Aggregate Implications of the Tax Reform of 2017: Can Taxes Guide Technology?

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Abstract

This paper analyzes the effects of the US tax reform of 2017 using a model of endogenous technological adoption. The lower tax levels induce large human capital investments that are augmented by the endogenous transition towards skill biased technologies.

Keywords: Endogenous Skill Biased Technical Change, Tax Policy

JEL Classifications: E23, E25, E65, J24, O33.

1 Introduction

This paper uses a model of endogenous technological adoption (in its skill bias) to capture the long term implications of the the tax reform of 2017, once technology is optimally chosen.

The main result is that, once technology is endogenous, the impact of changes in taxation (its progressivity and relative composition between capital and labor sources) on economic aggregates differs from that of the standard model. In particular, the model with endogenous technology generates a substantially larger reaction of the stock of skilled workers and a smaller increase of the capital stock. All this while preserving the impact of taxation on output, skill premium and consumption.

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2 The Tax Reform of 2017

Barro and Furman (2018) describe the tax reform of 2017 as “the most sweeping set of tax changes in a generation”. The new tax law altered the individual rates and brackets, simplified the system in general. On the corporate tax, the law reduced the income tax rate from 35% to 21%, as well as changing expensing dynamics related to investments.

In order to conduct the analysis as clean as possible, tax rates are obtained for the same individual both in 2017 (old tax regime), and in 2018 (under the new law).

Table 1 shows the income and taxation levels for a single individual with no children under the old tax regime. It shows what an individual earning 67%, 100% and 167% of average earnings would be earning and paying in taxes. Table 1 shows taxes to the central (federal) government, as well as total taxes paid.

Table 1: Taxation for a single individual with no children in 2017

<table>
<thead>
<tr>
<th>Average Earnings</th>
<th>67%</th>
<th>100%</th>
<th>167%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Gross Earnings</td>
<td>$35,502</td>
<td>$52,988</td>
<td>$88,490</td>
</tr>
<tr>
<td>Central Gov’t Income Tax paid</td>
<td>$3,299</td>
<td>$6,386</td>
<td>$15,261</td>
</tr>
<tr>
<td>Central Gov’t Income Tax rate</td>
<td>9.29%</td>
<td>12.05%</td>
<td>17.25%</td>
</tr>
<tr>
<td>Total payments to general Gov’t</td>
<td>$8,191</td>
<td>$13,769</td>
<td>$27,731</td>
</tr>
<tr>
<td>Average Income Tax Rate</td>
<td>15.42%</td>
<td>18.35%</td>
<td>23.69%</td>
</tr>
<tr>
<td>Average Tax wedge</td>
<td>29.21%</td>
<td>31.70%</td>
<td>36.46%</td>
</tr>
</tbody>
</table>


Table 2 shows the taxes that an individual making the same amounts as in table 1 would have to pay to the federal government under the new tax law. The last row of table 2 shows the percentage point difference for each of these individuals in terms of federal income tax due to the change in the tax regime.
Table 2: Taxation for a single individual with no children in 2018

<table>
<thead>
<tr>
<th>Average Earnings</th>
<th>67%</th>
<th>100%</th>
<th>167%</th>
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<tr>
<td>Total Gross Earnings</td>
<td>$35,502</td>
<td>$52,988</td>
<td>$88,490</td>
</tr>
<tr>
<td>Central Gov’t Income Tax paid</td>
<td>$2,633</td>
<td>$4,954</td>
<td>$12,764</td>
</tr>
<tr>
<td>Central Gov’t Income Tax rate</td>
<td>7.42%</td>
<td>9.35%</td>
<td>14.42%</td>
</tr>
<tr>
<td>Income Tax rate change</td>
<td>-1.88%</td>
<td>-2.70%</td>
<td>-2.82%</td>
</tr>
</tbody>
</table>


Finally, table 3 shows the income tax rates for corporation before and after the change. It shows the federal tax, as well as the combined (to all government levels) tax rate.

