

AGGREGATE IMPLICATIONS OF CORPORATE PROFIT TAXES IN THE ATKESON AND BURSTEIN (2018) MODEL

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1. INTRODUCTION

In this note, we describe ongoing work in which we use the model in Atkeson and Burstein (2018) (henceforth AB2018) to evaluate the impact of changes in corporate profits taxes on the dynamics of aggregate productivity and output. Our goal is to evaluate how much consideration of the impact of corporate profits taxes on firms' incentives to invest in innovation changes the forecast one obtains for the dynamics of output following the recent corporate profits tax reform relative to a standard analysis based on the assumption that the evolution of aggregate productivity is exogenous and hence independent of corporate profits tax rates. For examples of standard analyses based on the assumption that aggregate productivity is exogenous and hence independent of corporate profits tax rates, see Barro and Furman (2018) (henceforth BF2018) as well as the presentations from lunch at the NBER Macroeconomics Annual Conference (see <http://papers.nber.org/sched/Macro18>) given by Kent Smetters, using the Penn Wharton Budget Model, Mark Zandi, using a model developed by Moody's Analytics, and Wendy Edelberg of the Congressional Budget Office.

These standard analyses forecast a relatively modest impact on the dynamics of aggregate output both in the long run and over the next ten years. Our question for this note is whether these findings would be substantially different quantitatively in our model of the impact of firms' investments in innovation on the dynamics of aggregate productivity and output.

We find as a robust implication of our model that the recent change in corporate profits taxes should lead to a substantial increase in the innovation intensity of the economy (measured as the ratio of firms' investments in innovation to output) and in entry of new firms, at least in the long run.

What are the implications of this policy induced increase in the innovation intensity of the economy and of the policy induced reallocation of innovative investment towards entry for the dynamics of aggregate productivity and output in the long run? There is a great deal of uncertainty regarding the answer to this question. We identify two empirical issues that need to be resolved to give a robust quantitative answer to this question. First, how large are intertemporal knowledge spillovers?

Date: May 9, 2018.

As discussed in AB2018, if these spillovers are large, then a sustained uniform increase in the innovation intensity of the economy leads, over the very long run, to a large increase in aggregate productivity, output, and welfare. If intertemporal knowledge spillovers are small, as argued by Jones and others, then the long run responses of aggregate output are much closer to those found in standard models with exogenous productivity. Second, would a reallocation of innovative investment from incumbent firms to entering firms increase or decrease the growth rate of aggregate productivity? Depending on the answer to this question, our model predicts that the change in corporate tax policy can have a positive or negative impact on aggregate productivity, output, and welfare in the long run. And depending on parameters, this positive or negative impact could be large in magnitude.

What are the implications of this policy induced increase in the innovation intensity of the economy and of the policy induced reallocation of innovative investment towards entry for the dynamics of aggregate productivity and output over a ten year horizon as studied in BF2018? Here, our model gives a more robust quantitative answer about the magnitude of the response of aggregate productivity and output in absolute terms. The response can be higher or lower than what is found in standard models with exogenous productivity, but the magnitude of the difference at a horizon of ten years is within the range of standard business cycle fluctuations.¹

To establish these results we examine the impact of the change in the parameters of the corporate profits tax system studied in BF2018 on aggregate productivity and output in the long run and over a ten year horizon in the following three specifications of our model.

In the first specification of our model, we assume that innovative investment by entering and incumbent firms is fixed exogenously and does not respond to changes in tax policy. As a result of this assumption, aggregate productivity is not impacted by changes in tax policy, just as in the standard models referenced above. We use this first specification of our model to establish a baseline of comparison with results from standard models.²

In the second specification of our model, we assume that innovative investment by entering firms responds endogenously to changes in tax policies but that innovative investment by incumbent firms is fixed exogenously. As a result of this assumption, in this version of our model, in the long run, changes in corporate tax rates can impact the innovation intensity of the economy, but they do not impact the allocation of innovative investment across entering and incumbent firms.

¹In relative terms, the response of aggregate output can be almost double or half as large as in standard models with exogenous productivity.

²In this first version of our model, consideration of monopoly markups and investment in innovation make the procedure for calibrating this version of our model different from that followed in BF2018 and other standard analysis.

Thus, in this second version of our model, we can use the results on measurement in AB2018. We use this second version of our model to examine the effect of the change in corporate profits taxes on aggregate productivity through its impact on the innovation intensity of the economy while abstracting from the changes brought about through the impact of corporate profits tax policies on the efficiency of the allocation of innovative investment across firms. We consider this effect in the following version of our model.

In the third specification of our model, we assume that both incumbent and entering firms change their innovative investment endogenously in response to the change in corporate profits taxes. In this full version of the model, we must consider the additional effects that arise because changes in the system of corporate profits taxes can impact the allocation of innovative investment across firms and hence the overall social benefit from a given level of aggregate innovative investment.³ This implies that the direction of the change in aggregate productivity can be either positive or negative depending on the degree to which the change in corporate profits tax policies mitigates or aggravates inefficiency in the allocation of innovative investment across firms.

