter variable measures the cost at which it is possible to get physical capital (borrow money for investments) from the credit market (banks) and, at the same time, the remuneration that the credit market obtains by lending money with which investments are financed.
The coefficients η_3, η_4, ψ_3 and ψ_4 capture the effect of the crowding out on the physical capital supply and on the physical capital demand.
Let p_t^* be the equilibrium price of the physical capital market, namely the one that guarantees the market clearing condition:

$$I_t^{T^*} = S_t^* \qquad (6)$$

Through the (1), the (2), and the (6), it is possible to set up and solve the optimization problem of the profit of the firm:

$$max \sum_{t=0}^{\infty} \Pi_t \left(1 - \tau_t^{\Pi}\right) = \sum_{t=0}^{\infty} \left[A\, e^{\lambda t} k_t^{1-\alpha}\left(1 - \tau_t^{y}\right) - p_t k_t - w_t\right]$$

where Π_t is the per capita profit of the representative firm at constant prices, τ_t^{Π} is the corporate profit tax rate, τ_t^{y} represents the share of the per capita income that is absorbed by taxation, $p_t k_t$ is the total cost of physical capital at constant prices and w_t is the real wage.
From the solution of the previous problem it follows that the value of k_t that maximizes $\Pi_t(1 - \tau_t^{\Pi})$ is the following:

$$k_t^D = \left[\frac{p_t}{A\, e^{\lambda t}\, (1-\alpha)\left(1-\tau_t^{y}\right)}\right]^{-\frac{1}{\alpha}} \qquad (7)$$

namely, k_t^D is just the amount of physical capital demanded by the representative firm.

To identify the equilibrium physical capital, on the other hand, it is necessary to set up and solve the household optimization problem, namely the per capita consumption optimization problem:

$$max\sum_{t=0}^{\infty} U(c_t) = \sum_{t=0}^{\infty} \ln\left[A\, e^{ht} k_t^{1-\alpha}\left(1-\tau_t^y\right) - (1-\delta)k_t - I_t^{PC} + g_t + m_{1,t}\right]$$

obtained by assuming, as already done previously by other authors (Khan et al., 2015), that the household has a logarithmic utility function $\left(U(c_t)\right)$. The per capita consumption at constant prices of the representative household c_t is given by:

$$c_t(1-\tau_t^c) = y_t\left(1-\tau_t^y\right) - s_t + g_t + m_{1,t}$$

where τ_t^c is the consumption tax rate, τ_t^y is the share of the per capita national income of the household that is absorbed by taxation, s_t is the per capita saving at constant prices, g_t is the per capita government expenditure at constant prices and $m_{1,t}$ is the M_1 monetary aggregate per capita and at constant prices and, in this function, it represents the fraction of primary liquidity held by the household.
Since $s_t = k_{t+1}$, for the (3) the previous expression becomes:

$$c_t(1-\tau_t^c) = A\, e^{ht} k_t^{1-\alpha}\left(1-\tau_t^y\right) - (1-\delta)k_t - I_t^{PC} + g_t + m_{1,t}$$

From the solution of the previous optimization problem, it follows that the value of k_t that maximizes the per capita consumption at time t is the following:

$$k_t^S = \left[\frac{\delta}{A\, e^{\lambda t}(1-\alpha)\left(1-\tau_t^y\right)}\right]^{-\frac{1}{\alpha}} \qquad (8)$$

that is, k_t^S is just the quantity of per capita physical capital supplied by the household.
By equating k_t^D and k_t^S and by assuming that the (6) is satisfied, it is obtained the equilibrium value of the physical capital market:

$$k_t^* = p_t^* = \delta$$

The (8) indicates that, in equilibrium, the price of physical capital is such that the quantity of physical capital exchanged on the market (namely that the firms buy from the households to make their investments) is exactly equal to that which is amortized in the previous period.
Intuitively, in fact, in equilibrium, the only investment, that is made, is that of replacement.

4. The system of simultaneous equations: identification and estimate

The model presented in the previous paragraph, may be estimated through a simultaneous equations model (SEM) to which an equation for actual inflation and an equation representing the process of inflation expectations formation are added. The main steps in SEM include specifying the model, identifying the model and estimating the parameters.

