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Macroeconomic and Distributional Effects of Personal Income Tax reforms: A Heterogenous Agent Model Approach for the U.S.

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Macroeconomic and Distributional Effects of Personal Income Tax reforms: A Heterogenous Agent Model Approach for the U.S.[1]

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Abstract

This paper assesses the macroeconomic and distributional impact of personal income tax (PIT) reforms in the U.S. drawing on a multi-sector heterogenous agents model in which consumers have non-homothetic preferences and sectors differ in terms of their relative labor and skill intensity. The model is calibrated to key characteristics of the US economy. We find that (i) PIT cuts stimulate growth but the supply side effects are never large enough to offset the revenue loss from lower marginal tax rates; (ii) PIT cuts do "trickle-down" the income distribution: tax cuts stimulate demand for non-tradable services which raise the wages and employment prospects of low-skilled workers even if the tax cut is not directly incident on them; (iii) A revenue neutral tax plan that reduces PIT for middle-income groups, raises the consumption tax, and expands the Earned Income Tax Credit can have modestly positive effects on growth while reducing income polarization; (iv) The growth effects from lower income taxes are concentrated in non-tradable service sectors although the increased demand

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for tradable goods generate positive spillovers to other countries; (v) Tax cuts targeted to higher income groups have a stronger growth impact than tax cuts for middle income households but significantly worsen income polarization, even after taking into account trickle-down effects and an expansion of the Earned Income Tax Credit.

JEL Classification Numbers: E62, H24, H3

Keywords: Fiscal Policy, Tax Changes, Tax Multipliers, Income, Income Distribution

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I. INTRODUCTION

The consensus is that reducing distortionary taxes on labor and capital income can stimulate economic activity by encouraging an increase in labor supply and higher savings. Indeed, the empirical literature on tax multipliers is vast and points to measurable effects of reducing taxes on output and employment[2]. There is less of a consensus on the dynamic effects of tax cuts and where their ultimate incidence may lie. Empirical results on the distributional impact of changes to the individual tax system in the U.S. have focused on the response of top income groups to changes in marginal tax rates (see Saez et al. (2012) for a review, and Mertens (2015)). There is also an extensive literature using micro-data models to capture the distributional effects based on a broad sample of household characteristics. Heterogenous agent models offer a natural way to address these questions simultaneously—to assess jointly the size of the aggregate multipliers and to trace out the general equilibrium distributional effects of changes to personal income taxes (See Guner et al. (2016), and references therein). Our approach extends recent contributions in the field by incorporating multiple-sectors, multiple goods, and households that are heterogenous in their skills and consumption preferences. This allows us, in a model calibrated to features of the U.S. economy to (i) examine the sectoral response of the economy to changes to the personal income tax and (ii) capture distributional implications across different types of households.

In line with Guner et al. (2016), this paper develops a DSGE model with household heterogeneity, driven by both permanent and transitory differences in labor productivity, and an endogenous labor supply. We add four new sources of heterogeneity which, to our knowledge, are absent from standard models.

- First, we assume that the economy produces three different goods - one manufacturing tradable good and two non-tradable services – that use different levels of labor. For instance, we assume that services are more labor intensive than manufactured goods.

- Second, we allow for cross-sectoral linkages through intermediate inputs, such that manufactured goods need a non-trivial amount of services to be produced (and vice-versa). These intermediate linkages are calibrated to match those that currently exist in the U.S. economy.

- Third, we assume that sectors differ in the kind of worker they employ (low-skilled, middle skilled or high-skilled). In particular, we distinguish between low-skill services, produced by people closer to the bottom of the income distribution, and high skill services, produced by people closer to the top of the distribution.

[2] See, for example, Mertens and Ravn (2013) and Barro and Redlick (2011).

- Fourth, consumers differ in the composition of their spending: as in the U.S. data, wealthier groups dedicate a higher share of their consumption expenditures on (non-tradable) services.

After documenting several stylized facts for the U.S., we estimate a benchmark economy that captures aggregate and cross-sectional features of the U.S. economy. The resulting stationary benchmark equilibrium matches macro-economic ratios in the data (e.g. investment to GDP, consumption to GDP, etc.), sectoral ratios (e.g. sectoral shares of output, the input output structure of the economy, etc.), *and* distributional statistics (e.g. tax incidence by income level, consumption by decile, and the composition of consumption by income group). Our focus on heterogeneity captures a richer, and more plausible, distributional and sectoral effects of individual income tax reforms in a dynamic optimizing model. As such, the model simulations can inform the discussion of what is the appropriate design of personal income tax changes based on stated policy objectives.

Following Benabou (2002), Heathcote et al. (2016) and Guner et al. (2016), federal income taxes are introduced in the model using a parametric tax function, which captures the effective tax rates paid at different levels of income. To account for the presence of an EITC in the current US system, the tax function is negative at lower levels of income and progressive, particularly for households earning less than 50 percent of the median income. We simulate three types of tax policy changes (i) A "middle-class tax cut" which reduces the effective tax rates for households earning between 0.5 to 4 times the median income and is offset by lower government spending; (ii) A "middle-class tax cut" and an EITC expansion that is fully financed by an increase in consumption taxes; (iii) tax cut for high income groups that is also combined with an EITC expansion and financed by a higher consumption tax.

Our key results are as follows:

- The model generates positive effects on growth, consumption and investment that are broadly in line with the recent empirical literature on PIT multipliers. Despite the positive macro response, supply side effects are never strong enough to prevent cuts from being revenue losing (i.e., tax cuts do not "pay for themselves").

- The macroeconomic effect is sensitive to where in the income distribution the tax cuts is targeted. A tax cut for the middle-class, financed from a lump-sum reduction in government spending, results in a loss of revenues of 0.8 percent of GDP but raises the steady state GDP by just under 1 percent after 5 years (i.e., a personal income tax multiplier of 1.1).

- Not surprisingly, the growth effects are smaller when lower personal income taxes are paid for with a VAT. Nonetheless, the shift from direct to indirect tax still has a positive impact on growth.

- PIT cuts do have important "trickle down" effects. Both middle *and* low income households profit from a tax cut that is targeted at middle income groups. The tax cut generates an increased demand for non-tradable services which raises the demand for—and the wages of—low-skilled labor. This trickle-down mechanism implies that tax cuts, at least when applied to the middle-class, can have a progressive impact in general equilibrium and help reduce income polarization.

- Tax cuts for higher income groups tend to have a stronger aggregate impact than tax cuts for the middle class. Indeed, in the simple case where the tax cuts are paid for by lump sum cuts in government spending, the personal income tax multiplier is around 3. However, such a tax reduction generates negative distributional effects. Even accounting for the trickle-down effects and allowing for an increase in the EITC to protect the poor, tax cuts that are incident on high income households increase income polarization.

- The size of the tax multiplier is very sensitive to the general equilibrium feed through to interest rates. For example, the growth response in a small (financially) open economy subject to a world interest rate is around one-half that of a closed economy where higher savings automatically generate lower interest rates and higher investment.

The results from our calibrated model are in line with that in the empirical. The model generates growth effects that are in the range of Barro and Redlick (2011) and Mertens and Ravn (2013), who estimated tax multiplier between 1.1 and 2.5. Our findings support the findings of Mertens (2015) that top marginal rate cuts have sizeable real economic effects and spill over to lower income groups.[3]

[3] Mertens (2015) documented that a top marginal rate cut for the top 1% implies a short run taxable income elasticity for the top 1% around 1.5, a rise in real GDP, a lower aggregate unemployment and positive effect on incomes outside of the top 1%.

II. Stylized Facts

This section documents two stylized facts about the US economy. First, the US can be thought of as producing and consuming broadly three "baskets" of goods and services: (i) primary and manufactured goods produced with little labor and highly tradable (ii) low-skilled services produced using a lot of labor and are mostly not tradable and (iii) high-skill services, which are partly tradable and use a combination of high and low skilled labor. Second, different households dedicate different shares of consumption to these different baskets. Specifically, the share of services in consumption rises rapidly with household income. These stylized facts are documented in turn, and will serve as a basis for the calibration of the model in Section III.

A. Heterogeneity in Goods and Production

Using Input-Output accounts data from NIPA provided by the BEA, we first construct three different metrics for the standard 15 commodities classification[4]: (i) the share of each commodity in US domestic demand (or absorption) (ii) the tradability of each commodity and (iii) the labor intensity of each commodity.

In practice, we compute the share of private (and public) consumption and investment of commodity *i* as a share of total US absorption using the 2015 "use table" after redefinitions and evaluated at producer prices.[5] Using the same table, we approximate the "tradability" of each commodity by computing the ratio of exports and imports of commodity *i* to the final US demand of commodity *i.* Finally, we assess the labor intensity of each commodity using the network-adjusted labor share of each commodity (thereafter NALI). Traditionally, measures of sectoral labor intensity are proxied at the industry level by taking the share of output that is devoted to employees' compensation. Although spending a dollar on commodity *i* does stimulate the industry *i*, such spending also stimulates other industries along the supply chain to a significant extent. Thus, using the standard industry-level labor intensity of industry *i* as a proxy for the labor intensity of commodity *i* would be misleading.

