

Balanced-budget fiscal stimuli of investment and welfare value

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Abstract

Is a fiscal stimulus of investment a viable complement to, or substitute for, monetary policy? We address this issue by means of real option valuation of a private investment which generates private as well as public benefits. A surge in uncertainty about private profitability delays investment to an extent that may not be offset by monetary policy (conventional or not). Turning to fiscal policy, we examine the welfare effects of different policy schemes: (i) a simple subsidy on investment, (ii) a balanced-budget stimulus where the subsidy is covered by profit taxation, and (iii) by taxing public benefits as well. We show that, under a balanced-budget stimulus, investment acceleration may come at the expense of decreased total (private and public) welfare and that the higher is uncertainty about private returns, the more likely is a net efficiency loss. However, the risk of such negative outcome strongly declines when the government spending is balanced by taxing both private and public returns on investment.

KEYWORDS: INVESTMENT, FISCAL STIMULUS, BALANCED-BUDGET CONSTRAINTS, REAL OPTIONS.

JEL CLASSIFICATION: E62, E63, D92, G31.

1 Introduction

One of the most striking features of the Great Recession was the sharp decline of capital expenditures compared to consumption (Hall 2010). Moreover, in spite of the long period of extremely easy monetary conditions, in many advanced economies recovery of investment has been slow and anaemic (Banerjee et al. 2015; European Central Bank 2017, pp. 35). These recent events, however, may be regarded as extreme manifestations of well-known empirical regularities of investment brought to the forefront of macroeconomics by Keynes in the *General Theory* (1936; 1937) and later on confirmed by a large body of evidence over time and across countries (Fazzari et al. 1988; Hubbard 1990; Bond and Jenkinson 1996; Saltari and Ticchi 2007; Gennaioli et al. 2016). Capital expenditures are the most volatile component of aggregate demand, they are highly sensitive to uncertainty, but less responsive to interest rates, making monetary policy insufficient to stimulate investment as much as needed during a slump. The consequent policy prescription of the earlier Keynesian literature was that the more reliable anti-cyclical weapon is fiscal policy. After decades of dominance of the opposite view, the Great Recession led to a resurgence of fiscal activism, as monetary policy appeared to be trapped at the zero lower bound of interest rates with no major boost to the economy (Blanchard 2009; Blanchard et al. 2010).¹

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¹See also Krugman (1998; 2005) for earlier reassessment of fiscal policy.

Generally speaking, from a normative standpoint, a fiscal stimulus on investment can be justified on two main grounds. First, governments should support private initiatives that have the potential of generating aggregate gains which exceed those captured by individual agents. This may occur during recessions, when capital expenditures contribute to higher effective demand, but also in normal times, when investments in, say, new products and technologies, generate productivity spillovers or contribute to reducing negative externalities, such as those related to low-efficient or carbon-intensive energy use. Second, during periods of low overall business confidence or when specific, non-recoverable investments, pose relatively high risks, firms tend to delay capital outlays in order to improve their chances of making a correct decision (Bernanke 1983). Although the existence of uncertainty and irreversibility may not constitute by themselves a justification for government intervention (Dixit and Pindyck 1994), in the presence of market failures they can have the effect of exacerbating the gap between the privately and socially optimal timing of investment and, thus, call for a policy response.²

However, even though these arguments provide a rationale for public action, the governments' ability to foster investment can be bound by budgetary constraints, either self-imposed or imposed from outside. For instance, during the last recession and sovereign debt crisis in the European Union, the potential conflict between economic recovery via expansionary fiscal policies and long-term sustainability of public finances has emerged as one of the most controversial issues (CESifo 2019).

Parallel to the macroeconomics debate, a microeconomics literature, using real option models, has also emerged, in an attempt to predict the effects of fiscal stimuli in accelerating business investment as well as the ultimate impact on public accounts (see, *e.g.*, Danielova and Sarkar, 2011; Barbosa et al., 2016). Much of this work was inspired by Pennings (2000), who examined the possibility of reconciling short-term incentives on investment with long-term sustainability of public finances, showing that the government could accelerate capital outlays at zero budgetary cost by subsidizing upfront capital expenses and by subsequently collecting a share in the generated profits. Maoz (2011), however, has cast doubts about the seemingly free-lunch tax-subsidy scheme described by Pennings, by pointing out that investment acceleration would come at expense of reducing the firm's value. Thus, taken together, these findings suggest that, from an efficiency (total welfare) standpoint, government intervention must find a justification in market failures which, however, cannot be detected in Pennings' model, where it is implicitly assumed that investment acceleration would *per se* always be in the public interest.

In this paper we address the above two interrelated issues. On the one hand, building on real option theory, we show how an increase in uncertainty and, thus, an increase in the value of waiting - a typical feature, if not a cause, of deep recessions - may lead to socially undesirable delays of investment, hardly counteracted by even large cuts of the interest rate. On the other hand, turning to fiscal policy, we develop a consistent framework for assessing the welfare effects of a fiscal stimulus, by accounting for both the private and public benefits associated with private investment. The aim is to compare the outcome resulting from a balanced-budget fiscal stimulus with that obtained under "laissez-faire", when the exercise of the option to invest is entirely left to the firm without any sort of fiscal interference. In particular, we study the welfare effects of different policy schemes: (i) a simple subsidy, (ii) a balanced-budget stimulus where the subsidy is covered by a future profit tax, and (iii) by taxing public benefits as well.

We show that, under a balanced-budget stimulus, investment acceleration may come at the expense of decreased total welfare and that the higher is uncertainty about private returns, the

²This argument is also central to the "coordination failure" approach to Keynesian underemployment equilibria (see, *e.g.*, Cooper and John 1988; Haltiwanger and Waldman 1989; Hargreaves Heap 1992).

more likely is a net efficiency loss. However, the risk of such negative outcome strongly declines when government spending is balanced by taxing both private and public returns on investment.