The constitutive unit of structural equation models is the structural equation, namely a regression equation that expresses the causal relationship existing between a dependent variable and several independent variables, while the causal links between the variables are formalized, as a whole, through a system of equations.

Consider, therefore, the following system of simultaneous equations that describes the theoretical model exposed in the previous paragraph:

$$\dot{y} = A\lambda + (1-\alpha)\dot{k} + \varepsilon_t^y \tag{9}$$

$$k_t = I_{t-1}^{PC} + (1-\delta)k_{t-1} + \varepsilon_t^k \tag{10}$$

$$c_t^d = c_1 y_t^d - c_2 s_t + c_3 g_t + c_4 m_{1,t} + \varepsilon_t^c \tag{11}$$

$$\Pi_t^d = \varphi_1 y_t^d - \varphi_2 p_t k_t - \varphi_3 w_t + \varepsilon_t^\Pi \tag{12}$$

$$p_t = p_0 - \chi_1 M_{3,t} + \chi_2 r_t^{CB} + \chi_3 G_t + \chi_4 D_t + \chi_5 (I_t^T - S_t) + \chi_6 b_t + \varepsilon_t^D \tag{13}$$

$$\pi_t = \zeta_1 \tilde{Y}_{t-1} + \zeta_2 \mu_{t-1} + \zeta_3 Y_{t-1} + \zeta_4 r_{t-1}^{CB} + \varepsilon_t^\pi \tag{14}$$

$$\pi_t^e = \rho_1 \pi_{t-1} + \rho_2(\pi_t - \pi_{t-1}^e) + \rho_3 d_t^P + \rho_4 d_t^{IT} + \rho_5 r_t^{CB} + \rho_6 M_{1,t} + \varepsilon_t^e \tag{15}$$

where: $\dot{y}$ is the GDP per capita growth rate, $\dot{k}$ is the capital per capita growth rate, $c_t^d = c_t(1-\tau_t^C)$ is the after tax per capita consumption of the household, $y_t^d = y_t\left(1-\tau_t^y\right)$ is the disposable income of the household, π_t is the actual inflation, $\tilde{Y}_{t-1}$ is the output gap, μ_{t-1} is the monetary base growth rate, Y_{t-1} is the national income, π_t^e is the expected inflation, $\pi_t - \pi_{t-1}^e$ is the forecast error made by the operators between the time $t-1$ and the time t, d_t^P is a dummy variable that takes value 1 in periods in which extraordinary monetary policy operations are active, d_t^{IT} is a dummy variable that takes value 1 in periods in which the central bank sets an inflation target and ε_t^y, ε_t^k, ε_t^c, ε_t^Π, ε_t^K, ε_t^I, ε_t^π, ε_t^e are error terms.

The equation (9) is the logarithm of the per capita GDP growth rate.

The equation (13) was obtained by solving the system formed by the equation (4) and the equation (5). It is used to test the hypothesis that the capital goods market is in equilibrium ($I_t^T = S_t$). More precisely, a value of the coefficient χ_5 equal to zero, indicates that the market clearing condition of the capital goods market is satisfied. Still on the second member of the (13), the term p_0 represents the frictionality of the capital goods market, while the coefficients χ_3 and χ_4 represent