Table 3: Statutory Corporate Income Tax Rate

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2018</th>
<th>Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corporate Income Tax Rate (Central Gov’t)</td>
<td>35.00%</td>
<td>21.00%</td>
<td>-14.00%</td>
</tr>
<tr>
<td>Combined Corporate Income Tax</td>
<td>38.91%</td>
<td>25.84%</td>
<td>-13.07%</td>
</tr>
</tbody>
</table>


3 Model

In the model, households and firms interact to endogenously determine the stocks of human and physical capital as well as the endogenous skill bias in production.\(^1\)

3.1 Households

A set of atomistic representative households own capital and labor. They rent capital, skilled labor and unskilled labor to the firm every period. The capital and skilled labor they own is of type \(b\) and can only be used in production in a type \(b\) firm. They make investment and

\(^1\)The planner’s version of this model was proposed in Moscoso Boedo (2010) to analyze the post WWII performance of the US while matching the evolution of the skill premium and the cross country dispersion of skill premium around 1990, and in Moscoso Boedo (2018) to explain the main features seen after the collapse of the Soviet Union.
education decisions. That means that the household decides how much capital, skilled labor and unskilled labor supply to the market given prices, and the part of capital, skilled labor and unskilled labor that is not supplied is used to produce more skilled labor for next period. Every period the type of the physical capital and skills the household owns is given but can be changed for the future, so the household not only chooses the evolution of the quantity of physical capital and skilled labor but also its type for the future.

So, the problem of the representative household can be written as follows

$$\max \{C_t, I_t, S_{pt}, U_{pt}, K_{pt}, S_{et}, U_{et}, K_{et}, b_{t+1}\} \sum_{t=0}^{\infty} \beta^t u(C_t)$$ (1)

subject to

$$C_t + I_t \leq (1 - \tau_{st}) w_{st} S_{pt} (b_t) + (1 - \tau_{ut}) w_{ut} U_{pt} + (1 - \tau_{kt}) r_b K_{pt} (b_t) + Tr_t$$

$$S_t (b_t) \geq S_{pt} (b_t) + S_{et} (b_t)$$

$$U_{pt} + U_{et} \leq 1 - S_t (b_t)$$

$$K_t (b_t) \geq K_{pt} (b_t) + K_{et} (b_t)$$

$$S_{t+1} (b_{t+1}) \leq S_t [1 - \delta_s - G (b_t, b_{t+1})] + H (K_{et} (b_t), S_{et} (b_t), U_{et})$$

$$K_{t+1} (b_{t+1}) \leq K_t [1 - \delta_k - G (b_t, b_{t+1})] + I_t$$

Where $C_t$, $I_t$ denote consumption and investment in period $t$ respectively. $S_{pt}$, $U_{pt}$ and $K_{pt}$ denote skilled workers, unskilled workers and capital devoted to final production and $S_{et}$, $U_{et}$ and $K_{et}$ denote skilled workers, unskilled workers and capital into education. $b_t$ indexes the technology active in the final production sector in period $t$. $w_{st}$, $w_{ut}$ and $r_b$ stand for wages for skilled workers, unskilled workers and interest rate in period $t$ under technology $b$. Taxes are denoted by $\tau_{st}$, $\tau_{ut}$ and $\tau_{kt}$ where subscript $s$ denotes taxes on skilled workers, $u$
taxes on unskilled workers and $k$ taxes on capital income. The household will also be entitled to a transfer by the government which will be taken as given and is denoted by $Tr_t$. Finally, the function $G(b_t, b_{t+1})$ denotes de accelerated depreciation due to technological change.