In what follows, we describe the three versions of the model that we consider. Since this note is intended to be read alongside AB2018, we only describe the differences between each of these specifications of our model and the model in AB2018. We next discuss how we incorporate the impact of corporate profits taxes on the incentive of firms to accumulate physical capital in the context of the first version of our model. Here we show how consideration of monopoly markups and investment in innovation by firms impacts the calibration procedure for the model. We then discuss the impact of corporate profits taxes on the incentive of entering firms to invest in innovation in the context of the second version of our model. Here we show how we calculate the impact of a change in corporate profits taxes on the innovation intensity of the economy. Next, we discuss the impact of corporate profits taxes on the allocation of innovative investment across firms in the context of the third version of our model. Next, we briefly discuss the changes in the calibration relative to AB2018 because of our different specification of the parameters of corporate profits taxes in these notes. Finally, we present the results for aggregate productivity, output and welfare for the various model specifications.

2. MODEL SPECIFICATIONS

In all specifications of our model, the economic environment is as specified in subsections 2.1, 2.2, 4.1, and 4.2 in AB2018. What differs across specifications is whether we set the levels of innovative investment x_{ct} , x_{mt} , x_{et} by incumbent and

³We discuss how changes in the allocation of innovative investment across firms impacts our model's predictions for the dynamics of aggregate productivity in Proposition 6 in AB2018. Here we examine the quantitative implications on a particular policy change — a change in the parameters of corporate profits taxes.

entering firms exogenously or endogenously. The evolution of aggregate productivity is given as a function of innovative investment by entering and incumbent firms as described in subsection 4.3, Lemma 3 of that paper. In the first version of the model, this growth rate of aggregate productivity is exogenous because innovative investments by entering and incumbent firms are exogenous. In the second version of this model, the growth rate of aggregate productivity is a univariate function of investment in entry since the levels of investment by incumbent first is set exogenously. In the third version of this model, the growth rate of aggregate productivity depends on the endogenous choices of all three types of innovative investment.

We model aggregate labor supply L_t as exogenous and thus independent of changes in corporate profits tax policy.

Note that all of the results in subsection 2.5 of AB2018 regarding the division of output into payments to factors of production and the relationship between the innovation intensity of the economy and the allocation of labor between production and research hold in all three specifications of this model. The same is true for the results regarding the balanced growth path of this economy in subsection 2.6 of AB2018.

The definition of equilibrium in the three specifications of our model differs from that in Appendix A in AB2018 for two reasons. First, as described below, we modify the decentralization in our model to have a holding company manage and rent out the stock of physical capital rather than the household. This allows us to consider the impact of corporate profits taxes on the incentives of firms to accumulate physical capital. This change requires us to restate the problem of the household in equation (50) of Appendix A and to introduce a profit maximization problem for this new holding company. Second, we replace the policies considered in that appendix with a system of corporate profits taxes characterized by four parameters: the tax rate on corporate profits τ , the extent to which investment in physical capital is deductible against taxes λ_k , the extent to which innovative investment by incumbent firms is deductible against taxes λ_i , the extent to which innovative investment by entering firms is deductible against taxes λ_e . This second change requires us to modify equation (53) in Appendix A describing the value function for incumbent firms and equation (54) describing the zero-profits at entry condition for entering firms.

2.1. Model with exogenous innovative investment by all firms. In this section, we discuss the first version of our model in which innovative investment by entering and incumbent firms is fixed exogenously. We compare the forecasts for the dynamics of aggregate productivity and output we obtain from the model in AB2018 to the forecasts obtained by BF2018 in their paper for the Brookings Papers on Economic Activity. Our model differs from theirs because we assume that incumbent firms charge a markup of price over marginal cost and that both incumbent and entering firms invest in innovative activity. These assumptions

require us to calibrate our model in a manner that does not exactly align with the calibration chosen by BF2018 since their model includes neither a monopoly markup nor innovative investment by incumbent and entering firms. Thus, to allow for a direct comparison of our results to theirs, we nest their model in ours, which allows us to calibrate both models in a consistent manner.

As BF2018 discuss, the parameters of corporate tax policy that impact firms' incentives to accumulate physical capital are the corporate tax rate τ and the extent to which investment in physical capital can be expensed for tax purposes as indexed by $\lambda_k \geq 0$. The central equation in BF2018 (their equation 1) is that, on a balanced growth path, the pre-tax rental rate on capital \bar{R}_k should satisfy

$$(1) \quad \bar{R}_k = \left(\frac{1 - \tau \lambda_k}{1 - \tau} \right) (\bar{R} + d_k)$$

where \bar{R} is the consumption interest rate on the BGP and d_k is the depreciation rate of physical capital. BF2018 assume a competitive economy with a Cobb-Douglas aggregate production function (their equation 8)

$$Y_t = Z_t K_t^\alpha L_t^{1-\alpha}$$

so that the rental rate on physical capital is given by (their equation 9)

$$R_{kt} = \alpha \frac{Y_t}{K_t}$$

Note that AB2018 have the same aggregate production function (our equation 5), except that we assume that aggregate labor L_t is divided between two activities: current production (L_{pt}) and research (L_{rt}). Only current production labor L_{pt} enters into the Cobb-Douglas production function. Both types of labor, however, are paid equal wages, so the total wage bill in the economy is $W_t L_t$. This is one reason that, when we calibrate the model, we are no longer able to directly map the observed share of labor compensation in output to the parameter $1 - \alpha$ in the aggregate production function. The other reason, of course, is that we assume that intermediate goods producing firms charge a markup $\mu > 1$ of price over marginal cost.