the effect of the crowding out on the price of the physical capital.
For the actual inflation (equation (14)), the empirical model of Assenmacher-Wesche, Gerlach and Sekine (2008), just proposed for Japan, was used. More precisely, the equation (14) is the reduced form model of Assenmacher-Wesche, Gerlach and Sekine, namely that one obtained by directly putting r_t^{CB} in equation (4) of their paper and omitting equations (5) and (6) of their paper.
The three economists argue that μ_{t-1}, Y_{t-1} and r_{t-1}^{CB} determine the short-term fluctuations of the actual inflation rate around the steady state (low frequency movements), while the long-period oscillations (high frequency movements) depend on $\tilde{Y}_{t-1}$. A current-time monetary policy shock (ε_t^{π}) can involve either a high frequency movement or a low frequency movement.
To estimate this SEM, the three-stage least squares method (3SLS) was used because it, compared to the two-stage least squares estimator (2SLS), is more efficient and takes into account the correlation between the error terms of the equations .
The authors describe, then, the SEM identification strategy.
The following nine variables are used as instrumental variables: I_{t-1}^{PC}, r_t^{CB}, r_t^{B}, Y_{t-1}, r_{t-1}^{CB}, r_{t-1}^{B}, μ_{t-1}, $\tilde{Y}_{t-1}$, π_{t-1}, while all the other variables are endogenous.
The reason why r_t^{CB} and r_t^{B} are considered as exogenous variables, is that their respective values are determined by the decisions of policy makers.
More precisely, the BOJ directly set r_t^{CB} and, indirectly, also r_t^{B}, because the yield of the government bonds depends on its rate decisions and on the QQE (Oda and Ueda, 2005; Akram and Das, 2014).
The one period lagged variables $I_{t-1}^{PC}, Y_{t-1}, r_{t-1}^{CB}, r_{t-1}^{B}, \mu_{t-1}, \tilde{Y}_{t-1}$ e π_{t-1} are predetermined and therefore may be treated, at least asymptotically, as exogenous.
It may easily be verified that for each equation of the system holds:

$$N - n \geq z - 1$$

where N is the total number of instrumental variables, n is the number of instrumental variables in the generic equation and z is the number of endogenous variables in the generic equation.
Each SEM equation is, therefore, identified.
The model is estimated using quarterly historical data, in the sample period Q1 1994 - Q2 2020. The actual inflation was calculated with respect to the Consumer Price Index (CPI), while break even inflation, namely the difference between the nominal rate of return and the real rate of return of the 10-year government bond, was chosen as a measure of the actual inflation.

The reason of this choice is that Kamada and Nakajima (2014) have constructed a particular measure of expected inflation based on the Purchasing power parity (PPP) for Japan and have found that, in the long run, it just coincides with the break even inflation.
The output gap was estimated using the Hodrick-Prescott filter with a smoothing parameter equal to 1600.
The dummy variable d_t^P takes value 1 in the periods in which Quantitative easing (Q1 2001 - Q1 2006), Comprehensive monetary easing (Q1 2010 - Q4 2012) and Quantitative and qualitative easing (Q1 2013 - Q2 2020) are effective.
The dummy variable d_t^{IT} takes value 1 in the periods in which the Bank of Japan has explicitly set an inflation target (Q1 2012 - Q2 2020).
As a proxy for r_t^B, the 10 years government bond yield was used.
As proxies for the price of the physical capital factor and for the labor factor, the producer price index of capital goods and the Total Labor Compensation for unit of labor input, respectively, were used.
All other variables are expressed in billions of yen and are at constant prices.
Since all variables are integrated of order 1, $(I(1))$, the model was estimated using their respective first differences.
The estimation output is shown below in Table 1:

Table 1: Estimation of the coefficients of the SEM.

Equation 9 Dependent variable: $\dot{y}$				
Coefficient	**Estimated value**	**Standard error**	**z.**	**p-value**
$\hat{\beta}_0$	0,302757	0,102474	2,954	0,0032 ***
$\hat{\beta}_1$	0,405263	0,225249	1,799	0,0720 *
Equation 10 Dependent variable: k_t				
Coefficient	**Estimated value**	**Standard error**	**z.**	**p-value**
$\hat{\gamma}_1$	0,0109072	0,0110810	0,9843	0,3250
$\hat{\gamma}_2$	0,957357	0,0424820	22,54	1,86e-112 ***
Equation 11 Dependent variable: c_t^d				
Coefficient	**Estimated value**	**Standard error**	**z.**	**p-value**
$\hat{c}_1$	0,361405	0,0199001	18,16	1,05e-073 ***
$\hat{c}_2$	0,0276497	0,0528286	0,5234	0,6007
$\hat{c}_3$	0,00132984	0,000100622	13,22	7,07e-040 ***
$\hat{c}_4$	−4,68384e-05	3,23274e-06	−14,49	1,43e-047 ***
Equation 12 Dependent variable: Π_t^d				
Coefficient	**Estimated value**	**Standard error**	**z.**	**p-value**
$\hat{\varphi}_1$	0,0296389	0,0103142	2,874	0,0041 ***
$\hat{\varphi}_2$	0,000389820	0,00126382	0,3084	0,7577
$\hat{\varphi}_3$	407,319	1098,66	0,3707	0,7108