### 3.2 Firms

Final goods producing firms can be ordered according what technology they operate, by the parameter $b$. Firms operate for one period, that is they have a static problem. They rent unskilled labor, skilled labor and capital of type $b$ from the household in order to maximize profits. In other words in every period there is demand for unskilled labor, skilled labor and capital of every type $b$, $0 < b < 1$. The market under which firms operate is perfectly competitive. So problem each firm of type $b$ solves is:

$$
\max_{\{S_{pt}(b), U_{pt}, K_{pt}(b)\}} pt F(b, K_{pt}(b), S_{pt}(b), U_{pt})
- ws_{pt} S_{pt}(b) - wu_{pt} U_{pt} - r_{pt} K_{pt}(b)
$$

So the optimal conditions for each type $b$ firm are:

$$
\frac{w_{str}}{p_t} = F_{S_p}(b, K_{pt}(b), S_{pt}(b), U_{pt})
\frac{w_{unr}}{p_t} = F_{U_p}(b, K_{pt}(b), S_{pt}(b), U_{pt})
\frac{r_{ln}}{p_t} = F_{K_p}(b, K_{pt}(b), S_{pt}(b), U_{pt})
$$

Where $p_t$ stands for the price of final goods, which is normalized to 1. So, for every $b$-type firm, their maximizing behavior determines wages and interest rate under each technology. Therefore at every moment in time we have a function of wages and interest rate as function of the parameter $b$. 

5
3.3 Government

The government will have a very passive role in the model. It will only collect taxes and redistribute income through transfers. The government will run a balanced budget every period therefore the budget constraint of the government given by:

\[ \tau_{sts}w_{sbt}S_{pt}(bt) + \tau_{uts}w_{utb}U_{pt} + \tau_{ktb}r_{b}K_{p}(bt) = Tr_{t} \]

3.4 Equilibrium

Given taxes and transfers, an equilibrium is defined by a sequence of prices \( \{w_{sbt}, w_{utb}, r_{b}\}_{t=0}^{\infty} \), allocations \( \{C_{t}, I_{t}, S_{pt}, U_{pt}, K_{pt}, S_{et}, U_{et}, K_{et}\}_{t=0}^{\infty} \) and technology parameters \( \{b_{t}\}_{t=0}^{\infty} \), such that:

1. Households maximize utility. That is they solve the problem defined by equation (1).

2. Firms maximize profits. That is, for every technology parameter, equations (2) are satisfied.

3. Initial conditions. That is \( b_{0}, S_{0}, \) and \( K_{0} \), are given.

4. Feasibility: \( C_{t} + I_{t} \leq F(S_{pt}, U_{pt}, K_{pt}, b_{t}) ; 0 \leq b_{t} \leq 1 ; 0 \leq S_{pt} + S_{et} \leq 1 \)

5. Balanced budget of the government: \( \tau_{s}w_{sbt}S_{pt}(bt) + \tau_{ut}w_{utb}U_{pt} + \tau_{rtb}r_{b}K_{p}(bt) = Tr_{t} \)

Since household are identical they all make the same decision, so only one type of skills and physical capital is supplied in the market, therefore only one firm actually operates in the market.

3.5 Functional forms

The model stated above requires the choice of functional forms for the functions \( u(\cdot) \), \( F(\cdot) \), \( G(\cdot) \), and \( H(\cdot) \).
The instantaneous utility function is assumed to be of the following form:

\[ u(C_t) = \frac{C_t^{1-\phi}}{1-\phi} \]

The technology adjustment cost function \( G() \) is given by

\[ G(b_t, b_{t+1}) = e^{\zeta \left( \frac{b_{t+1}}{b_t} - 1 \right)^2} - 1 \] (3)

This function satisfies the requirements stated above, \( G(b_t, b_t) = 0 \) and \( G(b_t, b_{t+1}) > 0 \) for \( b_t \neq b_{t+1} \).

Note that the function \( G(b_t, b_{t+1}) \) is convex. Also note that it has the property that its derivatives in steady state are equal to zero. The function \( G(b_t, b_{t+1}) \) is affected by only one parameter, \( \zeta \). As \( \zeta \) increases the costs associated with technological change (in terms of skilled workers and physical capital), increase, affecting the dynamic transition of the model (while not in steady state).