The remainder is organised as follows. In Section 2 we present the model. In Section 3 we briefly illustrate the limits of monetary policy in boosting investment in a context characterized by an upsurge of economic uncertainty. In Section 4 we analyse the effects of a fiscal stimulus. Section 5 concludes. The proofs are presented in the appendices.

2 The model

Consider a representative firm that holds an option to invest at any time $t \geq 0$ in a infinitely-lived irreversible project which requires an initial outlay I . The project is expected to generate a time-stream of profits x_t , defined as the difference between the operating cash flows (measured by the unit rate ρ) and the cost of capital to be paid out to funders (measured by the market unit rate r), evolving according to the following geometric Brownian process:

$$dx_t = (\rho - r)x_t dt + \sigma x_t dz_t \quad x_0 = x \quad (1)$$

where dz_t is the increment of a standard Wiener process and σ is the constant proportional volatility of x_t per unit time.³ Eq. (1) implies that future profits are lognormally distributed with a variance that grows with the time horizon. Thus, by varying σ , it is possible to analyze how different levels of uncertainty affect investment decisions dynamically.

Under the above assumptions, there exists an option value of waiting. Specifically, since at any time $t > 0$ all the information about the future evolution of (1) is embodied in the current value x_t , there exists an optimal rule of the form: invest now if x_t is at or above a critical threshold, otherwise wait (Dixit and Pindyck 1994).

Formally, the firm's problem consists of choosing the optimal investment time (the "stopping time" in the real option jargon), defined as $\tau^P = \inf(t > 0 / x_t = x_{\tau^P})$, which maximizes the expected net present value (NPV):

$$\begin{aligned} F(x, x_{\tau^P}) &\equiv E_0(e^{-\rho\tau^P})[V(x_{\tau^P}) - I] \\ &= \left(\frac{x}{x_{\tau^P}}\right)^\beta [V(x_{\tau^P}) - I] \end{aligned} \quad (2)$$

where $V(x) = E_0(\int_0^\infty e^{-\rho t} x_t dt) = \frac{x}{r}$ and $E_0(e^{-r\tau^P}) = \left(\frac{x}{x_{\tau^P}}\right)^\beta < 1$.⁴

Eq. (2) implies that there exists a particular value ρ^* (known in capital budgeting as the "internal rate of return") that makes the expected NPV equal to zero and which sets the highest payable cost of capital for the investment to remain feasible, i.e., $r \leq \rho^*$.

Since the process (1) is time autonomous, the discount rate is constant and the option to invest perpetual, the optimal threshold of x_t for investing (the "entry trigger") is given by:

$$x_{\tau^P} = \frac{\beta}{\beta - 1} r I \quad (3)$$

³We remind that a world where the expected growth rate is set equal to $\rho - r$ is referred to as a "risk-neutral" world (see, *e.g.*, Cox and Ross 1976, Harrison and Kreps, 1979).

⁴The expected present value $E_0(e^{-\rho\tau^P})$ can be determined by using dynamic programming (see, *e.g.*, Dixit and Pindyck 1994).

where $\beta = \frac{1}{2} - \frac{\rho-r}{\sigma^2} + \sqrt{\left(\frac{\rho-r}{\sigma^2} - \frac{1}{2}\right)^2 + \frac{2\rho}{\sigma^2}} > 1$ is the positive root of the characteristic equation $\Psi(\beta) = (\sigma^2/2)\beta(\beta-1) + (\rho-r)\beta - \rho = 0$, and $\frac{\beta}{\beta-1} > 1$ is the standard option multiplier which captures the effect of uncertainty.

Eq. (3) shows that, under uncertainty, the entry trigger is higher than the pure market return rI , referred to by Dixit (1992) as the "Marshallian investment trigger". Moreover, since $\frac{d\beta}{d\sigma} < 0$ with $\lim_{\sigma \rightarrow \infty} \beta = 1$ and $\lim_{\sigma \rightarrow 0} \beta = \frac{\rho}{\rho-r}$, then $\lim_{\sigma \rightarrow \infty} x_{\tau P} = +\infty$ and $\lim_{\sigma \rightarrow 0} x_{\tau P} = \rho I$, i.e., the trigger is increasing in σ .

Finally, by substituting (3) into (2), we get the firm's value:

$$F(x, x_{\tau P}) = \left(\frac{x}{x_{\tau P}}\right)^\beta \frac{1}{\beta-1} I$$

3 Uncertainty and the limits to conventional monetary policy

Although waiting until the process (1) hits the threshold (3) is optimal for the firm, it may be wasteful from a social perspective. Notably, this can occur when the investment generates substantial economic benefits (*e.g.*, macroeconomic impacts through multiplier effects) beyond those able to be internalised by the firm itself.

To address this issue, in the first place we consider the role that could be played by conventional monetary policy, namely, by central bank's operations aimed at lowering the interest rate relevant to investment decisions. Leaving aside the details of the transmission mechanism from the policy rate to the relevant rate, we simply assume that the central bank has full leverage on the market cost of capital r as defined above. In the following, we take as a benchmark the so-called "marginal investment" with zero expected NPV, i.e., $\rho = r$.

In order to examine the effects of monetary policy, it is convenient to reformulate the trigger (3) as the ratio $z = \frac{x_{\tau P}}{I}$ (also known as the "hurdle rate"). To resume our previous results, under certainty the hurdle rate is just the market rate r , whereas uncertainty and irreversibility raise z above r .

These notions can usefully be portrayed in Figure 1, which plots the hurdle rate z as a function of r . The lowest straight line ($z = r$) represents the case of certainty ($\sigma = 0$). The functions determined by increasing levels of uncertainty lie above the certainty line.