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[4] The 15 commodity groups include: (1) Agriculture, forestry, fishing, and hunting. (2) Mining (3) Utilities; (4) Construction (5) Manufacturing (6) Wholesale trade (7) Retail trade (8) Transportation and warehousing; (9) information (10) Finance, insurance, real estate, rental, and leasing (11) Professional and business services; (12) Educational services, health care, and social assistance; (13) Arts, entertainment, recreation, accommodation, and food services (14) Other services (except government) and (15) Government.

[5] The label "after redefinitions" implies that secondary products and their associated inputs have been reassigned to the industry in which they are the primary products. Redefinitions are made when the input structure of the industry's secondary product differs significantly from the input structure of its primary product. For example, the restaurant services in hotels are redefined from the accommodations industry to the food services industry.

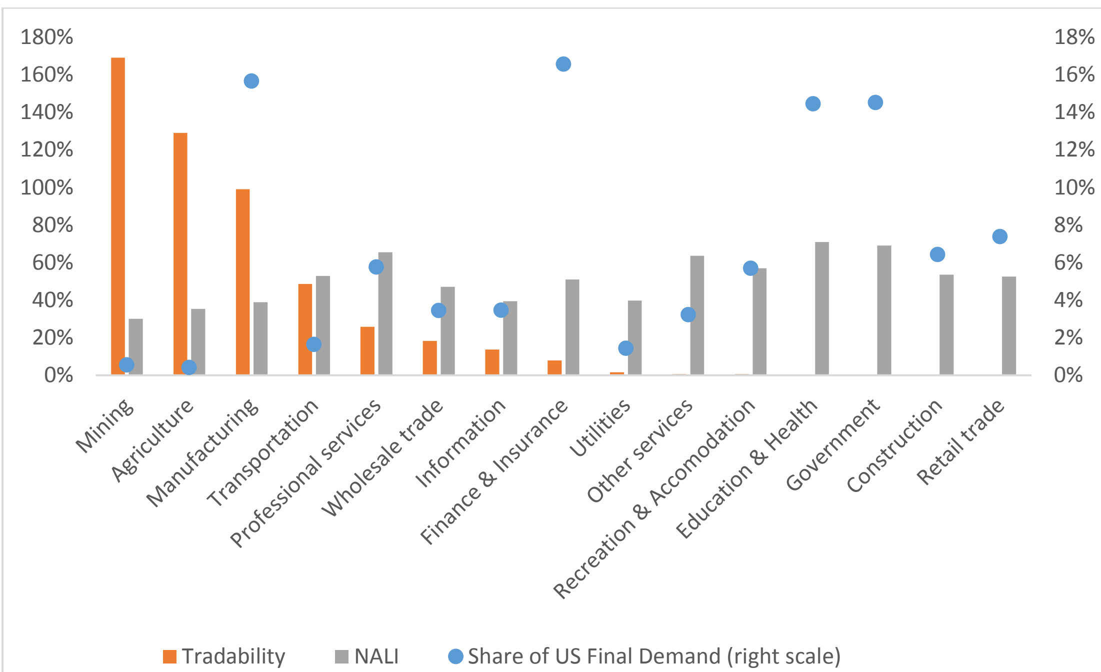
Intuitively, the NALI accounts for that fact and captures the labor compensation along the whole supply chain. Formally, the NALI of each commodity *i* is computed as follows:

$$NALI_i = Lw$$

Where L is the vector of labor compensation as a fraction of output by industry, and w is the industry-by-commodity domestic requirement matrix, which reports the domestic inputs by industry required (directly and indirectly) to deliver one dollar of commodity *i* output to final users.[6]

Two stylized facts emerge from Figure 1, which reports the three statistics for the 15 commodities. First, the heterogeneity in labor intensity across commodities is significant. Primary products (i.e. agriculture, mining and utilities) and manufactured goods are generally produced with much less labor than services, even after accounting for interlinkages.[7] On average, out of a dollar spent on such goods in 2015, only 35 cents ended up going to labor, against roughly 60 cents for a dollar spent on services. Second, except for transportation and warehousing services, primary and manufactured goods are much more traded than services.

Figure 1. Tradability, Labor Intensity, and Share of U.S. Final Demand for Commodities



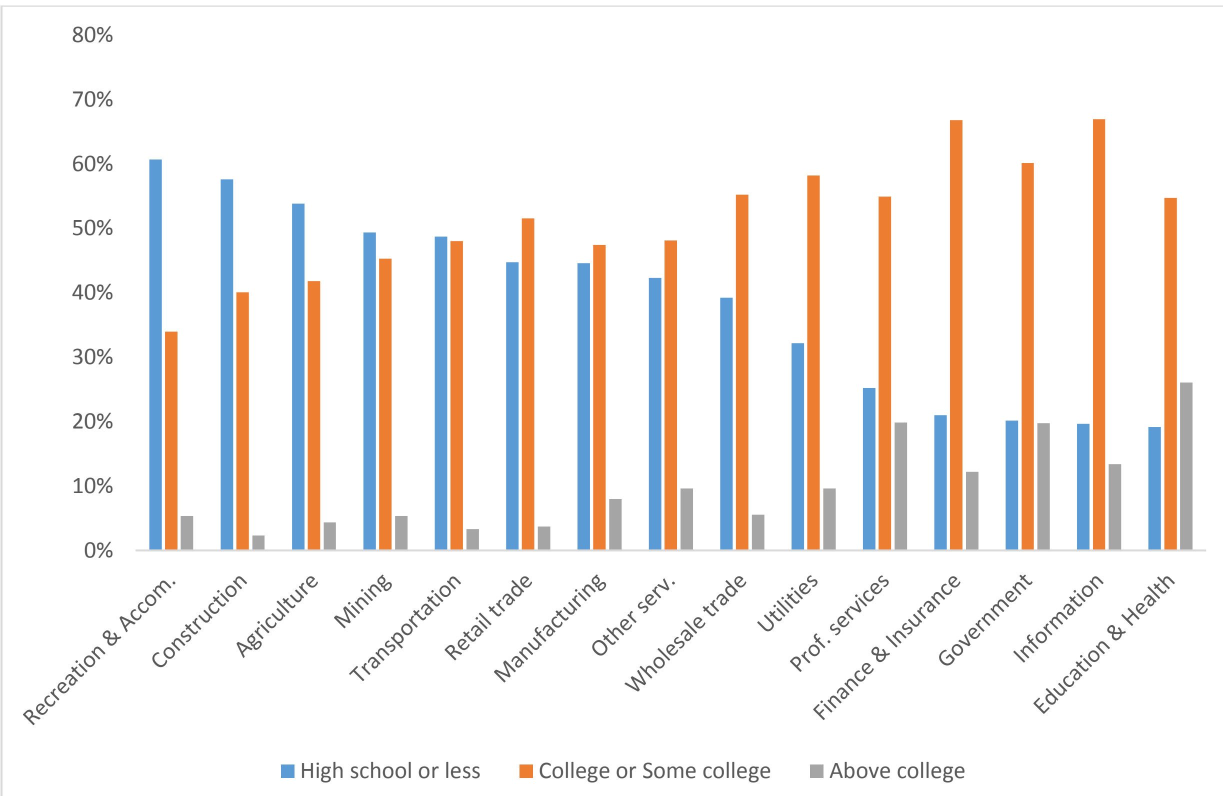
[6] In line with the 2015 Use table, the industry-by-commodity domestic requirement matrix is also evaluated at 2015 producer prices and after redefinitions.

[7] Roughly 20% of intermediate inputs used in the production of primary and manufactured goods come from services.

A third key aspect we document is the heterogeneity in the type of labor - skilled vs. unskilled - used across commodities, especially across different types of services. To proxy for the skill level by industry, we compute the distribution of educational attainment within each sector using employment data from the latest IPUMS-CPS vintage, distinguishing between (i) high school diploma or less (ii) college or some college and (iii) above college.

Figure 2 shows clearly that although some services display similar aggregate labor intensities per the NALI criteria (e.g. professional and business services vs. recreation, accommodation and food services), they use very different skill levels. For instance, more than half of the labor force employed in construction, recreation, accommodation and food services has only reached a high school diploma (or less). At the other extreme, education, health care or finance sectors employ mostly workers with at least some college background.