The production function of final goods, \( F(.,.) \), follows the functional form of choice in Funk and Vogel (2004), and it will be calibrated to moments estimated by Krusell et al. (2000), while inducing skill biased technical change as a result of total factor productivity improvements.

The production function used in the quantitative exercise is given by

\[ F(b_t, K_{pt}, S_{pt}, U_{pt}) = z_t \left\{ b_t \left[ aU_{pt}^{\rho_1} + (1 - a) K_{pt}^{\rho_1} \right]^{\frac{\mu}{\rho_1}} + (1 - b_t) S_{pt}^{\rho_2} \right\}^{\frac{1}{\rho_2}} \] (4)

Finally the function \( H() \) is assumed to be Cobb-Douglas:

\[ H(U_{et}, S_{et}, K_{et}) = \psi U_{et}^{\mu} S_{et}^{\xi} K_{et}^{1-\mu-\xi} \] (5)
4 Calibration

I calibrate the model to a steady state in the US in 2017, which uses the US tax schedule for 2017. A skilled worker is defined as one with tertiary education which is assumed to take four years. Moreover, in the model an unskilled worker is assumed to be taxed at rates obtained for the workers earning 67% of average earnings, and a skilled worker is taxed at rates observed for workers earning 167% of average earnings. Effectively assuming different income tax rates for different workers (according to skills). Because I only consider the steady state, there is one fewer parameter to be calibrated, $\zeta$. The match between the model and the data is shown in Table 5 and the parameters that implement that match are shown in Table 4. Some parameters are set according to the existing literature. For instance $\delta_k = .08$, $\beta = .96$, $\varphi = 2$ and following Manuelli and Seshadri (2014) $\delta_s = .02$.

Table 4: Parameter values in the model

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$z$</th>
<th>$\rho_1$</th>
<th>$\rho_2$</th>
<th>$a$</th>
<th>$\mu$</th>
<th>$\xi$</th>
<th>$\psi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>.3</td>
<td>.5</td>
<td>-.2</td>
<td>.3</td>
<td>.6</td>
<td>.1759</td>
<td>.18</td>
</tr>
</tbody>
</table>

Table 5: Comparison between the model and the data in 2017

<table>
<thead>
<tr>
<th>Moment</th>
<th>Model</th>
<th>Data US, 2017</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill Premium</td>
<td>1.72</td>
<td>1.83</td>
</tr>
<tr>
<td>Skilled workers</td>
<td>.277</td>
<td>.275</td>
</tr>
<tr>
<td>Consumption Output Ratio</td>
<td>.88</td>
<td>.82</td>
</tr>
<tr>
<td>Students over Labor Force</td>
<td>.072</td>
<td>.095</td>
</tr>
<tr>
<td>Expenditure per pupil over GDP per worker</td>
<td>.19</td>
<td>.22</td>
</tr>
<tr>
<td>Capital Share of GDP</td>
<td>.34</td>
<td>.33</td>
</tr>
<tr>
<td>Wage expenditure in education</td>
<td>.704</td>
<td>.710</td>
</tr>
</tbody>
</table>

The data sources for the moment targeted in calibration are as follows. The skill premium
was obtained from Montenegro and Patrinos (2014) where they report an average return of 15.2% per year of tertiary education. The stock of skilled workers from Lee and Lee (2016), equal to people with college completed or more between the ages of 15 and 64 for the year 2010. The consumption output ratio is the ratio of Personal Consumption Expenditures to Personal income reported by the Bureau of Economic Analysis, in its table 2.1 for the year 2017. The ratio of students to labor force is calculated as the ratio of students enrolled in college times the participation rate over the total labor force, obtained from The Statistical Abstract of the US for 2011 (data taken for 2010). Expenditure per pupil over GDP per worker and wage expenditures in education were obtained from the Statistical Abstract of the US 2011 for the year 2008.