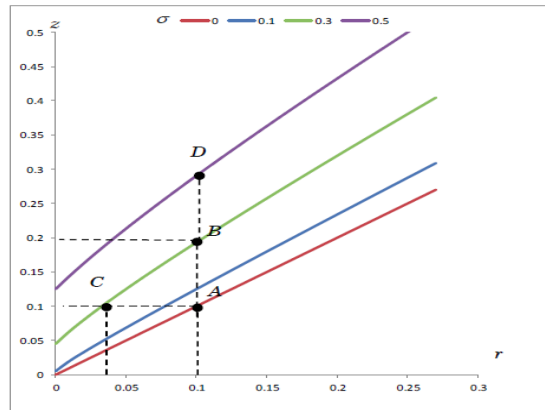


Figure 1

As a hypothetical starting point, let's consider the certainty case at point A . A surge of uncertainty (*e.g.*, $\sigma = 0.3$) shifts the hurdle rate to point B . The consequence for the representative firm is that a project that was immediately feasible at point A is now delayed until point B is observed.⁵ This effect may be offset by the central bank cutting the interest rate up to point point C . However, if the uncertainty is larger (*e.g.*, $\sigma = 0.5$), then z rises up to point D , making the monetary policy impotent even when the zero bound of r is reached.⁶

Two further considerations are in order. First, the hurdle rate of inframarginal investment projects (with $\rho > r$) does fall to zero as the interest rate falls to zero, so that monetary policy may retain some efficacy as a means of accelerating investment. However, this amounts to assuming quasi-rents which require a motivated relaxation of the standard conditions of perfect competition and risk neutrality. Second, at the zero lower bound of the interest rate, the central bank may switch to "unconventional" tools that in some way or another directly inject liquidity into the economy. A detailed analysis of this *modus operandi* falls outside the scope of this paper. However, it may be noted that the option value of waiting that we are considering does not depend on firms being liquidity constrained. Hence, liquidity injections do not seem to be an effective strategy for solving the underlying problem.

4 Accelerating investment by means of fiscal policy

We now move to examine how fiscal policy can contribute to accelerate investment. Herein, we shall hold the marginal investment ($\rho = r$) as benchmark, with r close, but not necessarily equal, to zero, *i.e.*, a situation where, even though the interest rate is not strictly at the zero lower bound, the effect of monetary policy is deemed insufficient because of uncertainty.

We base our model on the government's assessment of the project's public benefits denoted by B , by assuming that $B < I$.⁷

Hence, the maximand welfare function is:

$$W(x, x_{\tau W}) \equiv E_0(e^{-r\tau W})[B + V(x_{\tau W}) - I] \quad (4)$$

Accordingly, the welfare maximizing threshold for investing reduces to:

$$x_{\tau W} = \frac{\beta}{\beta - 1} r(I - B) < x_{\tau P} \quad (5)$$

4.1 A subsidy to the cost of investment

As a starting point, let's suppose the government decides to subsidize the investment cost at a rate $0 < \xi \leq 1$. Consequently, the new optimal investment time for the firm, denoted by $\tau^S = \inf(t > 0 / x_t = x_{\tau^S})$, can be derived by maximizing:

$$F^S(x, x_{\tau^S}) \equiv E_0(e^{-r\tau^S})[V(x_{\tau^S}) - (1 - \xi)I] \quad (6)$$

leading to the following threshold:

$$x_{\tau^S} = (1 - \xi)x_{\tau P} \quad (7)$$

⁵More precisely, the aggregate effect on investment is that all inframarginal projects with $z \in [A, B]$ are delayed.

⁶While stemming from a different conceptual and modeling framework, this result is in line with one of the key implications of Keynes's General Theory.

⁷As shown by (4), $B > I$ would imply that $W > 0$ even with zero (or negative) private value V .

Eq. (7) shows that the government could, in principle, reshape the threshold for investing, by simply lowering the private investment cost. For instance, the first-best trigger (5) may be implemented by setting $\xi = B/I$.

Why does the subsidy succeed whereas the interest rate cut may not? The reason must be found in the investment irreversibility. Unlike the interest rate, the subsidy, cutting directly the sunk cost of investment, reduces the (expected) loss to be incurred as a consequence of irreversibility and raises the ex-ante value of accelerating investment.

4.2 The balanced-budget fiscal stimulus with a profit tax

Now suppose that the government, while willing to accelerate investment, must comply with budgetary constraints. Specifically, as in Pennings (2000), suppose that the government is allowed to subsidize the investment only on the condition of subsequently rebalancing the budget by means of a profit tax $0 < \gamma \leq 1$, so as to render the NPV of the tax-subsidy program equal to zero. In the following, this program will be referred to as the "balanced-budget fiscal stimulus" (BBFS).⁸

Let's first derive the firm's optimal investment time $\tau^{TS} = \inf(t > 0 / x_t = x_{\tau^{TS}})$ that maximizes

$$F^{TS}(x, x_{\tau^{TS}}) \equiv E_0(e^{-r\tau^{TS}})[(1 - \gamma)V(x_{\tau^{TS}}) - (1 - \xi)I] \quad (8)$$

and, thus, the optimal trigger

$$x_{\tau^{TS}} = \frac{1 - \xi}{1 - \gamma} x_{\tau^P} \quad (9)$$

Eq. (9) shows that, as long as $\xi > \gamma$, the government enjoys a whole range of subsidy rates whereby it can reduce $x_{\tau^{TS}}$ relative to x_{τ^P} up to the first-best (i.e., $x_{\tau^{TS}} = x_{\tau^W}$) which now requires setting $\xi = \frac{B}{I} + \gamma(1 - \frac{B}{I})$.