Figure 2. Distribution of Educational Attainment, by Sector



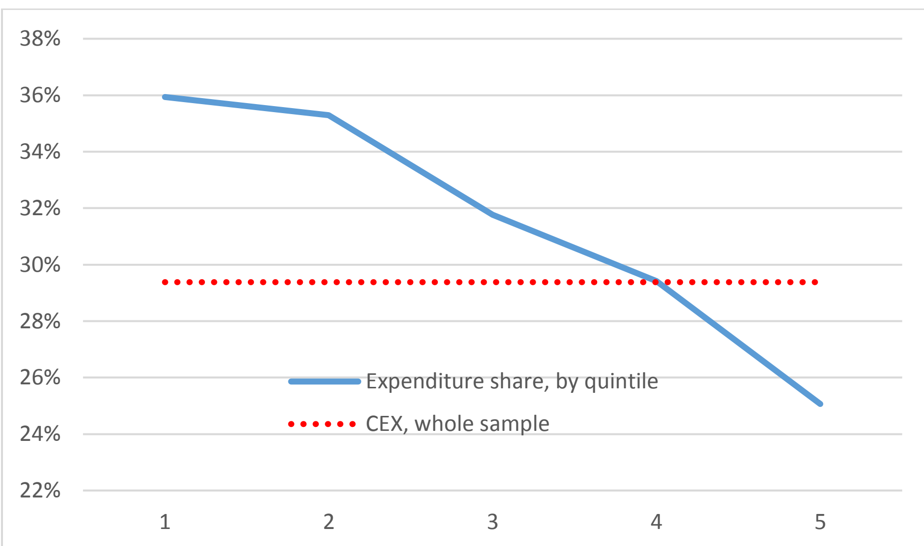
Putting these different findings together, this paper argues that the US economy is well represented by three "aggregate" commodities: (i) a highly tradable manufactured good, produced mostly with capital (which incorporates manufacturing, mining and agriculture); (ii) a non-tradable low-skill service (including retail trade, accommodation and food services etc..) and; (iii) a partly-tradable high skill service (including finance, healthcare, education). Table 1 in Appendix A provides detail on the aggregation method and shows the characteristics of the three aggregated sectors in terms of their share in total consumption and production; total employment or their NALI. All these metrics are used later to calibrate the model (Section III)

B. Heterogeneity in Consumption

How do consumers spend their income across such commodities? After aggregating commodities, we find that roughly 20% of US consumption (PCE) was devoted to what we define as primary and manufactured goods, 30% to low-skill services and 50% to high-skill services (see Appendix). This aggregate view, however, conceals an important heterogeneity across income levels.

To show this, we collect annual expenditures on goods and services, broken down by quintiles of income before taxes, from the 2015 Consumer Expenditure Survey (henceforth CEX). Although expenditure categories and accounting methodologies vary between the CEX and national accounts, we approximate the annual spending made by household in different quintiles on what we define as the "manufactured good". In practice, we sum, for each quintile of income before tax, the average annual expenditure made on (i) food at home (ii) alcoholic beverages (iii) tobacco products and smoking supplies (iv) utilities (minus telephone services) (v) housekeeping supplies and household equipment (vi) apparel (vii) gasoline and motor oil (viii) car maintenance and repair (ix) drugs and medical supplies (x) audio and visual equipment (xi) toys, hobbies and playground equipment. The result is plotted in Figure 3. Overall, we find that the share of spending dedicated to primary and manufactured goods decreases rapidly as income increases, from roughly 35% at the bottom of the income distribution to 25% at the top.

Figure 3. Average Expenditure Share on Manufactured Goods



III. MODEL

This section presents the key ingredients of the DSGE model used to simulate the different effect of tax reforms presented in section IV. In line with the stylized facts presented above, two new sources of heterogeneity are introduced. First, the economy produces three different goods, which differ in their terms of their tradability, labor and skill intensity. Second, consumers have non-homothetic preferences, reflecting the increasing share of expenditures on services as income grows. As we shall see, both aspects will have important consequences for the macroeconomic and distributional impact of tax reforms presented next section.

A. Production and Firms

We assume an economy that produces three goods: (i) a manufactured good, called M (ii) a low-skilled service, called L and (iii) a high-skilled service, called S. Although the manufactured good M is tradable (i.e. its price is determined exogenously on international markets and the country is a price-taker), we assume both types of services to be non-tradable. Production technologies can be summarized by constant returns to scale production functions satisfying standard assumptions. Markets are assumed to be competitive so that firms and individuals act as price takers and each factor commands its after tax marginal product. Different types of labor (h, x, l) will be assumed to deliver different effective levels of average productivity $\eta^i > 0, i = h, x, l$.

Manufacturing Sector:

Manufacturing goods are produced using labor from all type of skills (h, x, l), capital k and intermediate inputs originated in the manufacturing sector itself $m^{M,M}$, and in the high-skill services sector $m^{S,M}$.

$$M = F^M(h, x, l, k, m^{M,M}, m^{S,M})$$

The manufacturing sector is assumed to be capital intensive, and following the literature on job polarization, we assume that capital k and high skill labor h are complements as production inputs, while capital is substitute with medium skill labor x and low skill labor l (i.e. those types of jobs are "routinizable" in the sense of Autor (2003) and Abdih and Danninger (2017). Medium and low skill labor are imperfect substitutes.

High-skill Services Sector:

High-skill services are produced using high and medium skill labor, capital and intermediate inputs originated in the manufacturing sector $m^{M,S}$ and in the high-skill services sector itself $m^{S,S}$.

$$S = F^S(h, x, k, m^{M,S}, m^{S,S})$$

Like in the manufacturing sector, capital and high skill labor are complements in the production of high-skill services, whereas capital and medium skill labor are substitutes.

Low-skill Services Sector:

Low-skill services goods are produced using only low skill and medium skill labor.[8]

$$L = F^L(x, l)$$

B. Households

Household's heterogeneity is driven by permanent and transitory differences in labor productivity: permanent differences result from households being born with different levels of skills -they are either low-skill (l), medium skill (x) or high skill (h)-, while transitory differences result from idiosyncratic shocks to household's average deterministic productivity.[9]

Households of skill level $i = l, x, h$ maximize their life time utility from consumption c^i and leisure o^i, accumulate assets a^i that give them a market return r, receive a market wage w^i for each unit of labor time $1 - o^i$ that they supply to the market, face a transitory idiosyncratic shocks to their labor productivity $\zeta^i \in \aleph^i$, pay consumption (τ^s,τ^L, τ^M, τ^*) and income taxes $T(\zeta^i w^i(1 - o^i), (1 + r)a^i)$, and are subject to an exogenous borrowing constraint given by $-\kappa^i$ with $\kappa^i > 0$.

$$\max_{c,o,a'} E_o \sum \beta^t u\left(c^i\left(c^{s,i}, c^{L,i}, c^{M,i}, c^{*,i}\right), o^i\right)$$

$s.t$

$$p^c c^i + a'^{,i} = \zeta w^i\left(1 - o^i\right) + (1 + r)a^i - T\left(\zeta w^i\left(1 - o^i\right), (1 + r)a^i\right)$$

$$p^c c^i = (1 + \tau^s)p^s c^{s,i} + (1 + \tau^L)p^L c^{L,i} + (1 + \tau^M)c^{M,i} + (1 + \tau^*)p^* c^{*,i}$$

$$a^i \geq -\kappa^i$$

Preferences are identical across individuals and are represented by expected utility, where u is the Bernoulli utility function which satisfies standard assumptions (i.e., $u_c > 0,\ u_o > 0,$ $u_{cc} < 0,\ u_{oo} < 0,\ u_{co} > 0$). The discount factor is 0< $\beta < 1$ and E_0 denotes the

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[8] Our results would be qualitatively the same if production of low skill services used capital, as long as this sector is the least capital intensive; quantitatively, the results would not be too different from what we report here, as in the data this sector uses very little capital.

[9] For example, Conesa and Kruger (2006) present a model were heterogeneity is the result of differences in abilities and age plus transitory shocks to labor productivity.

expectations operator conditional on information at period 0. Consumption c^i denotes a vector of 4 consumption goods: $c^{s,i}$ is consumption of services with high-skill content, $c^{L,i}$ is consumption of services with low-skill content, $c^{*,i}$ is consumption of imported goods, and $c^{M,i}$ is consumption of tradable goods (manufactured goods). The numeraire of the economy are manufactured goods M, and their price is normalized to 1.

The stochastic process for the idiosyncratic shock to household's labor productivity ζ^i is identical and independent across agents and follows a finite state Markov chain with stationary transitions over time, i.e.

$$Q_t^i(\zeta^i, \aleph^i) = Prob(\zeta_{t+1}^i \in \aleph^i | \zeta_t^i = \zeta^i) = Q^i(\zeta^i, \aleph^i)$$

The realization of these idiosyncratic shocks give rise to income and wealth distributions even though a set of households have similar average skills.