More specifically, the ratio of labor compensation to output in AB2018 is given by

$$(2) \quad \frac{W_t L_t}{Y_t} = \frac{W_t L_{pt}}{Y_t} + \frac{W_t L_{rt}}{Y_t} = \frac{1 - \alpha}{\mu} + i_{rt}$$

where i_{rt} is the innovation intensity of the economy defined in page 12 in AB2018. This result follows from the assumption that research labor is the only input into innovative investment and the decomposition of output into factor shares discussed towards the bottom of page 11 in AB2018.

To make the decentralization of equilibrium in AB2018 (see Appendix A) consistent with that in the standard model in the sense that a firm, rather than the

household, manages the stock of physical capital, we assume that physical capital is managed by a holding company that chooses investment, rents out physical capital to intermediate goods firms, pays corporate profits taxes, pays dividends to households. Specifically, this firm owns the initial capital stock K_0 . Given a sequence of rental rates $\{R_{kt}\}$, tax policy parameters τ and λ_K , and intertemporal prices $\{Q_t\}$, this firm chooses capital stocks $\{K_{t+1}\}$, and dividends $\{D_{Kt}\}$ to maximize the value of dividends to the household

$$\sum_{t=0}^{\infty} Q_t D_{kt}$$

with after tax dividends

$$D_{kt} = (1 - \tau)R_{kt}K_t - (1 - \tau\lambda_K)[K_{t+1} - (1 - d_k)K_t]$$

The first order conditions of this problem imply that equation (1) above holds in the BGP of our model. Where we differ from BF2018 is that we have

$$(3) \quad R_{kt} = \frac{\alpha Y_t}{\mu K_t}$$

as discussed on page 11 of AB2018. The change in the logarithm of the capital-output ratio across BGPs (equal to the change in the ratio of physical investment to output) is, by equation (1),

$$(4) \quad \log \frac{\bar{K}'_t}{\bar{Y}'_t} - \log \frac{\bar{K}_t}{\bar{Y}_t} = \log \left(\frac{1 - \tau'}{1 - \lambda'_k \tau'} \right) - \log \left(\frac{1 - \tau}{1 - \lambda_k \tau} \right)$$

A reduction in τ increases the investment to output ratio only if expensing is less than complete, $\lambda_k < 1$.

To calibrate this first version of our model, we must calibrate the initial and final parameters of tax policy τ , λ_k and τ' , λ'_k , the growth rate of output on the initial BGP \bar{g}_Y (see subsection 2.6 of AB2018), preference parameters β and γ (see equation 2 in AB2018), the depreciation rate of physical capital δ_k , the capital share parameter in production α , the markup μ , and the initial innovation intensity of the economy \bar{i}_r which corresponds to a division of labor between production and research \bar{l}_r and \bar{l}_p (see equation 13 of AB2018).

To measure the innovation intensity of the economy on the initial BGP \bar{i}_r , we follow a procedure very similar to that described on pages 35 of AB2018 with further details given on Appendix pages 23 and 25. We make modifications to this procedure described below in equations (7) and (8) in this document to account for the different specification of policies in this model versus that in AB2018. We describe our procedure for doing so below.

2.2. Model with endogenous entry but exogenous investment by incumbent firms. We next consider a version of our model in which entering firms adjust their investments in innovation in response to the change in corporate profits taxes but incumbent firms continue to hold their investments fixed at exogenously

specified levels. Our purpose in examining this simplified model of innovative investment by firms is to allow us to use the results on measurement in AB2018 directly. Specifically, in that paper we showed that the dynamics of aggregate productivity following a policy-induced change in innovative investment could, under certain conditions, be characterized by two sufficient statistics: the extent of intertemporal knowledge spillovers ϕ and the impact elasticity Θ of aggregate productivity growth with respect to changes in aggregate innovative investment, with the latter evaluated around the initial BGP.

In this version of the model, we must add additional parameters to specify corporate profits taxes. Specifically, we must add parameters $\lambda_e \geq 0$ and $\lambda_i \geq 0$ characterizing the extent to which entering firms and incumbent firms can deduct their expenditures on innovative investment from their taxed corporate profits. The more empirically plausible case is that incumbent firms can deduct all of their innovative investments ($\lambda_i = 1$). We discuss the case in which entrants can also deduct their investments ($\lambda_e = 1$) and not ($\lambda_e = 0$). These parameters λ_e and λ_i remain unchanged to the change in the corporate profits tax.

With these parameters of corporate tax policies, the value function for incumbent firms given in equation (55) of AB2018 has the first line of that equation, representing the dividend to the owner of the firm, now given by

$$(1 - \tau)\pi_t(z) - (1 - \tau\lambda_i)P_{rt}[x_m + x_e]$$

with all other terms in that equation remaining the same. This value function simplifies as in equation (61) of AB2018 to

$$(5) \quad V_t = \max_{x_m, x_c \geq 0} (1 - \tau) \frac{\mu - 1}{\mu} Y_t - (1 - \tau\lambda_i) P_{rt}[x_m + x_e] + \frac{1}{1 + R_t} V_{t+1} [\eta_m h(x_m) + (1 - \delta_{ct}) \zeta(x_c)] \frac{Z_t^{\rho-1}}{Z_{t+1}^{\rho-1}}$$

Equation (54) in AB2018 characterizing the zero-profits at entry condition for entering firms is now given by

$$(6) \quad (1 - \tau\lambda_e) \frac{P_{rt}}{M_t} \geq \frac{1}{1 + R_t} V_{t+1} \frac{\eta_e Z_t^{\rho-1}}{M_t Z_{t+1}^{\rho-1}}$$

In the first version of the model discussed above in which the levels of real innovative investment $\bar{x}_m, \bar{x}_c, \bar{x}_e$ are exogenously specified, aggregate real innovative investment \bar{Y}_r is also exogenously specified from equation (27) in AB2018. In this second specification of the model, we calibrate the parameters of the economy so that the endogenous allocation of innovative investment on the initial BGP is equal to the allocation exogenously specified here.