However, the budget constraint requires that:

$$\xi I = \gamma \frac{x_{\tau^{TS}}}{r} \rightarrow \xi I = \frac{\beta\gamma}{\beta - (1 - \gamma)} I \quad (10)$$

By substituting (10) into (9) we obtain the firms' optimal trigger under BBFS:

$$x_{\tau^{BB}} = \frac{\beta}{\beta - (1 - \gamma)} rI \quad (11)$$

Comparison between (3) and (11) shows two things. First, as pointed out by Pennings (2000), a BBFS still induces a downward revision of the entry trigger. Second, the higher is the subsidy rate (and, consequently, the tax rate required to balance the budget), the lower will be the trigger value. For instance, if $\xi = 1$ and $\gamma = 1$ (i.e., in the extreme case where the government subsidized entirely the investment ahead of 100% taxation of future profits) a BBFS would entirely offset the option value of waiting, by driving the hurdle rate to its zero-uncertainty trigger value r .⁹

Stated differently, under BBFS, the greater is the fiscal interference (i.e., the higher are ξ and γ), the more effective is public policy in terms of project acceleration. The question, however, is whether government intervention actually increases total welfare relative to *laissez-faire* (i.e., $\xi = 0$ and $\gamma = 0$).

⁸This program entails that the government finances the initial subsidy by borrowing. We assume that this has no effect on the rate of interest because the amount borrowed is fully matched by the subsequent tax revenue. Under this condition, the government could, for instance, directly borrow from the central bank. Under severe economic conditions, direct lending to government has been part of central banks' monetary easing programs.

⁹From this point of view, fiscal policy is the right complement to monetary policy.

To see this, we first need to look at the impact upon the firm's value. By substituting (10) and (11) into (8) and indicating with $F^{BB}(x, x_{\tau BB})$ the firm's value under BBFS, we get (see Appendix A):

$$F^{BB}(x, x_{\tau BB}) = \mu(\gamma, \beta)F(x, x_{\tau P}) \quad (12)$$

where $\mu(\gamma, \beta) = (1 - \gamma) \left(\frac{\beta - (1 - \gamma)}{\beta - 1} \right)^{\beta - 1} \in [0, 1)$.

Eq. (12) shows that, similarly to Maoz (2011), investment acceleration comes at the expense of reducing the firm's value. Within our framework, the term $\mu(\gamma, \beta)$, which summarizes the relevant parameters, can be interpreted as the measure of the "distortion" due to government intervention. Since $\frac{\partial \mu}{\partial \gamma} < 0$, the greater is the fiscal interference, the higher is the value loss for the firm.

Let's now consider the impact on total welfare. Denoting with $W^{BB}(x, x_{\tau BB})$ and $W^P(x, x_{\tau P})$ the total welfare under BBFS and laissez-faire respectively, we get:

$$W^P(x, x_{\tau P}) = \left(\frac{x}{x_{\tau P}} \right)^{\beta} B + F(x, x_{\tau P}) \quad (13.1)$$

$$W^{BB}(x, x_{\tau BB}) = \left(\frac{x}{x_{\tau BB}} \right)^{\beta} B + \mu(\gamma, \beta)F(x, x_{\tau P}) \quad (13.2)$$

Rearranging, we get:

$$W^{BB}(x, x_{\tau BB}) - W^P(x, x_{\tau P}) = [\phi(\gamma, \beta) - 1] \left(\frac{x}{x_{\tau P}} \right)^{\beta} B + [\mu(\gamma, \beta) - 1] F(x, x_{\tau P}) \quad (14)$$

where $\phi(\gamma, \beta) = \left(\frac{\beta - (1 - \gamma)}{\beta - 1} \right)^{\beta} > 1$.

As already pointed out, the second term on the RHS of (14) is negative, whereas the first term is always positive because investment acceleration increases the present value of public benefits. Thus, the net effect is ambiguous.

Working on (14), we get that the sign of the difference between $W^{BB}(x, x_{\tau BB})$ and $W^P(x, x_{\tau P})$ depends on the sign of:

$$\Omega(\gamma, \sigma) \equiv B + \frac{(1 - \gamma)}{\beta - (1 - \gamma)} I - \left(\frac{\beta - 1}{\beta - (1 - \gamma)} \right)^{\beta} \left(B + \frac{I}{\beta - 1} \right)$$

with $\Omega(0, \sigma) = 0$ and $\Omega(1, \sigma) = B - \left(\frac{\beta - 1}{\beta} \right)^{\beta} \left(B + \frac{I}{\beta - 1} \right) \geq 0$ (See Appendix B).

However, looking more in detail at the effect of uncertainty, we can show the following proposition.

Proposition 1 For any given $B < I$ there exists a value of $\hat{\sigma}$ such that: for $\sigma < \hat{\sigma}$, $W^{BB}(x, x_{\tau BB}) > W^P(x, x_{\tau P})$ for all $\gamma \in (0, 1]$. Otherwise, for $\sigma \geq \hat{\sigma}$, there exists a tax rate $\hat{\gamma}(\sigma)$ such that $W^{BB}(x, x_{\tau BB}) < W^P(x, x_{\tau P})$ for all $\gamma > \hat{\gamma}(\sigma)$.

Proof. See appendix B ■

The proposition says two things. First, for any given subsidy rate (and, thus, tax rate) ensuring a balanced budget, the higher is the uncertainty about private earnings, the higher is the likelihood that a BBFS will not help to increase total welfare relative to laissez-faire. Second, given the level of uncertainty, the greater is the fiscal interference, the lower are the welfare gains deriving from a BBFS.

This ambiguity of results sets limits to, but does not kill altogether, the viability of a BBFS as is clarified by the following numerical example.

Let's assume the following values for the relevant parameters: the investment cost is normalized to $I = 1$, the external benefits $B = 0.5$ and the cost of capital $r = 1\%$.¹⁰ Given these parameters, in Figure 2 we plot $\Omega(\gamma, \sigma)$ as a function of γ for different values of σ : $\beta(\sigma = 10\%) = 2.0$ (Solid-Thin), $\beta(\sigma = 30\%) = 1.2$ (Solid-Dots), $\beta(\sigma = 40\%) = 1.1$ (Solid-Medium).