C. Government

The government in this economy consumes manufacturing goods G^M, high-skill services G^S, and low skill services G^L, invests in infrastructure I^G, levies taxes (τ^s, τ^L, τ^M, τ^*, $\tau^{M,M}$, $\tau^{S,M}$, $\tau^{M,S}$, $\tau^{S,S}$, $T(.)$) and issues foreign debt B^*. Its budget constraint is given by

$$\sum_i \int \Gamma^i \, Q^i(\zeta^i, \aleph^i) + \Xi + \sum_i \int T\big(\zeta^i w^i (1 - o^i), (1+r)a^i\big) \, Q^i(\zeta^i, \aleph^i) + (1+r^*)B^*$$
$$= G^M + G^S + G^L + I^G + B^{*\prime}$$

$s.t.$

$$\int \Gamma^i \, Q^i(\zeta^i, \aleph^i) = \int \big(\tau^S p^S c^{S,i} + \tau^L p^L c^{L,i} + \tau^M c^{M,i}\big) Q^i(\zeta^i, \aleph^i)$$

$$\Xi = \tau^{M,M} m^{M,M} + \tau^{S,M} p^S m^{S,M} + \tau^{M,S} m^{M,S} + \tau^{S,S} p^S m^{S,S}$$

D. Stationary Competitive Equilibrium

In this economy households' state variables are their skill type i, their asset holdings a^i, and their idiosyncratic labor productivity status ζ^i. The aggregate state of the economy at any point in time is described by a joint measure $\beth_t$ over those individual states. Let $a^i \in \boldsymbol{A^i} = [-\kappa^i, \infty)$, $\zeta^i \in \aleph^i = \{\zeta_1^i, \zeta_2^i, \cdots, \zeta_n^i\}$, $\boldsymbol{A} = \boldsymbol{A^l} \times \boldsymbol{A^x} \times \boldsymbol{A^h}$, $\aleph = \aleph^{\boldsymbol{l}} \times \aleph^{\boldsymbol{x}} \times \aleph^{\boldsymbol{h}}$ and $\boldsymbol{\Phi} = \boldsymbol{A} \times \aleph$. Let $\boldsymbol{B}(\boldsymbol{A})$ be the Borel σ-algebra of $\boldsymbol{A}$ and $\boldsymbol{P}(\aleph)$ the power set of $\aleph$. Let $\boldsymbol{\Omega}$ be the set of all finite measures over the measurable space $(\boldsymbol{\Phi}, \boldsymbol{B}(\boldsymbol{A}) \times \boldsymbol{P}(\aleph))$.

Given sequences of the tax rates for final consumption τ^{s},τ^{L}, τ^{M}, τ^{*}, the tax rates for intermediate demand of inputs $\tau^{M,M}, \tau^{S,M}, \tau^{M,S}, \tau^{S,S}$, income tax function $T(.)$, government expenditure G^{M}, G^{S}, G^{L}, and I^{G}, government's external borrowing B^{*}, the international interest rate on government's debt r^{*}, the international prices for consumption goods p^{*} (and manufacturing goods which is normalized to 1), a competitive equilibrium is a sequence of functions for the households $\{v, c, o, a' : \boldsymbol{\Phi} \rightarrow \boldsymbol{R}\}$, production plans for the firms in the manufacturing sector $\{l^{M}, x^{M}, h^{M}, k^{M}, m^{M,M}, m^{S,M}\}$, the high-skill services sector $\{x^{S}, h^{S}, k^{S}, m^{M,S}, m^{S,S}\}$, and the low skill services sector $\{l^{L}, x^{L}\}$, prices $\{w^{l}, w^{x}, w^{h}, p^{L}, p^{S}, r\}$ and measures ϑ with $\vartheta \epsilon \boldsymbol{\Omega}$ such that:

1. Given prices, policies for each period v^{i} solves the functional equation (with $c^{i}, o^{i}, a'^{,i}$ associated policy functions)

$$v^{i}\left(a^{i}, \zeta^{i}, i\right) = \max_{c^{i}, o^{i}, a'^{,i}} \left\{ u\left(c^{i}, o^{i}\right) + \beta \int v'^{,i}\left(a', \zeta'^{,i}, i\right) Q^{i}\left(\zeta^{i}, d\zeta'^{,i}\right) \right\}$$

$$s.t$$

$$p^{c} c^{i} + a'^{,i} = \zeta^{i} w^{i}\left(1 - o^{i}\right) + (1 + r) a^{i} - T\left(\zeta^{i} w^{i}\left(1 - o^{i}\right), (1 + r) a^{i}\right)$$

$$p^{c} c^{i} = (1 + \tau^{s}) p^{s} c^{s,i} + (1 + \tau^{L}) p^{L} c^{L,i} + (1 + \tau^{M}) c^{M,i} + (1 + \tau^{*}) p^{*} c^{*,i}$$

$$c^{i} = F^{c}\left(c^{s,i}, c^{L,i}, c^{M,i}, c^{*,i}\right)$$

$$a'^{,i} \geq -\kappa^{i}, \qquad c^{i} > 0, \qquad 0 \leq o^{i} \leq 1$$

2. Factor prices $\{w^{l}, w^{x}, w^{h}, r\}$ satisfy:

$$w^{l} = p^{L} F_{l}^{L} = F_{l}^{M}$$

$$w^{x} = p^{L} F_{x}^{L} = F_{x}^{M} = p^{S} F_{x}^{S}$$

$$w^{h} = F_{h}^{M} = p^{S} F_{h}^{S}$$

$$r + \delta = p^{s} F_{k}^{S} = F_{k}^{M}$$

3. Government budget balance:

$$\sum_{i} \int \Gamma^{i}\, Q^{i}\left(\zeta^{i}, \aleph^{i}\right) + \Xi + \sum_{i} \int T\left(\zeta^{i} w^{i}\left(1 - o^{i}\right), (1 + r) a^{i}\right) Q^{i}\left(\zeta^{i}, \aleph^{i}\right) + (1 + r^{*}) B^{*} = G^{M} + G^{S} + G^{L} + I^{G} + B^{*\prime}$$

4. Markets clear:

$$k = k^{M} + k^{S} = \sum_{i} \int a^{i}\, \vartheta^{i}\big(da^{i} \times d\zeta^{i}\big)$$

$$l = l^{L} + l^{M} = \eta^{l} \int \zeta^{l} o^{l}\, \vartheta^{l}(da^{l} \times d\zeta^{l})$$

$$x = x^{L} + x^{M} + x^{S} = \eta^{x} \int \zeta^{x} o^{x}\, \vartheta^{x}(da^{x} \times d\zeta^{x})$$

$$h = h^{M} + h^{S} = \eta^{h} \int \zeta^{h} o^{h}\, \vartheta^{h}(da^{h} \times d\zeta^{h})$$

$$\sum_{i} \int c^{L,i}\big(a^{i}, \zeta^{i}, i\big)\, \vartheta^{i}\big(da^{i} \times d\zeta^{i}\big) + G^{L} = L$$

$$\sum_{i} \int c^{S,i}\big(a^{i}, \zeta^{i}, i\big)\, \vartheta^{i}\big(da^{i} \times d\zeta^{i}\big) + G^{S} + m^{S,M} + m^{S,S} = S$$

5. Law of motion

$$\vartheta' = H(\vartheta)$$

where the function $H: \boldsymbol{\Omega} \to \boldsymbol{\Omega}$ can be written explicitly as:

$$\vartheta'(A \times \aleph) = P\big((a, \zeta, i);\ \boldsymbol{A} \times \aleph\big)\vartheta(da \times d\zeta \times di)$$

where

$$P\big((a, \zeta, i);\ \boldsymbol{A} \times \aleph\big)\vartheta(da \times d\zeta \times di) = \sum_{i \in \boldsymbol{I}} \sum_{\zeta'^{,i} \in \aleph^{i}} \begin{cases} Q^{i}\big(\zeta'^{,i} \vert \zeta^{i}\big) & if \quad a'^{,i}\big(a^{i}, \zeta^{i}, i\big) \in A^{i} \\ 0 & else \end{cases}$$

A stationary equilibrium is a competitive equilibrium in which all policy variables, international prices, domestic prices, aggregate variables and all other variables (and functions) are time-invariant.

IV. BENCHMARK ECONOMY

Before simulating tax reforms, we first discipline the model to account for aggregate and cross-sectional facts of the U.S. economy presented above. Our quantitative analysis therefore departs from an estimation of parameter values such that the resulting stationary equilibrium matches key macro-economic ratios (private investment to GDP, consumption to GDP, etc.), sectoral ratios, as well as key distributional statistics. This steady state of the model, which we denote as the "benchmark US economy" will serve as the baseline for the comparison of different steady states throughout the paper. We detail below how the benchmark economy is calibrated.