To solve for the innovation intensity on the initial balanced growth path, $Y_{rt}P_{rt}/Y_t$, we need only solve for the value of P_{rt}/Y_t on the balanced growth path using an

appropriately modified version of equations (76) and (77) of AB2018. Specifically, on a balanced growth path, with $\bar{v} \equiv \bar{V}_t/\bar{Y}_t$, we have

$$(7) \quad \bar{v} = \left[(1 - \tau) \frac{\mu - 1}{\mu} - (1 - \tau \lambda_i) \frac{\bar{P}_{rt}}{\bar{Y}_t} [\bar{x}_m + \bar{x}_c] \right] \times \left[1 - [(1 - \delta_0 - \delta_m h(\bar{x}_m) - \delta_e \bar{x}_e) \zeta(\bar{x}_c) + \eta_m h(\bar{x}_m)] \frac{\exp(\bar{g}_Y - (\rho - 1)\bar{g}_Z)}{1 + \bar{R}} \right]^{-1}$$

and

$$(8) \quad (1 - \tau \lambda_e) \frac{\bar{P}_{rt}}{\bar{Y}_t} = \frac{\exp(\bar{g}_Y - (\rho - 1)\bar{g}_Z)}{1 + \bar{R}} \bar{v} \eta_e$$

As discussed in AB2018 Appendix page 15, these two equations have a unique solution for the ratio $\frac{\bar{P}_{rt}}{\bar{Y}_t}$. The level of aggregate productivity consistent with this BGP is then given as in equations (78) and (79) of AB2018.

Note that we use equation (8) to infer the innovative intensity of entering firms $\bar{P}_{rt}\bar{x}_e/Y_t$ when we calibrate the overall innovative intensity of the economy \bar{i}_r .

We now describe how we solve for the change in the innovation intensity of the economy, $Y_{rt}P_{rt}/Y_t$, across BGPs. Since the levels of real innovative investment by incumbents \bar{x}_m, \bar{x}_c are exogenously specified, then investments by entrants \bar{x}_e must also be unchanged across BGP in order to obtain a constant aggregate productivity growth rate, \bar{g}_Z . Therefore, \bar{Y}_r is unchanged and the change in the innovation intensity of the economy is determined by the change in P_{rt}/Y_t across BGPs, which can be calculated using equations (7) and (8).

If $\lambda_e = \lambda_i = 1$, then innovative investments are unchanged relative to output across BGPs, that is $\log \bar{i}'_r - \log \bar{i}_r = 0$. If, on the other hand, $\lambda_e = 0$ and $\lambda_i = 1$, the log change in \bar{i}_{rt} across BGPs is, up to a first-order approximation,

$$\log \bar{i}'_r - \log \bar{i}_r = [\log(1 - \tau') - \log(1 - \tau)] \times \bar{\text{div}}/\bar{\text{prof}},$$

where $\bar{\text{div}}/\bar{\text{prof}} = \left[(1 - \tau) \frac{\mu - 1}{\mu} - (1 - \tau \lambda_i) \frac{\bar{P}_{rt}}{\bar{Y}_t} [\bar{x}_m + \bar{x}_c] \right] / \left[(1 - \tau) \frac{\mu - 1}{\mu} \right] \leq 1$. If innovative investments by incumbents are zero ($\bar{\text{div}}/\bar{\text{prof}} = 1$) then we obtain the same expression for the change in innovative investments relative to output as for physical investment relative to output in equation (4) when physical investment cannot be expensed. More generally, the response of innovative investments relative to output across BGPs is decreasing in the ratio of innovative investment by incumbents relative to output. When we compute the model numerically, we take into account the transition arising from changes in the interest rate and the price of the research good.

In this version of the model in which only investment by entrants changes in response to tax policies, we have that the dynamics are qualitatively the same as those implied by the simple model studied in section 3 of AB2018. Specifically, we can use Proposition 1 in AB2018 to characterize the impact of changes in corporate profits taxes on aggregate productivity in the long run once we have used equations

(7) and (8) above to solve for the change in the innovation intensity of the economy across BGP's induced by the change in taxes.

We solve for the dynamics of aggregate productivity as the economy transitions from one BGP to another. As shown in Proposition 2 of AB2018, the impact elasticity Θ plays an important role in shaping these dynamics of aggregate productivity.⁴ In this version of the model in which only investment by entrants can change along the transition path, we have, from equation (30) of AB2018 that the impact elasticity $\Theta = \Theta_e$. In terms of measurement, Θ_e is given as in equation (36) of AB2018. We consider two alternative values of Θ_e , determined by the degree of business stealing (δ_e), as described in Appendix C.1 and Appendix C.2 of AB2018.

The dynamics of aggregate output given the path for the allocation of labor are described as in Lemma 1. The impact of this transition on welfare is given as in Lemma 2.