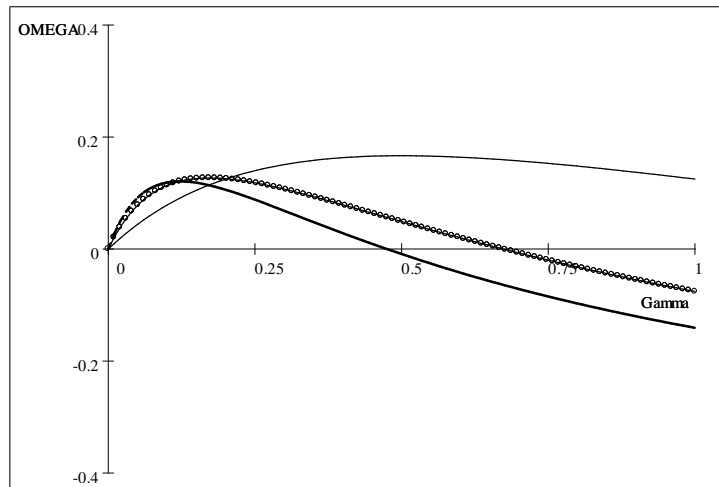


Figure 2

The Figure 2 highlights the kind of "Laffer Curve" implied by Proposition 1. For any given level of uncertainty, one may spot a subsidy-and-tax rate such that the welfare gains of BBFS are maximized. Beyond that point the net benefits decline and eventually become negative.

Taking another viewpoint, an analogy can be drawn between the fiscal program considered here and the "golden rule of public finance", which, simply stated, posits that public deficits over the economic cycle are justified, indeed they can be beneficial, if they are used to fund productive expenditures.¹¹ However, our findings suggest that the range of viability of BBFS shrinks as uncertainty rises, i.e., exactly when investment delays are likely to be more severe and, thus, a government response is more needed. As the solid-medium line exemplifies, with high uncertainty the maximal total welfare is reached at a very low subsidy and tax rate, which generates a negligible acceleration of investment.

4.3 Taxing public benefits

The taxation arm of BBFS is one of the factors determining the rate of decline of total welfare. This is largely attributable to the assumption that the up-front government expenditure will be

¹⁰From a macroeconomic point of view, since the subsidised share of I is public spending, B may be regarded as the induced increase in national income, and hence one may look for reference values at the empirical research on so-called "fiscal multipliers". Results are far from conclusive, however the consensus estimates before the Great Recession may be located around 0.5, whereas post-crisis studies have unveiled that fiscal stimuli (contractions) in recessions are more powerful, with estimates pointing to higher values, around 1 or more (see, *e.g.*, IMF 2010; Gechert et al. 2015). The same conclusion is reached by the specific study of the impact of public expenditure via private investment by Carillo and Poilly (2013). Hence $B = 50\%$ can be considered a conservative hypothesis.

¹¹As a matter of fact, the golden rule is much debated, and invoked by several governments, in the Euro Zone, without substantial effect.

subsequently balanced by the revenues collected by taxing the profits generated by the project. However, since we are considering a situation where the investment generates additional public benefits, it may be thought that they can contribute to further increase the tax base and, thus, allow the government to reduce the tax burden to the firm required to achieve a balanced budget.

Clearly, the extent to which the tax base goes up will depend, *inter alia*, on the economic nature of the spillover effects. Here, we simplify by assuming that all B will be taxed at the same rate γ as profits.

Therefore, the government's budget constraint becomes:

$$\xi I = \gamma \frac{x_{\tau TS}}{r} + \gamma B \rightarrow \xi I = \frac{\beta \gamma}{\beta - (1 - \gamma)} I + \frac{(\beta - 1)\gamma(1 - \gamma)}{\beta - (1 - \gamma)} B \quad (15)$$

By substituting (15) into (9) we obtain the firm's entry threshold:

$$x_{\tau BBT} = \frac{\beta}{\beta - (1 - \gamma)} r(I - \gamma B) < x_{\tau BB} < x_{\tau P} \quad (16)$$

which, as can be expected, is lower than (11).

Finally, by substituting (15) and (16) into (8) and indicating with $F^{BBT}(x, x_{\tau BB})$ the firm's value under a BBFS with public benefits taxed, we get:

$$F^{BBT}(x, x_{\tau BB}) = \mu^T(\gamma, \beta) F(x, x_{\tau P}) \quad (17)$$

where $\mu^T(\gamma, \beta) \equiv \mu(\gamma, \beta) \left(\frac{I}{I - \gamma B}\right)^{\beta - 1} \in [0, 1]$ (See Appendix C).

As in the previous section, we can compare the total welfare under government intervention with the one achieved under *laisser-faire*:

$$W^{BBT}(x, x_{\tau BB}) - W^P(x, x_{\tau P}) = [\phi^T(\gamma, \beta) - 1] \left(\frac{x}{x_{\tau P}}\right)^{\beta} B + [\mu^T(\gamma, \beta) - 1] F(x, x_{\tau P}) \quad (18)$$

where $\phi^T(\gamma, \beta) = \phi(\gamma, \beta) \left(\frac{I}{I - \gamma B}\right)^{\beta} > 1$.

The sign of the difference is given by:

$$\Omega^T(\gamma, \sigma) \equiv B + \frac{(1 - \gamma)}{\beta - (1 - \gamma)} (I - \gamma B) - \left(\frac{\beta - 1}{\beta - (1 - \gamma)}\right)^{\beta} \left(\frac{I - \gamma B}{I}\right)^{\beta} \left(B + \frac{I}{\beta - 1}\right)$$

with $\Omega^T(0, \sigma) = 0$ and $\Omega^T(1, \sigma) = B - \left(\frac{\beta - 1}{\beta}\right)^{\beta} \left(\frac{I - B}{I}\right)^{\beta} \left(B + \frac{I}{\beta - 1}\right) > \Omega(1, \sigma)$ (See Appendix C).