A. Preferences

We assume preferences over consumption and leisure that can be represented by a period utility of the form

$$u(c,o) = \frac{1}{1-\sigma}\left(c - \omega\frac{(1-o)^{\theta+1}}{\theta+1}\right)^{1-\sigma}$$

The consumption aggregator is given by

$$c = \left[\gamma\left(c^T(c^M,c^*)\right)^{\rho} + (1-\gamma)\left(c^N(c^S,c^L) + \overline{c^N}\right)^{\rho}\right]^{\frac{1}{\rho}}$$

$$c^T = \left[\gamma^T(c^M)^{\rho^T} + (1-\gamma^T)(c^*)^{\rho^T}\right]^{\frac{1}{\rho^T}}$$

$$c^N = \left[\gamma^N(c^L)^{\rho^N} + (1-\gamma^N)(c^S)^{\rho^N}\right]^{\frac{1}{\rho^N}}$$

To calibrate our preferences, we fix our coefficient of risk aversion to $\sigma = 2$. The discount factor β is chosen so that the equilibrium of the benchmark has the capital-output ratio close to its value in the data. ω and θ are chosen so that average hours worked in the economy by the household correspond to $\frac{1}{3}$ of their time, and the labor elasticity to wages is approximately $\frac{1}{3}$. The elasticity of substitution between consumption goods is assumed to be 1 (so that $\rho = \rho^T = \rho^N$, and $\rho \to 0$. The setting the parameter $\overline{c^N} > 0$ ensures that income elasticity demand for services increases with income, this parameter is then chosen such that consumption of manufacturing and imported consumption goods share of total consumption is approximately eight percentage points larger for the top quintile than for the bottom quintile of income distribution. The share of services on total consumption $1-\gamma$ and low skill services in total services consumption γ^N are calibrated in such way that, given the shares of high-skill intermediate inputs in the production of manufacturing and high-skill services sectors (derived from input-output data), the model matches the total share of low skilled and high skilled services production in GDP (which corresponds respectively to 30 percent and 50 percent of total GDP). The share of domestically produced goods in tradable goods consumption γ^T is calibrated to match a share of consumption of imports in total consumption expenditure of approx. 10 percent.

Table 1. Preferences Parameters

Parameter	Value	Target
β	0.96	$\frac{K}{Y} = 3$
σ	2	Fixed: in the range of common values used for this parameter.
ρ	0.01	Elasticity of substitution between different types of consumptions being 1. $\frac{1}{1-\rho} = 1$
γ	0.17	$\frac{p^L L + (p^S S - m^{M,S} - p^S S m^{M,S})}{GDP} = 0.8$
γ^N	0.45	$\frac{p^L L}{GDP} = 0.8$
γ^T	0.4	$\frac{p^* c^*}{p^c c}$=0.1
$\overline{c^N}$	0.025	$\left(\frac{c^M}{p^c c}\right)_{1st\ Quintile}$=0.42 $\left(\frac{c^M}{p^c c}\right)_{5th\ Quintile}$=0.33
ω	12	Average hours $\frac{1}{3}$
θ	3	Elasticity of labor demand approx. $\frac{1}{3}$

B. Household's labor productivity

Household's labor productivity has a permanent component given by their skill level η_i, and a transitory idiosyncratic stochastic component. The permanent component given by skill levels in the model is proxied by education attainment levels in the US population as reported by the Census Bureau (2016). We classify individuals with high school degree or less as low skill individuals, and individuals with more than bachelor's degree as high skill individuals. We normalized the average labor productivity of medium skill level households to 1 (i.e., $\eta_x = 1$), and consider differences in average years of education as proxies for differences in skill levels, therefore as high school years of education are 66 percent or less than the years required to achieve a bachelors' degree we set $\eta_l = 0.7$. In the other hand, while a Master's degree takes approximately 16% more years of education to achieve than a Bachelor's degree, we consider the possibility of decreasing returns to human capital accumulation, and opt to set conservatively the skill level of those households with more than a bachelor's degree as being only 10 percent higher than the skill level of those classified as medium skill (i.e., $\eta_h = 1.1$)

Table 2. Skills Parameters

Parameter	Value	Target
μ_l	0.39	Population share with high school degree or less.
μ_x	0.48	Population with some college, no degree, associate degree or bachelor degree.
μ_h	0.13	Population share with a Bachelor's degree or more
η_l	0.7	Approx. 12 years of education.
η_x	1	Approx. 16 years of education.
η_h	1.1	More than 16 years of education.

The stochastic idiosyncratic productivity component is calibrated to minimized the distance between the model's and the data's Lorenz curve for pre-tax income for the US (See Appendix). Each of the process is governed by a 3 state Markov chain, and can be summarized by a persistence parameter φ^i and the variance of the process $\sigma^2_{\epsilon,i}$. The parameters of these three process are shown in Table 3.

Table 3. Stochastic Productivity Parameters

Stochastic Productivity Parameters: $\zeta^i_{t-1} = \zeta^i_{t-1}\varphi^i + \epsilon^i_t$; $\epsilon^i_t \sim N\left(0, \sigma^2_{\epsilon,i}\right)$

Parameter	Value	Target
φ^l	0.76	Persistence parameter of the stochastic idiosyncratic shock for low skill households.
φ^x	0.76	Persistence parameter of the stochastic idiosyncratic shock for medium skill households.
φ^h	0.73	Persistence parameter of the stochastic idiosyncratic shock for high skill households.
$\sigma^2_{\epsilon,l}$	0.01	Variance of the process for the idiosyncratic labor productivity shock for low skill households.
$\sigma^2_{\epsilon,x}$	0.0289	Variance of the process for the idiosyncratic labor productivity shock for medium skill households.
$\sigma^2_{\epsilon,h}$	0.0484	Variance of the process for the idiosyncratic labor productivity shock for high skill households.

C. Technology

We assume CES production functions for the three sectors. The parameters that determined the participation of the factors are jointly calibrated such that labor intensities and intermediate output intensities match the data.

D. Government

We set consumption (and intermediate consumption) tax rates to 7.5%, which is the approximate mid-point for the range of state sale taxes in US. For the benchmark calibration government consumption is chosen to be 16% of GDP, as the average in the data for the period 2009-2015 per the World Bank data. Additionally, we assumed that total government consumption is concentrated on manufacturing goods (i.e., $G^L = G^S = I^G = 0$).[10]

To approximate the US income tax code, we used a variation of the function used in Conesa and Kruger (2006) which seems to properly represent the US system. More specifically this function takes the functional form:

$$T(y^j) = a_o \left[y^j - \frac{a_3}{a_o} \left((y^j)^{-a_1} + a_2 \right)^{-\frac{1}{a_1}} \right]$$

where y^j is household j pre-tax income. Following Benabou (2002), Heathcote et al. (2016) and Guner et al. (2016), federal income taxes are parameterized to capture the various effective tax rates paid at different levels of income. The benchmark tax function, which approximates the current US system, is plotted in Figure 4 and reports the effective tax rate as a function of multiples of median income. To account for the presence of an EITC in the current US system, the tax function is negative and very progressive for households earning less than 50% of the median income. At the other extreme, the function is set to peak around 28% for people approaching high multiples of the median income (10 and above).

V. Experiments and Key Results

We simulate two tax cut scenarios, plotted in Figure 5. Tax cuts are applied to both labor and investment income.

(i) A middle-class tax cut which reduces the effective tax rates for households earning between 0.5 to 4 times the median income. To ensure revenue neutrality of the tax cut, as a first stage, we assume that the loss in income tax is paid for by a cut in wasteful government spending (that has no feedback into the model).

(ii) The same middle-class tax cut with an EITC expansion for lower income groups, entirely paid for by an increase in consumption taxes. To mitigate the regressive effects of the consumption tax on the poor, the EITC is calibrated to ensure a representative household that earns one-half of the median income is, in a static sense, fully compensated for their higher consumption tax outlays.

[10] This assumption is made to isolate the distributional and macro impact of tax changes only, and abstract the potential effects coming from the government spending side (and its composition).

After the tax system is modified, key features of the new stochastic steady state (macro, sectoral and distributional) are then contrasted to those of the benchmark economy.