2.3. Model with endogenous investment by entering and incumbent firms.

In the third version of our model, with endogenous investment by entering and incumbent firms, we must take into account the fact that a change in corporate tax policies will lead to a reallocation of innovative investment across the three different types of investment. As discussed in Proposition 6 of AB2018, this can impact the dynamics of aggregate productivity. Equation (56) in the proof of Proposition 1 in AB2018 indicates that a change in aggregate real innovative investment \bar{Y}_r across BGP's, which can occur only if there is a reallocation of this investment, also impacts our model's implications for the response of aggregate productivity in the long run. Quantitative analysis of the impact of policies in this case requires us to specify the technologies for innovative investment by incumbent firms $h(\cdot)$ and $\zeta(\cdot)$.

We solve for the impact of changes in policies on the allocation of innovative investment as follows. The analogs of equations (64) and (65) in AB2018, derived from the first order conditions of the incumbent firm's profit maximization problem (5) and the zero profits at entry condition (6) above, are

$$(9) \quad \frac{1 - \tau\lambda_i}{1 - \tau\lambda_e}\eta_e = (1 - \delta_{ct})\zeta'(x_{ct})$$

and

$$(10) \quad \frac{1 - \tau\lambda_i}{1 - \tau\lambda_e}\eta_e = \eta_m h(x_{mt})$$

We have in addition equations (27) and (28) from AB2018 given real aggregate innovative investment Y_{rt} and the growth rate of aggregate productivity g_{zt} . To solve for the allocation of innovative investment on a BGP corresponding to a specification of tax policy, we set $g_{zt} = \bar{g}_z$ in equation (28) from AB2018 and solve

⁴Note that in Proposition 2, we take the transition path for the allocation of labor between production and research as given. Here we take the change in policy as given and solve for the endogenous transition path for the allocation of labor.

these four equations for the allocation of innovative investment $\bar{x}_c, \bar{x}_m, \bar{x}_e$ and \bar{Y}_r . In solving for the transition of the economy from one BGP to another, we use these four equations together with the production function for the research good equation (8) in AB2018 to solve for the allocation of innovative investment at time t and the growth rate of aggregate productivity as a function of the allocation of labor to research L_{rt} and the state variables A_{rt} and Z_t . More details on this procedure for solving the model given fixed policies are given in Appendix C.4 of AB2018.

The impact elasticities $\Theta_c, \Theta_m,$ and Θ_e are given from equations (66), (67), and (68) in AB2018. Now, without further restrictions on policies, we cannot assume that the initial allocation of innovative investment is conditionally efficient, so we cannot apply Proposition 5 of AB2018. Nor can we assume that the change in policies is proportional, so we cannot use the results of Proposition 7 or its Corollary 2. Instead, we must use the results in Proposition 6.

Here we can only conduct numerical experiments since we do not have convincing evidence to calibrate the elasticities of the technologies for innovative investment by incumbent firms $h(\cdot)$ and $\zeta(\cdot)$. We provide examples of economies in which $\bar{Y}'_r \leq \bar{Y}_r$ and $\Theta_e > \Theta_c$, so that a change in tax policies that encourages entry results in an increase in productivity growth in the transition and an amplified response of aggregate productivity in the long run. We also provide examples of economies in which $\bar{Y}'_r > \bar{Y}_r$ and $\Theta_e < \Theta_c$, so that a change in tax policies that encourages entry results in a decrease in the level of aggregate productivity in the long run.

3. CALIBRATION

Relative to the calibration in AB2018 (described in Section 6 and in the Appendix), we consider the following changes:

First, we set to zero the production subsidy, τ_y , which is introduced in AB2018 to eliminate the distortion in physical capital accumulation due to the markup and the corporate profits tax.

Second, to focus on the role of the corporate profits tax as an innovation policy, we abstract from other innovation subsidies that we considered in AB2018.

Third, we follow BF2018 in setting the corporate profit tax rates, $\tau = 0.38$ and $\tau' = 0.26$. We allow for a full or partial deduction of investments (of both physical investment and innovative investments) from the base of the tax.⁵ Specifically, we assume that incumbent firms can deduct all of their innovative investments ($\lambda_i = 1$), while entering firms cannot ($\lambda_e = 0$) since they are not incorporated at the time of their investments. We set the value of the extent of physical investment expensing in the initial BGP to $\lambda_k = 0.87$ to target a capital-output ratio of

⁵In contrast to AB2018, we do not pick the corporate profit tax rates to match the ratio of payments of taxes on income and wealth relative to the tax base of the corporate profits tax in the data.

$K/Y = 2.12$ as in AB2018. We choose the new value $\lambda'_k = 1$ to match the change in the user cost of capital across BGPs implied by the BF2018 calibration (so that the increase in the log of the output/capital ratio across BGPs is equal to 0.08) .

As in AB2018, we consider parameterizations of the model with and without business stealing (or, equivalently, with a high and a low contribution of entering firms to growth), as well as parameterizations with low and high intertemporal knowledge spillovers ($\phi = -1.6$ and $\phi = 0.96$). In each case, we report results in the model specifications with exogenous and with endogenous innovation by incumbent firms. In the latter case, we follow AB2018 (page 28 of the Appendix) in setting the parameters that shape curvatures of the functions $h(\cdot)$ and $\zeta(\cdot)$.