Equation 13 Dependent variable: p_t				
Coefficient	**Estimated value**	**Standard error**	**z.**	**p-value**
$\hat{p}_0$	37,9715	43,9517	0,8639	0,3876
$\hat{\chi}_1$	2,72224e-08	6,48994e-09	4,195	2,73e-05 ***
$\hat{\chi}_2$	8,56273	2,04990	4,177	2,95e-05 ***
$\hat{\chi}_3$	1,04857e-06	6,18813e-07	1,694	0,0902 *
$\hat{\chi}_4$	−1,00477e-05	2,22584e-06	-4,514	6,36e-06 ***
$\hat{\chi}_5$	0,000145523	5,51478e-05	2,639	0,0083 ***
$\hat{\chi}_6$	13,0763	3,85599	3,391	0,0007 ***
Equation 14 Dependent variable: π_t				
Coefficient	**Estimated value**	**Standard error**	**z.**	**p-value**
$\hat{\zeta}_1$	2,53147e-05	5,92552e-06	4,272	1,94e-05 ***
$\hat{\zeta}_2$	0,0328951	0,0226872	1,450	0,1471
$\hat{\zeta}_3$	−1,23630e-07	1,57723e-07	−0,7838	0,4331
$\hat{\zeta}_4$	0,113435	0,108237	1,048	0,2946
Equation 15 Dependent variable: π_t^e				
Coefficient	**Estimated value**	**Standard error**	**z.**	**p-value**
$\hat{\rho}_1$	−0,00141667	0,00505217	−0,2804	0,7792
$\hat{\rho}_2$	0,00915435	0,0108106	0,8468	0,3971
$\hat{\rho}_3$	−0,0352164	0,0164155	−2,145	0,0319 **
$\hat{\rho}_4$	−0,0519546	0,0101178	−5,135	2,82e-07 ***
$\hat{\rho}_5$	0,0206736	0,00916066	2,257	0,0240 **
$\hat{\rho}_6$	1,18039e-010	2,79381e-011	4,225	2,39e-05 ***

In the next section, the estimation results are discussed.

5. Discussion of the results

In the equation (9), the coefficients $\hat{\beta}_0$ and $\hat{\beta}_1$ indicate that, between the first quarter of 1994 and the second quarter of 2020, the main driver of the Japan's (low) per capita GDP growth was the technological progress, while the evidence that there has been a contribution from the physical capital accumulation process is weak ($\hat{\beta}_1$, in fact, is low statistically significant).

In equation (10), the non-significance of $\hat{\gamma}_1$ and the value of $\hat{\gamma}_2$ suggest that the optimal level of the per capita investments (both public and private) is higher than the current one, namely that the investments made between 1994 and 2020 were not, on average, sufficient even to offset the depreciation (equal to 4.26% in each quarter) of the per capita physical capital. This result is consistent with the fact that both the endowment of the per capita physical capital at constant prices and the per capita investment at constant prices fell steadily between the fourth quarter of 1996 and the first quarter of 2010 and started to grow again (at modest rates) only between the second quarter of 2010 and the second quarter of 2020.