Figure 4. Baseline Tax Function

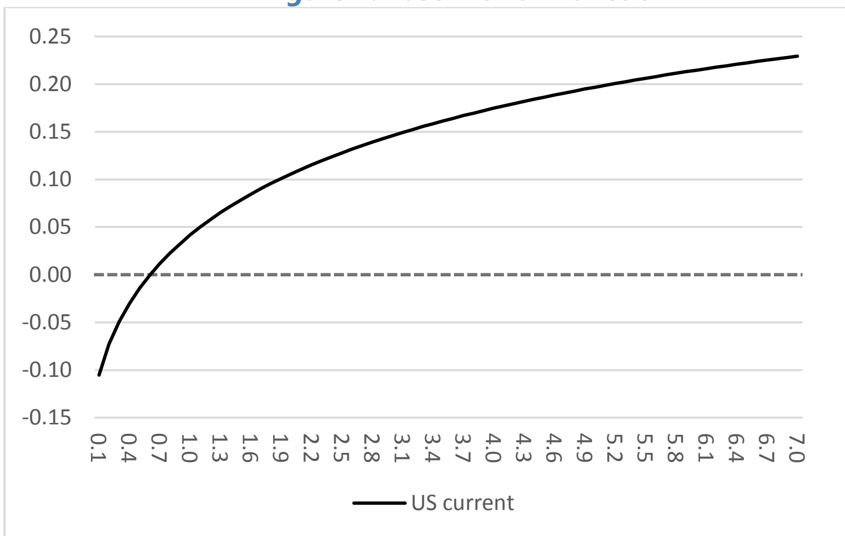
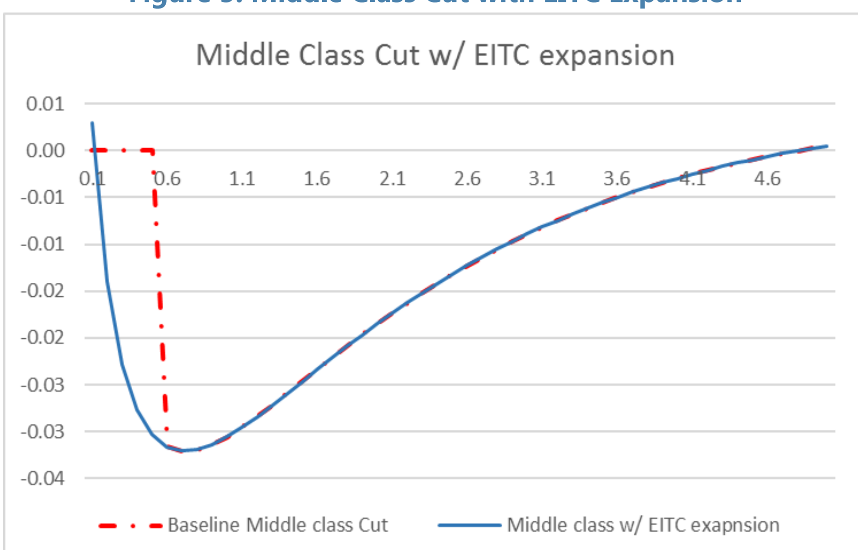


Figure 5. Middle Class Cut with EITC Expansion



A. The middle-class tax cut

The key results from the middle-class tax cut are as follows.[11] First, we find that the tax cut stimulates output, from both an increase in the labor supply and higher savings (which in turn lowers the cost of capital). Higher after-tax incomes stimulate consumption, further raising the demand for both capital and labor. Despite the richness of the model and the scope for various general equilibrium effects, the supply-side response is not large enough to offset the revenue loss from the tax cuts (i.e., income tax cuts cannot "pay for themselves").

On aggregate, we find that the tax cut results in a loss of revenues of 0.8 percent of GDP and raises the steady state level of GDP by just under 1 percent after 5 years, implying a personal income tax multiplier of 1.1. Most of the expansion occurs in both low-skill and high-skill services, whereas the manufacturing sector shrinks, both in absolute terms and as a share of total output.

In terms of distribution, we find that both middle- *and* low-income households profit from the cut. Even though the lowest quintile does not receive a tax cut in this first simple experiment, the increased demand for non-tradable services by middle income households raises the demand for—and the wages of—low-skilled labor, which helps to support their income and consumption. The higher prices for non-tradables, combined with a lower interest rate, makes the top quintile slightly worse off. Overall, the middle-income tax cut reduces income inequality and polarization by moving people lower income households back into the middle class (defined as agents receiving between 50% and 150% of the median income). Quantitatively, we find that the middle class would expand by roughly 4%.

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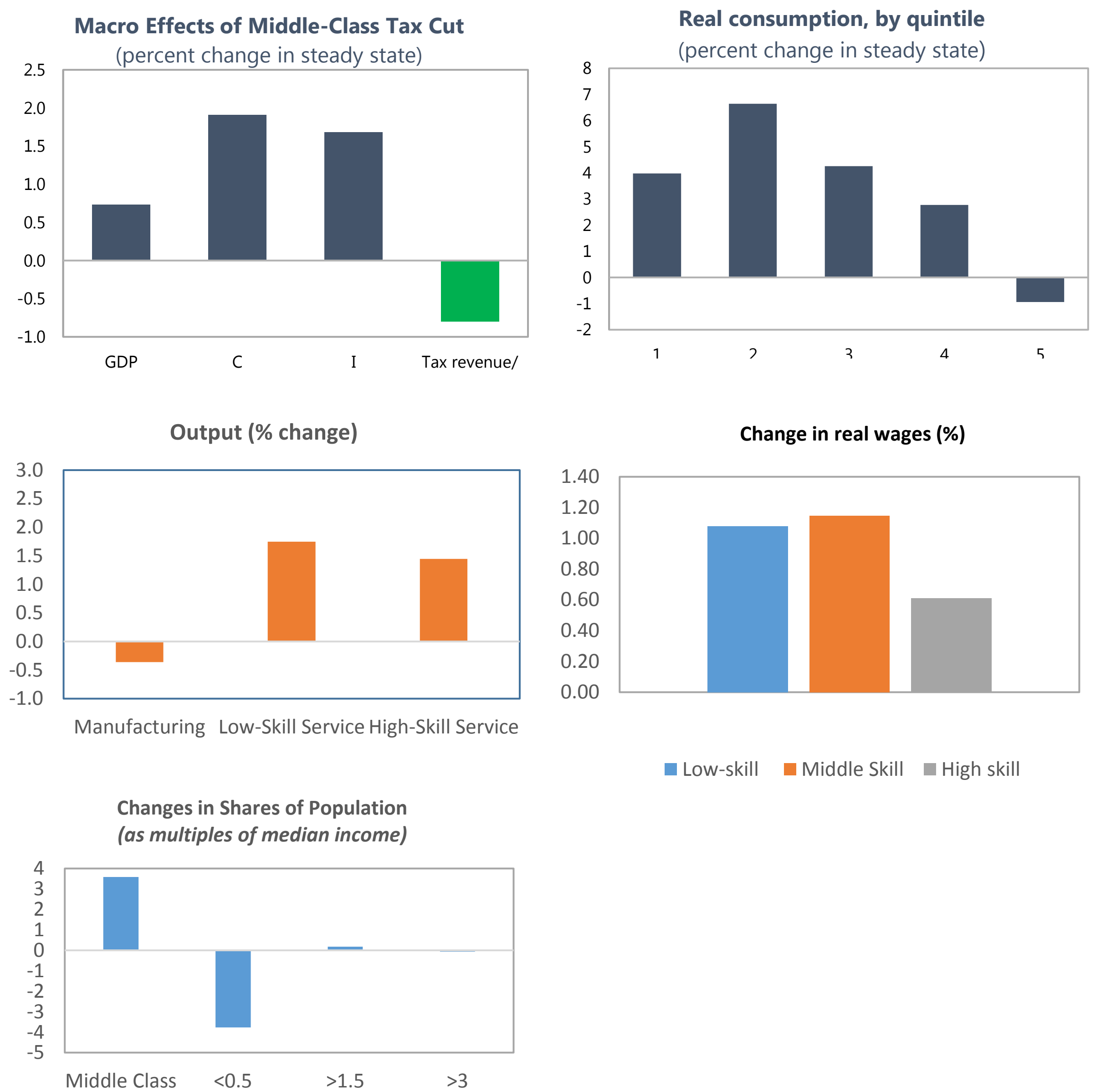
[11] In the United States all forms of income are taxed; hence, the tax cut affects labor and capital income (interest earnings). The model abstracts from capital gains and dividend payments to keep the analysis simple (models that correctly account for trends in asset prices and dividend payments are extremely complicated) although these forms of income have their own tax schedules. If the tax cut also lowered divided or capital gain taxes our results would be lower bounds on the impact of such tax cuts.