Table 1 reports the impact elasticities in the new BGP, Θ' , implied by each model specification given our policy experiment. In the specification of the model with endogenous entry only, we have that $\Theta' = \Theta = \Theta_e$, where Θ_e is given in equation (36) in AB2018. With no business stealing, Θ is given as in equation (38) in AB2019. With business stealing, we use the procedure described in the paragraph immediately below equation (38) to calculate Θ . In the specification of the model with endogenous entry and innovation by incumbents, we calculate Θ' using the formulas in Proposition 6 of AB2018, given our policy changes. The magnitude of the impact elasticities do not vary much across the second and third versions of our model, and moreover, are not significantly different to the values in AB2018.

TABLE 1. Impact elasticities in the new BGP, Θ'

	Endogenous entry	Endogenous entry and incumbents
No business stealing	0.0297	0.0277
With business stealing	0.0111	0.0128

4. RESULTS

In all of the experiments that we consider, we assume that the change in corporate profits taxes is unanticipated and permanent, and solve for the full transition dynamics of our economy from the BGP corresponding to the initial tax policy to the BGP corresponding to the new tax policy.

Across all of the specifications of our model that we consider, the change in corporate profits taxes leads to an increase in the ratio of physical investment to output both in the long run and in the transition to the new BGP. For the two specifications of our model in which innovative investment by firms is endogenous, the change in corporate profits taxes also leads to an increase in the innovation intensity of the economy in the long run. In most of the cases that we consider, it

also leads to an increase in the innovation intensity of the economy in the transition to the new BGP.

We report on these dynamics of physical and innovative investment in Figures 1 and 2. In these figures, we see that the ratio of physical investment to output increases by roughly 1.4 percentage point between BGPs, while the innovation intensity of the economy increases between 0.3 and 0.8 percentage points across BGP, depending on the model specification. Transition dynamics in these ratios are driven by changes over time in the interest rate and in the price of the research good (with a low ϕ , the price of the research good rises quickly over time, which gives incentives to firms to front-load their innovative investments).

Table 2 reports the log change in aggregate productivity (relative to its BGP path) in the first ten years of the transition and in the long run for each of our model specifications described above. Table 3 reports similar information for aggregate output, and Table 4 for welfare (equivalent variation in consumption). We display the path of aggregate productivity and output in the first 100 years of the transition in Figures 3 and 4.

Consider first the results from our version of a standard model with exogenous productivity. By construction, the response of aggregate productivity reported in the first row of Table 2 is zero at all horizons. In the first row of Table 3, we find that output per worker rises by 2.6% in the long run relative to the path for output per worker that would have occurred on the BGP corresponding to the old tax policy. In the first ten years of the transition, output per worker rises by 1.9% relative to its BGP trend corresponding to the old tax policy (in BF2018, output per worker rises by 1.2% in the first years of the transition in response to a permanent policy change). The impact of the change in corporate profits taxes in this version of our model is reported in the first row of Table 4. Here, the consumption equivalent change in welfare is 0.4%.

We report the analogous results for the second version of the model in which only entrants choose their innovative investment in the second row of Tables 2, 3 and 4. As discussed above, the change in corporate tax policy increases the innovation intensity of the economy in the long run from 0.088 on the initial balanced growth path to 0.096 on the new BGP. From Proposition 1 of AB2018, the magnitude of the change in aggregate productivity in the long run brought about by this change in the innovation intensity of the economy is determined by the degree of intertemporal knowledge spillovers. If these spillovers are high (so that the model is close to an endogenous growth model), then the impact on aggregate productivity in the long run is very large: the ratio of aggregate productivity on the new BGP relative to the initial BGP is 6.85. (The log of this ratio is reported in the table). If these spillovers are small, as argued by Jones and others, then the impact on aggregate productivity in the long run is not very large (the ratio of aggregate productivity on the new BGP relative to the initial BGP is 1.03). These long run effects are reflected in the model's implications for welfare (taking

into account the full transition dynamics), which can be very large if spillovers are high.

The dynamics of aggregate productivity and output over the first 100 years of the transition to the new BGP for this version of our model are shown in Figure 3. As we can see from this figure, the dynamics of output in the first decade of the transition are not very sensitive to the extent of intertemporal knowledge spillovers. Specifically, as we see in the second row of Table 3, the response of aggregate output over ten years is between 1.6% and 3.4%, depending on parameter values. These responses of aggregate output are similar to those shown for the standard model with exogenous TFP in the first row of the Table (the predictions for the change in output after 10 years are within 1.5 percentage points of the change predicted from the model with exogenous productivity). Note that aggregate productivity does rise over ten years by in this specification of our model (by between 0.7% and 2.4%, as shown in the second row of Table 2), but the impact of the policy on output is muted because labor is reallocated from current production to research. Note as well that the model with business stealing implies a smaller response of aggregate productivity and output because the impact elasticity of entry is lower in this case.