Although the sign is still ambiguous we can prove the following proposition

Proposition 2 While an increase in uncertainty still reduces the benefits of BBFS, the taxation of external benefits enlarges the range of tax rates γ (for any given value of σ) and of σ (for a given value of γ) where BBFS provides a welfare gain relative to *laisser-faire*.

Proof. See Appendic C ■

Again, a numerical example helps to illustrate these results. Using the same parameters used for generating Figure 2, in Figure 3 we plot $\Omega^T(\gamma, \sigma)$ as a function of γ .

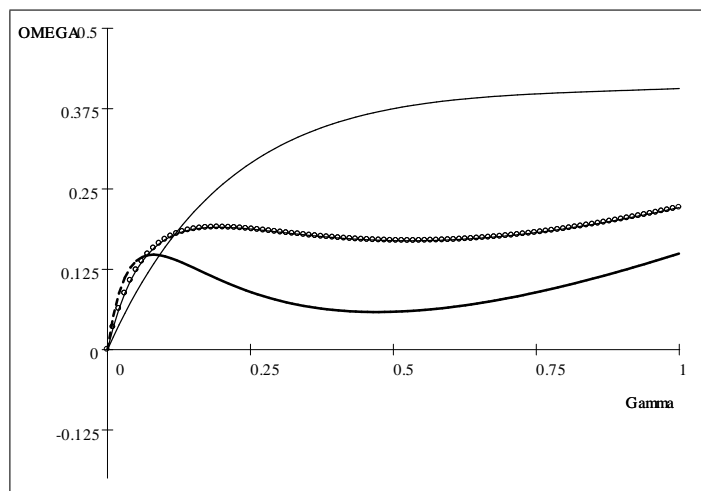


Figure 3

Comparison between Figure 2 and 3 shows that the expansion of the tax base modifies substantially the welfare effects. In fact, the contribution of external benefits to the tax revenue allows a faster acceleration of investment while keeping total welfare positive. This effect can be seen in the convexity of the iso-uncertainty curves. Moreover, contrary to the previous case, there is now a subsidy-tax rate beyond which total welfare increases. This favourable combination can also be obtained with high uncertainty, though at a lower scale.

5 Final Remarks

One of the most striking features of the Great Recession in advanced economies has been the persistent fall of business investment combined with the substantial impotency of monetary policy up to the zero lower bound of interest rates. In this paper we have addressed the issue whether a fiscal stimulus is a viable complement to, or substitute for, monetary policy.

Drawing on real option theory, we have shown that a surge of uncertainty about private earnings has the effect of exacerbating the gap between the privately and socially desirable timing of investment to an extent that may not be offset by monetary policy (conventional or not).

Taking stock of other real option models, we have framed the public benefits of accelerating investment, within the total welfare assessment of alternative fiscal policy schemes: (i) a simple subsidy to the private cost of investment, (ii) a balanced-budget stimulus where the up-front subsidy is covered by subsequently taxing the profits generated by the project, and (iii) by taxing external benefits as well. The policy conclusions of our analysis can be summarised as follows.

First, a subsidy is a powerful tool that the government can use to achieve a more socially efficient time of investment. Second, introducing a balanced-budget constraint, satisfied by future taxation of profits, has a twofold effect. On the one hand, the government can still gear the subsidy-tax scheme so as to accelerate investment and the ensuing provision of public benefits. On the other, the scheme has a negative impact on the firm's value. Thus the net welfare effect is ambiguous. Notably, we have shown that the net effect is more likely to turn negative the higher is uncertainty, that is when the public interest in spurring investment is stronger. Third, the government can however enlarge the scope of net welfare gains of the BBFS by including public benefits in the tax base. In fact, the contribution of public benefits to the tax revenue allows a faster acceleration of

investment while keeping total welfare positive even for higher levels of uncertainty.

In essence, we find support for the so-called "golden rule of public finance", which justifies deficits aimed at fostering investment (public or private as in our case), covered by future tax revenues, provided that these arise from an appropriately broad tax base.

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A Appendix

First, substituting (3) in (2) we get:

$$F(x, x_{\tau P}) = \left(\frac{x}{x_{\tau P}} \right)^{\beta} \frac{x_{\tau P}}{\beta \delta} \quad (\text{A.1})$$

Second, substituting (10) and (11) in (8), we obtain:

$$\begin{aligned} F^{BB}(x, x_{\tau BB}) &= \left(\frac{x}{x_{\tau BB}} \right)^{\beta} (1 - \gamma) \frac{x_{\tau BB}}{\beta \delta} = (1 - \gamma) F(x, x_{\tau BB}) \\ &= (1 - \gamma) \left(\frac{\beta - (1 - \gamma)}{\beta - 1} \right)^{\beta - 1} F(x, x_{\tau P}) \\ &= \mu(\gamma, \beta) F(x, x_{\tau P}) \end{aligned} \quad (\text{A.2})$$

where $\mu(\gamma, \beta) \equiv (1 - \gamma) \left(\frac{\beta - (1 - \gamma)}{\beta - 1} \right)^{\beta - 1}$. Since $\mu(1, \beta) = 0$, $\mu(0, \beta) = 1$, and:

$$\frac{\partial \mu}{\partial \gamma} = \left(\frac{\beta - (1 - \gamma)}{\beta - 1} \right)^{\beta - 1} \left[-\frac{\gamma \beta}{\beta - (1 - \gamma)} \right] < 0 \quad (\text{A.3})$$

we may conclude that $\mu(\gamma, \beta) \in [0, 1]$.