From the coefficients of equation (11), it is deduced that the marginal propensity to consume ($\hat{c}_1$) is significantly lower than the marginal propensity to save ($1 - \hat{c}_1$) and this implies that Japanese households prefer to allocate most of their income (about 63%) to savings instead of consumption. Furthermore, the positive effect of an increase in the per capita government spending on the per capita consumption ($\hat{c}_3$) is limited, while monetary policy seems to be irrelevant ($\hat{c}_4$).
From the equation (12), it can be derived that the per capita corporate profits depend only on the per capita GDP ($\hat{\varphi}_1$) and that the costs of the factors of production have a negligible impact ($\hat{\varphi}_2$ and $\hat{\varphi}_3$, in fact, are statistically not significant). This evidence can probably be explained by the continuous reduction in the price of physical capital and by the stagnation of real wages between 1994 and 2020. In fact, the cost of physical capital has always decreased between the first quarter of 1994 and the second quarter of 2020 and real wages recorded a negative trend between the fourth quarter of 1997 and the fourth quarter of 2013, starting to grow again only from the first quarter of 2014.
The coefficients of the equation (13), show that there is no significant frictionality in the capital goods market ($\hat{p}_0$), that an increase in the money supply does not lead to a reduction in the price of physical capital ($\hat{\chi}_1$), that an increase the basic discount and loan rate corresponds to an increase in the cost of physical capital and vice versa ($\hat{\chi}_2$), that the capital goods market is close to its equilibrium ($\hat{\chi}_3$) and that there is no evidence of crowding out ($\hat{\chi}_4$ and $\hat{\chi}_5$).
The coefficients of the equation (14), indicate that none of the monetary policy instruments among those considered is adequate to stimulate the actual inflation.
From the coefficients of equation (15), instead, it is possible to deduce some important considerations regarding the expected inflation. More specifically, from the coefficients $\hat{\rho}_3$ and $\hat{\rho}_4$ it may be deduced that the agents do not formulate adaptive expectations.
The coefficients $\hat{\rho}_3$ and $\hat{\rho}_4$,then, suggest that the inflation target and the open market operations are very ineffective in improving inflation expectations (indeed, these tools even seem to have a counterproductive effect).
The other two monetary policy variables, namely the official discount rate (ρ_5) and the primary liquidity (ρ_6), are totally irrelevant.

6. Conclusions and political implications

From the results obtained by the authors, it is clear that, between the first quarter of 1994 and the second quarter of 2020, the main driver of Japan's (poor) economic growth was the technological progress, while the physical capital accumulation process had an insignificant role. In fact, although the price of physical capital is steadily declining since 1994, the investment in each quarter was, on average, below the replacement investment. The consequence of this has been the continuous deterioration of the physical capital endowment.
The monetary policy does not appear to have encouraged the investment in any way. In fact, there is no evidence that the expansion of the money supply, the ZIRP and

the NIRP have stimulated an increase in the investments thanks to the reduction in the cost of the physical capital. It was also highlighted that in the physical capital goods market there are no significant frictionalities and that the expansive fiscal policy does not involve any crowding out effect.

Only the interbank call money market rate seems to affect significantly the price of the physical capital. In other words, the price of the physical capital seems to depend only on the private credit market and not on the decisions taken by policy makers. In any case, the price of physical capital is near to its equilibrium value, that is, the one that guarantees that the aggregate investment equals the aggregate private savings. Therefore, the resources needed to make investments to revive the Japanese economic growth are unlikely to come from the private credit market and a public intervention may be appropriate.

The Japanese government, indeed, should aim to raise the per capita investment in each quarter to, at least, 4.26% of the previous quarter's physical capital endowment, in order to block the erosion of the stock of the per capita physical capital. To strengthen growth, however, it is necessary to exceed this threshold (which represents, in fact, only the replacement investment).

The increase in the primary liquidity held by the households does not seem to have involved an increase in the consumption. Even with respect to the actual inflation and the expected inflation, the results are not very encouraging. The monetary policy, in fact, has not been useful in increasing the actual inflation and, on the contrary, has contributed to worsening the inflation expectations. The Bank of Japan does not appear to have any adequate tools for these two variables. Since disposable income seems to be the main determinant of per capita consumption, the government could consider the hypothesis of reducing the individual income tax rate to increase the aggregate consumption and, consequently, also the actual inflation.

In conclusion, as already mentioned above, the main innovation of this manuscript consists precisely in demonstrating that the monetary policy is not effective in favoring the per capita GDP growth rate, the private consumption, the investments, the actual inflation and the expected inflation.

The authors believe that their economic policy proposal may be particularly important in the phase following the end of the Covid-19 epidemic, which will require political decision makers to face the challenge of rebuilding the Japanese economy by seeking new strategies to promote economic growth.

Conflict of interests

Author A declares that she has no conflict of interest.
Author B declares that he has no conflict of interests.

Ethical approval

This article does not contain any studies with human partecipants performed by any of the author.

References

[1] Bernanke, B. (1999). Japanese Monetary Policy: A Case of Self-Induced Paralysis?. Paper presented at the ASSA meetings. Boston MA. December. pp. 1-27.

[2] Blanchard, O. (2000). Bubbles. Liquidity Traps. and Monetary Policy. Paper presented at a Conference of Institute for International Economics. Washington DC. September. pp. 1-14.