We report the results for the third version of the model in which both entrants and incumbents choose their innovative investment in the third row of Tables 2, 3 and 4. The results for this specification of our model differ from those for the previous specification in that aggregate productivity, output, and welfare may rise by more or by less (or even fall) relative to what we found in our two previous specifications. To be more specific, note that the change in corporate profits tax policies reallocate innovative investment from incumbent to entering firms. The share of innovative investment by entering firms in total innovative investments is 30.2% in the initial BGP, 47.8% in the new BGP without business stealing, and 58.1% in the new BGP with business stealing. Whether or not reallocation of investment towards entry is desirable in our model depends on the extent of business stealing and the extent to which the initial corporate profits tax policies had favored investment by incumbent firms over investment by entering firms on the initial BGP. If the initial tax policy had favored investment by incumbent firms and the extent of business stealing by entrants is low, then the increase in investment in entry induced by the change in corporate tax policies is likely to improve the efficiency of any given level of aggregate innovative investment and hence amplify the positive effects of the tax change on aggregate productivity growth. If the initial tax policy did not have a strong bias in favor of investment by incumbent firms and the extent of business stealing by entering firms is large, then the increase in investment in entry induced by the change in corporate tax policies is likely to worsen the efficiency of any given level of aggregate innovative

investment and hence dampen the positive effects of the tax change on aggregate productivity growth or even make them negative.⁶

The change in aggregate productivity over a ten year horizon can be either positive (without business stealing) or negative (with business stealing). In both cases, the magnitude of changes in aggregate productivity is modest: roughly +3% without business stealing and -2% with business stealing. Relative to the model with fixed productivity growth, the change in output per worker over a ten year horizon can be slightly larger (+3% without business stealing) or slightly lower (-2% with business stealing). These changes in aggregate productivity and output over a ten year horizon are not very sensitive to the degree of intertemporal knowledge spillovers. However, the change in aggregate productivity and welfare can be very large in absolute terms (positive without business stealing and negative without business stealing) if spillovers are high.

We also construct, as in AB2018, histograms of the change in aggregate productivity and output after ten years of the policy reform, obtained from 3,000 simulations of our model with the addition of Hicks-neutral AR1 productivity shocks with a persistence of 0.9 and an annual standard deviation of 0.018. We introduce these shocks as a proxy for business cycle shocks around the BGP. These histograms are reported in Figure 5. These histograms illustrate how the magnitude of the changes to output and productivity that we forecast at a ten year horizon in the Tables above are not very large relative to business cycle variation in these variables, regardless of parameters.

⁶The logic of this negative effect of increased entry on aggregate productivity growth is related to that discussed in Acemoglu and Cao (2015).

TABLE 2. Aggregate Productivity

	10 years		Long run	
	$\phi = -1.6$	$\phi = 0.96$	$\phi = -1.6$	$\phi = 0.96$
1. Exogenous productivity	0	0	0	0
2. Endogenous entry				
No business stealing	0.024	0.020	0.03	1.92
With business stealing	0.009	0.007	0.03	1.92
3. Endogenous entry and incumbents				
No business stealing	0.030	0.026	0.04	2.45
With business stealing	-0.017	-0.015	-0.04	-2.46

TABLE 3. Aggregate Output

	10 years		Long run	
	$\phi = -1.6$	$\phi = 0.96$	$\phi = -1.6$	$\phi = 0.96$
1. Exogenous productivity	0.019	0.019	0.026	0.026
2. Endogenous entry				
No business stealing	0.034	0.029	0.05	2.58
With business stealing	0.016	0.017	0.07	2.60
3. Endogenous entry and incumbents				
No business stealing	0.047	0.040	0.07	3.28
With business stealing	0.002	0.002	-0.03	-3.26

TABLE 4. Long run welfare (equivalent variation)

	$\phi = -1.6$	$\phi = 0.96$
1.Exogenous productivity	0.004	0.004
2.Endogenous entry		
No business stealing	0.03	0.17
With business stealing	0.02	0.07
3. Endogenous entry and incumbents		
No business stealing	0.04	0.22
With business stealing	-0.04	-0.11

FIGURE 1. Investment (endogenous entry only)

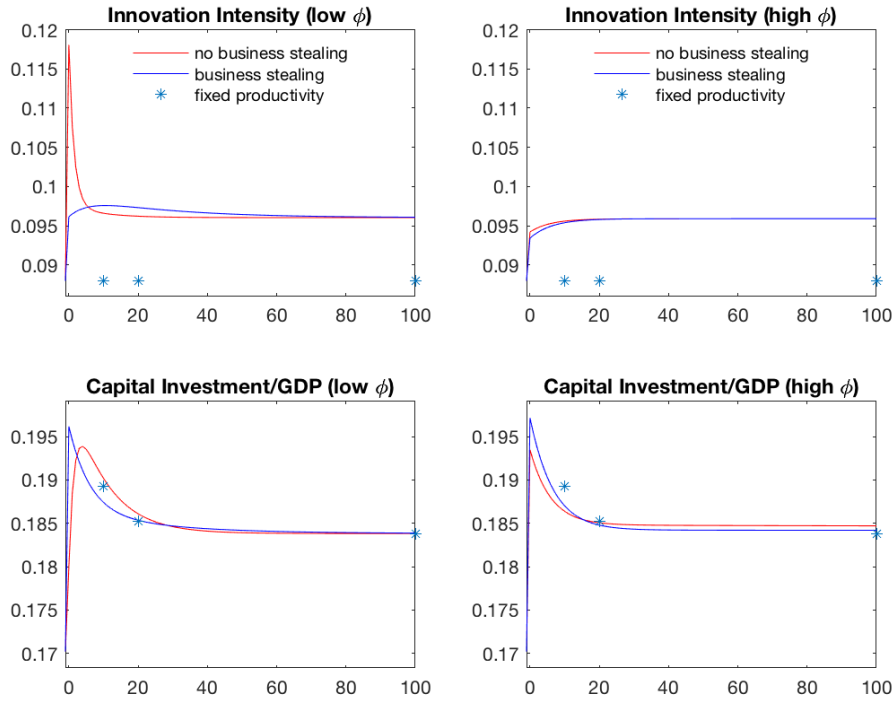


FIGURE 2. Investment (endogenous entry and innovation by incumbents)