Figure 6. Middle-Class Tax Cut Effects



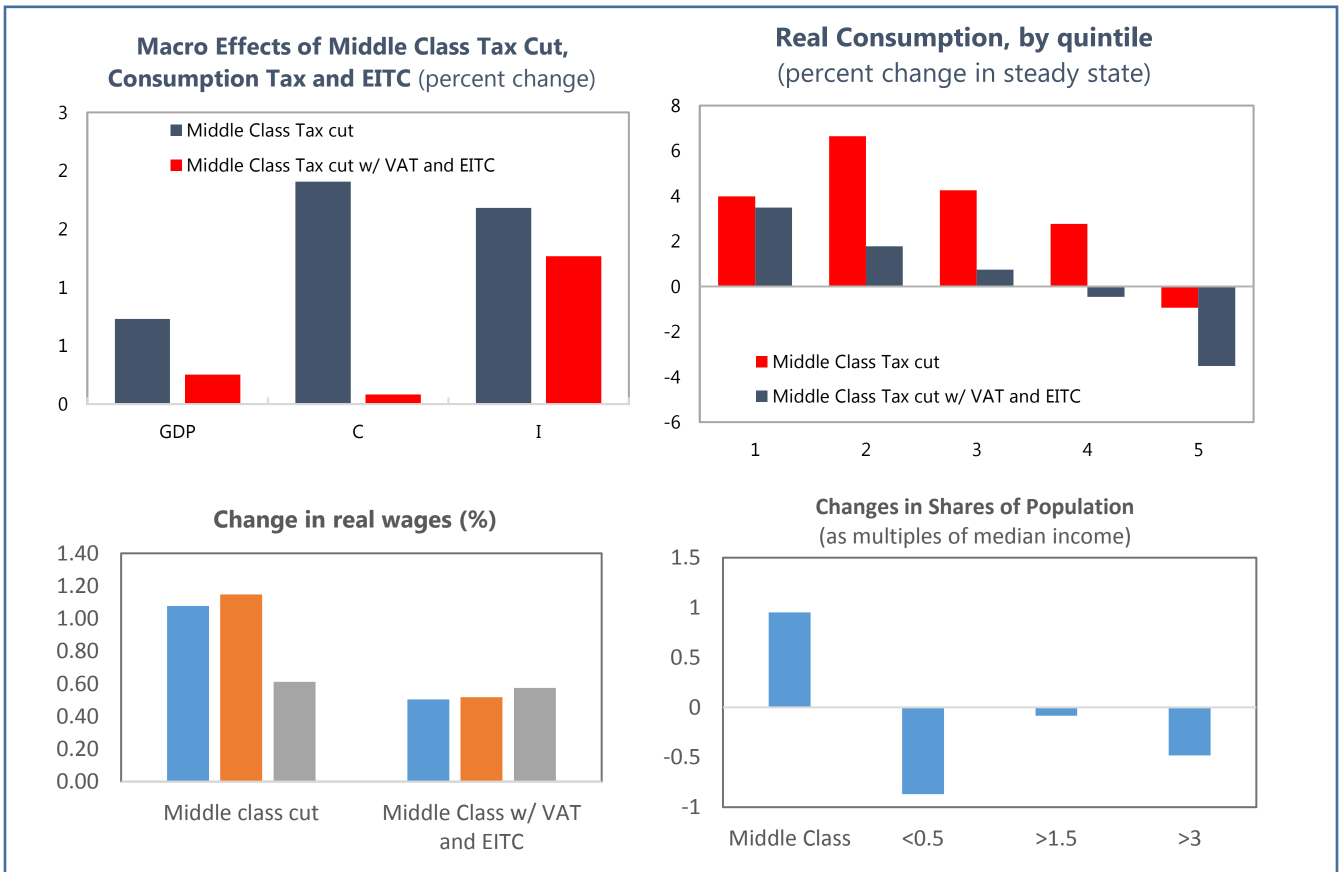
Note: Middle class refers to agents receiving between 50% and 150% of the median income.

B. Consumption Tax and EITC Expansion

Instead of assuming a drop in wasteful government spending, revenue neutrality is now enforced by increasing consumption taxes. To mitigate the regressive effects of the consumption tax on the poor however, the EITC is expanded for households earning less than one-half of the median income (see blue line in Figure 5).

As expected, the shift from direct to indirect tax has a more modest on growth, mainly because of the muted response of consumption. However, the reform still has a positive impact on growth. The tax cuts and EITC expansion still leave the bottom 60 percent of the income distribution better off. However, the increased after-tax cost of non-tradables and the lower interest rate both make the highest earners worse off in terms of steady state consumption, in particular the top 20%. Although both reforms (middle class cut and middle class cut with EITC expansion and VAT) differ in terms of macroeconomic and distributional impact, both have a very progressive impact on the income distribution and reduce polarization.

Figure 7. Consumption Tax and EITC Expansion Effects

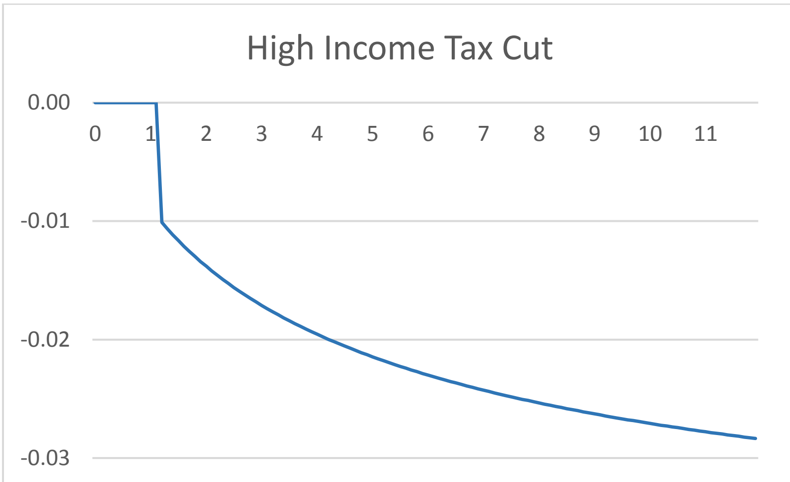


Note: Middle class refers to agents receiving bewteen 50% and 150% of the median income.

C. Tax cuts for high income groups

Instead of targeting tax cuts at the middle class, the same experiment was run (with consumption tax and EITC expansion) but with the tax reductions accruing, instead, to those in the top quintile. The shape of the high-income tax cut is reported in Figure 8, which plots the percentage change in effective tax rate for different multiples of the median income.

Figure 8. High Income Tax Cut



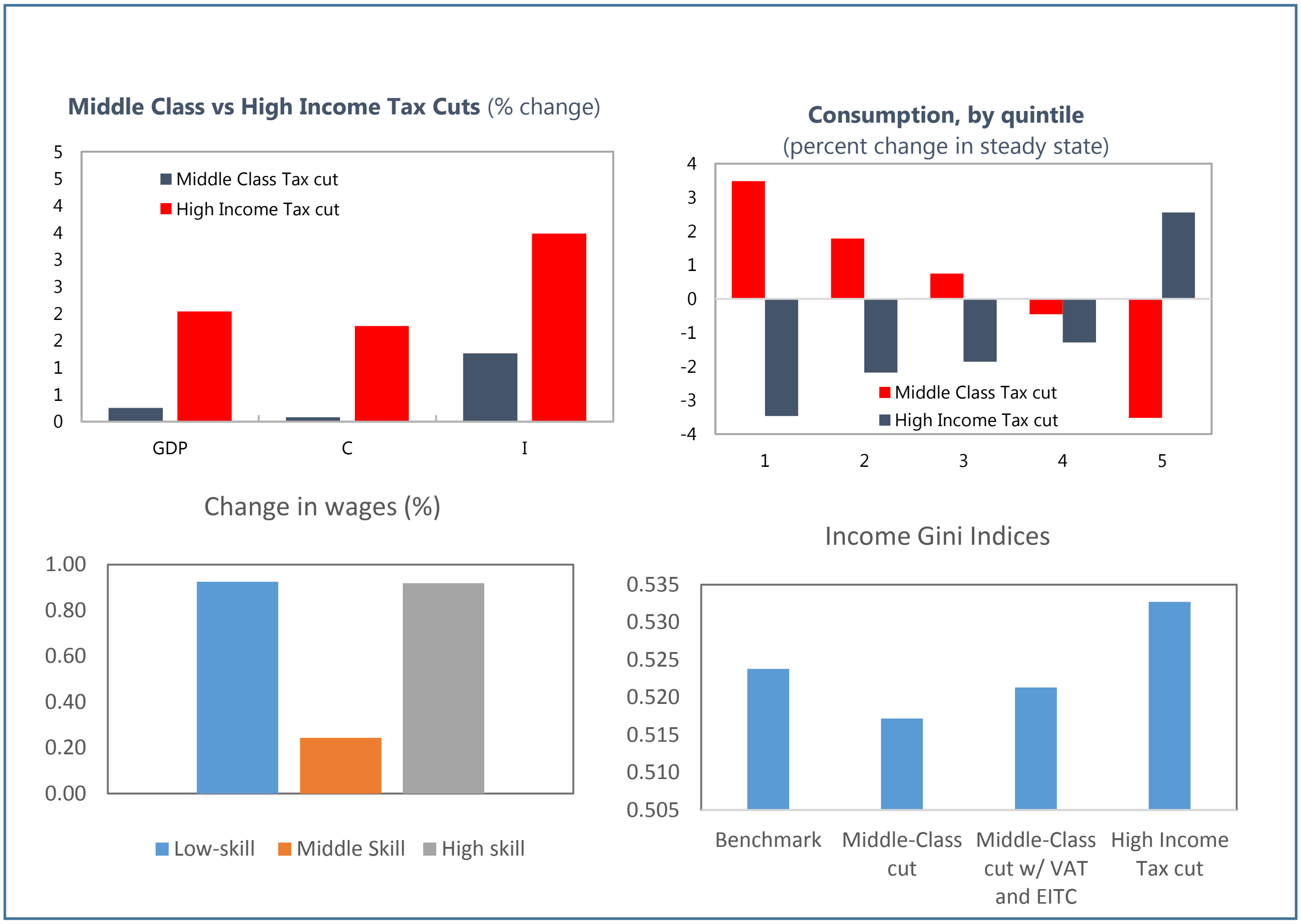
Relative to the case where the tax cut is incident on the middle-class, there are larger growth effects when the tax cut is incident on the higher income groups. The reasons behind this are two-fold: First, the top quintile responds to lower taxes by saving more which, in the closed economy version of the model, leads to more capital formation and a decline in the equilibrium real interest rate. Second, those receiving a reduction in their tax rate supply more high-skilled labor which helps boost output[12]. On the demand side, the increase in the after-tax income of higher income households translates into higher real consumption that is particularly incident on non-tradables (even despite the increase in the consumption tax rate). These services, in turn, are produced by low- and middle-income groups which raises the demand for their labor and increases their real wage.