Finally, comparing (A.1) and (A.2), the difference between $F(x, x_{\tau P})$ and $F^{BB}(x, x_{\tau BB})$ becomes:

$$\begin{aligned} F(x, x_{\tau P}) - F^{BB}(x, x_{\tau BB}) &= F(x, x_{\tau P}) - (1 - \gamma) F(x, x_{\tau BB}) \\ &= [1 - \mu(\gamma, \beta)] F(x, x_{\tau P}) > 0 \end{aligned} \quad (\text{A.4})$$

B Appendix

The project's total economic value is the sum of the firm's private value and external benefits. When the firm invests at (3), the total value is:

$$\begin{aligned} W^P(x, x_{\tau P}) &= \left[\left(\frac{x}{x_{\tau P}} \right)^{\beta} \left(B + \frac{x_{\tau P}}{\delta} - \pi(\tau^P) \right) + \left(\frac{x}{x_{\tau P}} \right)^{\beta} \left(\frac{x_{\tau P}}{\delta} - I + \pi(\tau^P) \right) \right] \\ &= \left(\frac{x}{x_{\tau P}} \right)^{\beta} \left(B + \frac{x_{\tau P}}{\beta \delta} \right) = \left(\frac{x}{x_{\tau P}} \right)^{\beta} B + F(x, x_{\tau P}) \end{aligned} \quad (\text{B.1})$$

When the firm invests at (11), the total value is:

$$\begin{aligned} W^{BB}(x, x_{\tau BB}) &= \left[\left(\frac{x}{x_{\tau BB}} \right)^{\beta} \left(B + \gamma \frac{x_{\tau BB}}{\delta} - \pi(\tau^{BB}) \right) + \left(\frac{x}{x_{\tau BB}} \right)^{\beta} \left((1 - \gamma) \frac{x_{\tau BB}}{\delta} - I + \pi(\tau^{BB}) \right) \right] \\ &= \left(\frac{x}{x_{\tau BB}} \right)^{\beta} \left(B + \frac{(1 - \gamma)x_{\tau BB}}{\beta \delta} \right) = \left(\frac{x}{x_{\tau BB}} \right)^{\beta} B + (1 - \gamma) F(x, x_{\tau BB}) \end{aligned}$$

The difference between (B.2) and (B.1) becomes:

$$\begin{aligned} W^{BB}(x, x_{\tau BB}) - W^P(x, x_{\tau P}) &= \left(\frac{x}{x_{\tau BB}}\right)^\beta \left(B + \frac{(1-\gamma)x_{\tau BB}}{\beta\delta}\right) - \left(\frac{x}{x_{\tau P}}\right)^\beta \left(B + \frac{x_{\tau P}}{\beta\delta}\right) \quad (\text{B.3}) \\ &= \left(\frac{x}{x_{\tau P}}\right)^\beta \left(\frac{\beta - (1-\gamma)}{\beta - 1}\right)^\beta \left[B + I \frac{(1-\gamma)}{\beta - (1-\gamma)} - \left(\frac{\beta - 1}{\beta - (1-\gamma)}\right)^\beta \left(B + \frac{I}{\beta - 1}\right) \right] \end{aligned}$$

Let's define $\Omega(\gamma, \sigma) \equiv \left[B + I \frac{(1-\gamma)}{\beta - (1-\gamma)} - \left(\frac{\beta - 1}{\beta - (1-\gamma)}\right)^\beta \left(B + \frac{I}{\beta - 1}\right) \right]$. We first prove that, for a given σ , there may be a value of $\gamma \in (0, 1)$ such that $\Omega(\gamma, \sigma) = 0$. Then we show how this value varies with σ .

Since $\Omega(\gamma, \sigma)$ is continuous in γ , by fixing σ , it is easy to show that:

$$\Omega(0, \sigma) = 0 \text{ and } \Omega(1, \sigma) = B - \left(\frac{\beta - 1}{\beta}\right)^\beta \left(B + \frac{I}{\beta - 1}\right) < 0 \rightarrow \text{if } B < \frac{1}{\left[\left(\frac{\beta}{\beta - 1}\right)^\beta - 1\right]} \frac{I}{\beta - 1} \quad (\text{B.4})$$

where $\left(\frac{\beta}{\beta - 1}\right)^\beta > 1$. Further $\Omega(\gamma, \sigma)$ is a concave function on γ . Taking the first and second derivatives with respect to γ we get:

$$\frac{\partial \Omega}{\partial \gamma} = \frac{\beta}{(\beta - (1-\gamma))^2} \left[-I + (\beta - 1) \left(\frac{\beta - 1}{\beta - (1-\gamma)}\right)^{\beta - 1} \left(B + \frac{I}{\beta - 1}\right) \right] \quad (\text{B.5})$$

$$\frac{\partial^2 \Omega}{\partial \gamma^2} = \frac{\beta}{(\beta - (1-\gamma))^2} \left[-(\beta - 1)^2 \left(\frac{\beta - 1}{\beta - (1-\gamma)}\right)^{\beta - 2} \frac{\beta - 1}{\beta - (1-\gamma)} \left(B + \frac{I}{\beta - 1}\right) \right] < 0 \quad (\text{B.6})$$

and the value of γ such that $\frac{\partial \Omega}{\partial \gamma} = 0$ is:

$$\gamma^{\max} = (\beta - 1) \left[\left(1 + (\beta - 1) \frac{B}{I}\right)^{\frac{1}{\beta - 1}} - 1 \right] \quad (\text{B.7})$$

Since $1 + (\beta - 1) \frac{B}{I} > 1$ we get that $\gamma^{\max} > 0$ while it is less than 1 if :

$$B < \left[\left(\frac{\beta}{\beta - 1}\right)^{\beta - 1} - 1 \right] \frac{I}{\beta - 1} \quad (\text{B.8})$$

Finally, comparing (B.4) and (B.8), it is easy to show that if (B.4) holds then (B.8) is always satisfied. This implies that there exists a value of $\hat{\gamma}(\sigma) \in (0, 1)$ such that for $\gamma \geq \hat{\gamma}(\sigma)$, $\Omega(\gamma, \sigma) < 0$ and positive otherwise.