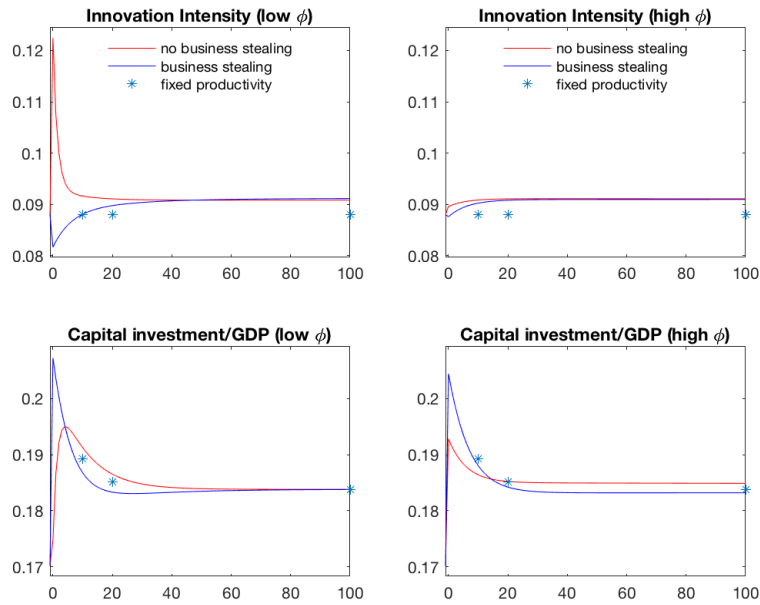


FIGURE 3. Productivity and output (endogenous entry only)

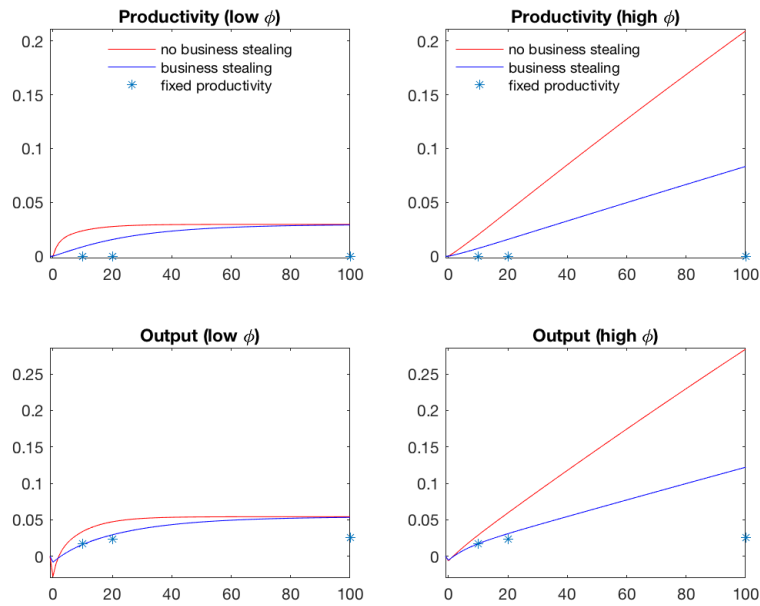


FIGURE 4. Productivity and output (endogenous entry and innovation by incumbents)

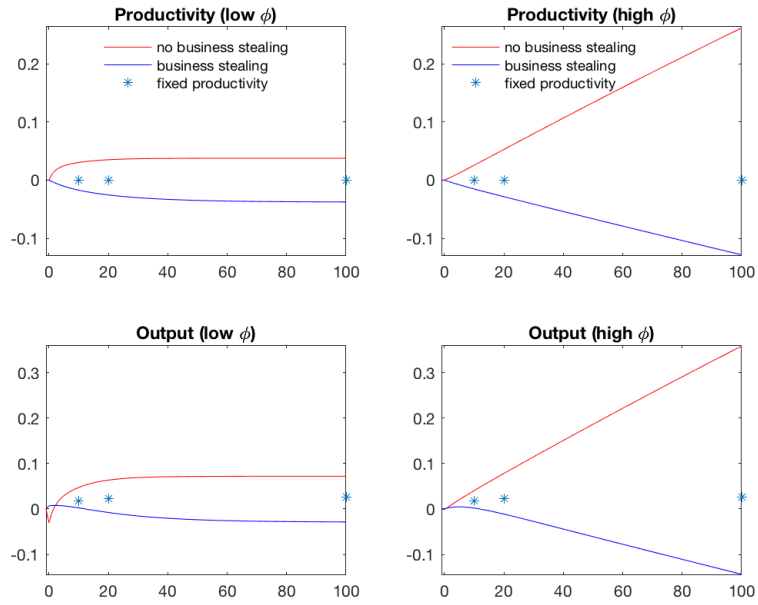


FIGURE 5. Histogram of changes in aggregate output and productivity at 10 year horizon.