However, the larger growth impact comes alongside important trade-offs on the income distribution. Even though the policy experiment includes the same expansion of the EITC as with the middle-income tax cut and there are second-round effects that are supportive of low- and middle income households, the net result is a significant decline in consumption of low and middle- income households, and a significant reduction of the middle class. As such, the tax cut for the wealthy funded by higher consumption taxes significantly worsens the

[12] The elasticity of labor supply for the higher earners is calibrated at 0.3 which is in line with the empirical literature.

polarization of income with the "trickle-down" effects insufficient to raise the welfare of the bulk of the population.

Figure 9. Middle Class vs. High Income Tax Cuts



VI. Sensitivity Analysis

It would be of concern that the results presented above are specific to the chosen calibration of the model. Although the model is calibrated to match the aggregate, sectoral and distributional features of the U.S., it is important to understand which of the parameters the growth and distributional effects are sensitive to.

Specifically, we look at the effects of changing:

(i) the labor supply elasticity of workers and

(ii) the impact on investment and interest rates from higher household saving.

Elasticity of labor supply

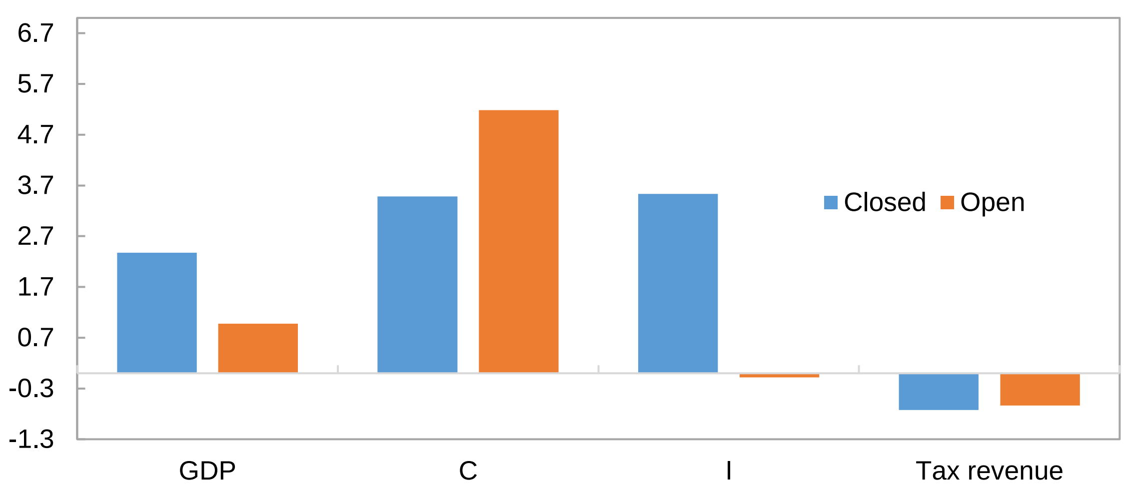
Lowering the labor supply elasticity for the high-income workers from 0.3 to 0.15 would reduce the growth effect by around one half both for the middle and high income tax cut. This implies PIT multipliers of around 0.5 for middle-class tax cuts, and 1.5 for high-income tax cuts. However, the finding that high income tax cuts have a larger macroeconomic effect is preserved for a range of parameterizations.

Savings, investment and the real interest rate

To understand the sensitivity of macro multipliers, both high and middle-income income tax cut are simulated in a small (financially) open economy, with an offset in government spending to impose revenue neutrality. In this environment, the real interest rate is pinned down by the foreign real interest rate and changes in domestic savings induced by the tax cuts do not translate into equal changes in investment any more (i.e. the current account deficit can move instead).

In the case of the high-income tax cut, the net result of the tax cut is a negligible effect on investment compared to the closed economy. Instead the response is an increase in the current account surplus. When the interest rate does not fall, capital does not go up as much compared to the closed economy version, implying a smaller substitution between capital and labor. This results in higher wages and after tax incomes accruing to individuals with relatively higher propensities to consume, which boosts aggregate consumption. Still, the increase in consumption is insufficient to offset the lower investment path and the net multiplier to GDP is around one-half of that in the closed economy version (see Figure 10). While the growth effect is smaller, a tax cut targeted at higher earners still worsens income polarization in both the open and closed economy version of the model.

Figure 10. High Income Tax Cuts: Closed vs. Open (% change)



VII. Conclusions

This paper uses a DSGE model calibrated to key features of the U.S. economy to examine the macro, sectoral and distributional response of the economy to changes to the personal income tax. Although the model generates positive effects on growth, consumption and investment that are broadly in line with the recent empirical literature on PIT multipliers, the positive macro response is never strong enough to prevent cuts from being revenue losing. We also find the macroeconomic and distributional effect are highly sensitive to where the tax cuts are targeted. Middle class tax cuts are found to have both positive effects on growth, income inequality and polarization, whereas tax cuts targeted at high income earners display a strong multiplier/polarization trade-off. In addition, we find that services are more likely to expand than manufacturing as a result of tax reforms.

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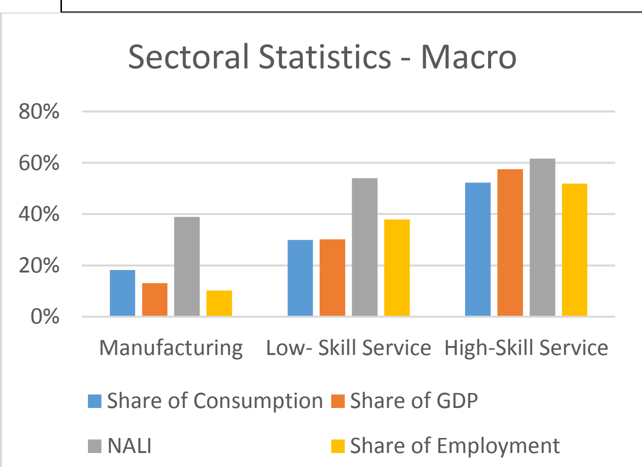
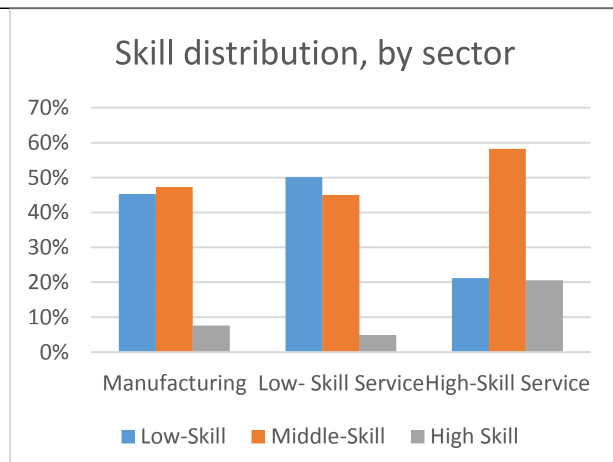
APPENDIX I.

a. Commodity Aggregation and Production

Using 2015 "use table" after redefinitions and evaluated at producer prices by the BEA, we aggregate the standard 15 commodities into 3 commodities (see below). Building on this decomposition, we then compute the following statistics for each aggregate commodity, using both BEA and CPS data presented above: (i) share in Consumption (PCE) (ii) share in GDP (iii) share in total employment (iv) Network Adjusted Labor Intensity (or NALI) (v) Skill distribution within each industry. As a convention, we denote "low skill" workers with a high school diploma or less, "middle skill" workers with at least some college education and "high skill" workers with an education above college. These statistics are then used to discipline and calibrate the production side of the model.

Final Commodity	**Original Commodity in NIPA**
Manufactured Good	Agriculture, forestry, fishing, and hunting; Mining; Utilities; Manufacturing
Low Skill service	Wholesale trade; Retail trade; Transportation and warehousing; Construction; Arts, entertainment, recreation, accommodation, and food services; Other services (except government)
High Skill Service	Information; Finance, insurance, real estate, rental, and leasing; Professional and business services; Educational services, health care, and social assistance; Government





b. Income distribution: Model vs. Data