[3] De Michelis, A., Iacovello, M. (2016). Raising an inflation target: the Japanese experience with Abenomics. European Economic Review, vol. 88, pp. 67-87.

[4] Ferrentino, R., Vota, L. (2019). A structural vector autoregression model for the study of the Japanese GDP and of the Japanese inflation. Advances in Management and Applied Economics, vol. 9, n. 2, pp. 69-93.

[5] Filardo, A., Hofmann, B. (2014). Forward guidance at the zero lower bound. BIS Quarterly Review, pp. 37-53.

[6] Fukuda, S. (2015). Abenomics: Why was it so successful in changing market expectations?. Journal of the Japanese and International Economies, vol. 37, pp. 1-20.

[7] Fukuda, S. (2018). Impacts of Japan’s negative interest rate policy on Asian financial markets. Pacific Economic Review, vol. 23, n. 1, pp. 67-79.

[8] Kamada, K., Nakajima, J. (2014). On the reliability of Japanese inflation expectations using purchasing power parity. Economic Analysis and Policy, vol. 44, n. 3, pp. 259-265.

[9] Katagiri, M. (2016). Forward guidance as a monetary policy rule. Bank of Japan Working paper n. 16-E-6, June, pp. 1-49.

[10] Khan, K., Fei, C., Kamal, M., A., Shaikh, S., A. (2015). Determinants of consumption function, in case of China and G7 countries. International Journal of Economics and Empirical Research, vol. 3, n. 4, pp. 202-210.

[11] Koeda, J. (2019). Macroeconomic effects of quantitative and qualitative monetary easing measures. Journal of the Japanese and International Economies, vol. 52, pp. 121-141.

[12] Kondo, Y., Nakazono, Y., Ota, R., Sui, Q. (2020). Heterogeneous impacts of Abenomics on the stock market: A Fund flow analysis. Journal of the Japanese and International Economies, vol. 55, pp. 1-10.

[13] Krugman, P. (1998). It’s Baaak: Japan’s Slump and the Return of the Liquidity Trap. Brookings Papers on Economic Activity, vol. 29, n. 2, pp. 137-204.

[14] Leigh, D. (2009). Monetary Policy and the Lost Decade: Lessons from Japan. IMF Working paper n. 09/232, October, pp. 3-33.

[15] Levin, A., Salido, D., L., Nelson, E., Yun, T. (2010). Limitations on the Effectiveness of Forward Guidance at the Zero Lower Bound. International Journal of Central Banking, vol. 6, n. 1, pp. 143-189.

[16] Młodawska-Bronowska, J. (2019). Japan’s Expansionary Monetary Policy under Abenomics (2013-2018). Studa Prawno Ekonomiczne, n. 111, pp. 307-324.

[17] Shioji, E. (2003). Who killed the Japanese money multiplier? A micro-data analysis of banks. Paper presented at the Econometric Society 2004 Far Eastern Meetings. Hillhouse Avenue. February. pp. 1-18.
[18] Tonogi, A. (2017). Economic growth analysis of Japan by dinamic general equilibrium model with R&D investment. Public Policy Review, vol. 13, n. 3, pp. 207-239.
[19] Ueda, K. (1999). Individual contribution presented at FRB Boston Conference "Monetary Policy in a Low-Inflation Environment". Woodstock. October.
[20] Assenmacher-Wesche, K., Gerlach, S., Sekine, T. (2008). Monetary factors and inflation in Japan. Journal of the Japanese and International Economies, vol. 22, n. 3, pp. 343-363.
[21] Christiano, L., Eichenbaum, M., Trabandt, M. (2018). On DSGE Models. Journal of Economic Perspectives, vol. 32, n. 3, pp. 113-140.
[22] Oda, N., Ueda, K. (2005). The Effects of the Bank of Japan's Zero Interest Rate Commitment and Quantitative Monetary Easing on the Yield Curve: A Macro-Finance Approach. Bank of Japan Working Paper series 05-E-6, Bank of Japan.
[23] Akram, T., Das, A. (2014). The Determinants of Long-Term Japanese Government Bonds' Low Nominal Yields. Economics Working paper, Levy Economics Institute.