5 Impact of the tax reform

The tax reform is implemented as follows into the model. First an initial steady state is computed using the average tax wedges shown in table 1. The average tax wedges are taken for the individuals earning 67% and 167% as the labor income tax rates for the unskilled and skilled individuals respectively. For the new tax regime, we take the old regime average tax wedges and add the income tax rate change (shown in table 2). The tax on capital income is matched to the combined statutory corporate income tax rate shown in table 3. Note that firms in the model do not generate profits as they are perfectly competitive and use a technology that is homogeneous of degree one. In this environment, the only non-labor income generated by firms is captured by the return to capital. Table 6 shows the tax rates in the old and new tax regimes.
Table 6: Tax Rates

<table>
<thead>
<tr>
<th></th>
<th>$\tau_s$</th>
<th>$\tau_u$</th>
<th>$\tau_k$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Old Regime</td>
<td>36.46%</td>
<td>29.21%</td>
<td>38.91%</td>
</tr>
<tr>
<td>New Regime</td>
<td>33.63%</td>
<td>27.53%</td>
<td>25.84%</td>
</tr>
</tbody>
</table>

Table 7 shows the impact of changing permanently the taxes from the old regime to the new one in steady state. The exercise is performed in two steps. First, the solution to a model where technology is exogenously given is generated, and then one where the technological choice is open. This allows us to understand the role of the technological adoption mechanism vs. a standard, exogenous, production function.

Table 7: Model generated impact of taxation

<table>
<thead>
<tr>
<th></th>
<th>Old Regime</th>
<th>New Regime</th>
<th>New Regime</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Exogenous b</td>
<td>Endogenous b</td>
</tr>
<tr>
<td>Skill Premium</td>
<td>1.717</td>
<td>1.683</td>
<td>1.686</td>
</tr>
<tr>
<td>Stock of Skilled Workers</td>
<td>0.278</td>
<td>0.332</td>
<td>0.363</td>
</tr>
<tr>
<td>Capital Share</td>
<td>0.342</td>
<td>0.388</td>
<td>0.371</td>
</tr>
<tr>
<td>K/Y</td>
<td>1.717</td>
<td>2.366</td>
<td>2.262</td>
</tr>
<tr>
<td>Cons/Y</td>
<td>0.878</td>
<td>0.817</td>
<td>0.821</td>
</tr>
<tr>
<td>Y</td>
<td>1.000</td>
<td>1.270</td>
<td>1.274</td>
</tr>
<tr>
<td>(1-b)</td>
<td>0.350</td>
<td>0.350</td>
<td>0.387</td>
</tr>
<tr>
<td>K</td>
<td>1.000</td>
<td>1.750</td>
<td>1.679</td>
</tr>
</tbody>
</table>

Note: Author’s calculations. Model generated steady state comparison with exogenous skill bias parameter and endogenous skill bias parameter

The first significant implication of allowing the skill bias in technology to be endogenously determined is that physical capital is partially substituted by human capital the third column of figure 7. Compared to a model with an exogenous production function, the endogeneity in skill bias produces much larger increases in the stock of skilled workers, but lower increases in the stock of physical capital. This is done, while keeping the capital share, skill premium and capital output ratios relatively close to levels generated by the model without endoge-
nous technological choices. The key difference between both impacts, is that the skill bias parameter moves towards relatively skill intensive technologies, as $(1-b)$ increases by almost 11%.

Note that table 7 compares steady states across three different specification of the model. The transition between those specifications would be a function of the parameter $\zeta$, determining the destruction of production inputs given by the function $G(b_t, b_{t+1})$.

6 Conclusion

This paper shows that allowing for endogenous technological choices can have large implications in the aggregates. It uses the tax reform of 2017 in the US to calibrate the model and finds that the long term implications of the change is mostly seen as a partial substitution of physical capital by human capital, as the stocks of skilled workers increase substantially more in an environment where technology is optimally chosen. Also, the paper shows that the new tax law generates incentives towards additional increases in the skill bias in technology.

7 References