Let's now consider the effect of σ . Recalling that $\frac{d\beta}{d\sigma} < 0$, with $\lim_{\sigma \rightarrow 0} \beta = +\infty$ and $\lim_{\sigma \rightarrow \infty} \beta = 1$, we get:

$$\lim_{\beta \rightarrow \infty} \Omega(\gamma, \sigma) = \lim_{\beta \rightarrow \infty} \left[B + I \frac{(1-\gamma)}{\beta - (1-\gamma)} - \left(\frac{\beta - 1}{\beta - (1-\gamma)}\right)^\beta \left(B + \frac{I}{\beta - 1}\right) \right] = 0 \quad (\text{B.9})$$

and:

$$\begin{aligned}\lim_{\beta \rightarrow 1} \Omega(\gamma, \sigma) &= \lim_{\beta \rightarrow 1} \left[B + I \frac{(1-\gamma)}{\beta - (1-\gamma)} - \left(\frac{\beta-1}{\beta - (1-\gamma)} \right)^\beta \left(B + \frac{I}{\beta-1} \right) \right] = \left[B + I \frac{(1-\gamma)}{\gamma} - \frac{I}{\gamma} \right] \\ &= B - I < 0\end{aligned}\quad (\text{B.10})$$

Note that (B.10) is negative. Thus, by (B.4), there exists a value of $\hat{\sigma}$ such that for $\sigma < \hat{\sigma}$, $\Omega(\gamma, \sigma) > 0$ for all $\gamma \in [0, 1]$. On the contrary, for $\sigma \geq \hat{\sigma}$, as proved above, there may exist a value $\hat{\gamma}(\sigma) > \gamma^{\max}$ such that for $\gamma < \hat{\gamma}(\sigma)$ we get $\Omega(\gamma, \sigma) > 0$, and $\Omega(\gamma, \sigma) < 0$ for $\gamma > \hat{\gamma}(\sigma)$.

C Appendix

Let's compare $F^{BBT}(x, x_{\tau BBT})$ with the first-best, i.e.:

$$\begin{aligned}F^{BBT}(x, x_{\tau BBT}) &= \left(\frac{x}{x_{\tau BBT}} \right)^\beta \frac{(1-\gamma)}{\beta - (1-\gamma)} (I - \gamma B) \\ &= \left(\frac{x_{\tau P}}{x_{\tau BBT}} \right)^\beta \left(\frac{x}{x_{\tau P}} \right)^\beta \frac{I}{\beta-1} \frac{(I - \gamma B)}{I} \frac{(1-\gamma)(\beta-1)}{\beta - (1-\gamma)} \\ &= (1-\gamma) \left(\frac{\beta - (1-\gamma)}{\beta-1} \right)^{\beta-1} \left(\frac{I}{I - \gamma B} \right)^{\beta-1} F(x, x_{\tau P}) \\ &= \mu^T(\gamma, \beta) F(x, x_{\tau P})\end{aligned}\quad (\text{C.1})$$

where $\mu^T(\gamma, \beta) \equiv (1-\gamma) \left(\frac{\beta - (1-\gamma)}{\beta-1} \right)^{\beta-1} \left(\frac{I}{I - \gamma B} \right)^{\beta-1}$. Since the term $\mu^T(\gamma, \beta)$ is monotone in γ with $\mu^T(1, \beta) = 0$ and $\mu^T(0, \beta) = 1$, we may conclude that $\mu^T(\gamma, \beta) \in [0, 1]$.

Let's now consider the total welfare, by taking into account the external benefits associated with project acceleration. Denoting with $W^{BBT}(x, x_{\tau BBT})$ the total welfare, the difference is:

$$W^{BBT}(x, x_{\tau BBT}) - W^P(x, x_{\tau P}) = [\phi^T(\gamma, \beta) - 1] \left(\frac{x}{x_{\tau P}} \right)^\beta B + [\mu^T(\gamma, \beta) - 1] F(x, x_{\tau P}) \quad (\text{C.2})$$

where $\phi^T(\gamma, \beta) = \left(\frac{\beta - (1-\gamma)}{\beta-1} \right)^\beta \left(\frac{I}{I - \gamma B} \right)^\beta > 1$. By simple algebra we get:

$$W^{BBT}(x, x_{\tau BBT}) - W^P(x, x_{\tau P}) = \left(\frac{x}{x_{\tau P}} \right)^\beta \left(\frac{x_{\tau P}}{x_{\tau BBT}} \right)^\beta \Omega^T(\gamma, \sigma) \quad (\text{C.3})$$

where:

$$\begin{aligned}\Omega^T(\gamma, \sigma) &\equiv \left[B + \frac{(1-\gamma)}{\beta - (1-\gamma)} (I - \gamma B) - \left(\frac{\beta-1}{\beta - (1-\gamma)} \right)^\beta \left(\frac{I - \gamma B}{I} \right)^\beta \left(B + \frac{I}{\beta-1} \right) \right] \\ &= \Omega(\gamma, \sigma) - \frac{(1-\gamma)}{\beta - (1-\gamma)} \gamma B + \left(\frac{\beta-1}{\beta - (1-\gamma)} \right)^\beta \left(B + \frac{I}{\beta-1} \right) \left[1 - \left(\frac{I - \gamma B}{I} \right)^\beta \right]\end{aligned}\quad (\text{C.4})$$

Since $\Omega^T(\gamma, \sigma)$ is continuous in γ , it is easy to show that for any given σ :

$$\Omega^T(0, \sigma) = 0 \text{ and } \Omega^T(1, \sigma) = B - \left(\frac{\beta - 1}{\beta}\right)^\beta \left(\frac{I - B}{I}\right)^\beta \left(B + \frac{I}{\beta - 1}\right) \quad (\text{C.5})$$

As $\Omega^T(1, \sigma) > \Omega(1, \sigma)$, and $\frac{\partial \Omega^T}{\partial \sigma} > 0$, this confirms the result in Proposition 2.