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The Social Cost of Optimal Taxes in an Imperfectly Competitive Economy

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November, 2010.

Abstract:

In this paper we calibrate the social cost of optimal taxes in a class of imperfectly competitive economies and examine the correspondence of this social cost with the number of tax instruments and the number and the sources of distortions. We calibrate the Ramsey equilibrium for three standard models of imperfect competition. These settings are different in number of sources of market distortion and number of tax instruments. Our calibration clearly shows that optimal taxes in an imperfectly competitive economy incur lower social cost than those in a competitive economy, implying that they are generally more efficient as competition enhancing policy tools. We find that optimal taxes in our models can cost up to 48% less forgone consumption relative to those in a competitive market economy.

Keywords: Optimal taxation, Ramsey problem, Welfare cost.

***JEL* Codes:** D42, E62, H21, H30.

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Introduction.

In this paper we examine the social cost of optimal taxes in an imperfectly competitive economy. A combined measure of the welfare cost and the administrative cost of taxes is represented by a single multiplier of the standard Ramsey (1927) planner's optimization problem. This multiplier, associated with the *implementability* constraint of the Ramsey planner's problem, is a present value measure of the loss in utility due to distorting taxes. We define this loss as the social cost of optimal taxes, and we present a simple method of calibrating this multiplier. We conduct the analysis on imperfectly competitive economies because we aim to examine the correspondence between taxes and monopoly distortions and the impact of this correspondence on the social cost of taxes. We examine the correspondence between the size of market distortion, the sources of distortions, the number of tax instruments and the social cost of optimal taxes.

Previous studies, such as Ortiguieira (1998) and Coleman II (2000) calibrate the welfare gains from switching to the Ramsey policy in a competitive economy. Guo and Lansing (1999) calibrate the steady state Ramsey taxes in an imperfectly competitive economy and explain the sensitivity of Ramsey taxes for changes in key parameters of the model. Jonsson (2004) considers an environment of imperfect competition and calibrates the welfare cost of taxes in a decentralized competitive equilibrium. The main concentration of Jonsson (2004) was to examine the loss in consumption (and utility) that is induced by a combination of monopoly distortions and a set of arbitrarily chosen tax rates. In this paper we extend these important works.

We extend a standard model of Ramsey taxation with an imperfectly competitive goods market, with multiple sources of monopoly distortions, and with a single as well as many tax instruments. This enables us to present a class of models that can be explored in order to examine the correspondence between the sources of market distortions, the number of tax instruments and the social cost of *optimal* taxes. We present a method of calibrating the social cost of Ramsey taxes and the same if the economy were perfectly competitive. We also calibrate the sensitivity of the social cost of optimal taxes for changes in the key parameters of the models. This analysis is therefore useful if one is interested in comparing the social desirability of the optimal (and not arbitrarily chosen) taxes in both perfectly and imperfectly competitive economies.

We follow the primal approach to the optimal taxation problem (due primarily to Atkinson and Stiglitz, 1980). This approach characterizes the optimal wedges in allocations that can be implemented in a decentralized equilibrium. The taxation authority needs to choose the taxes that can implement the wedges. This optimal choice of taxes is derived from the welfare maximization problem of the taxation authority. Typically, an implementable set of distorting taxes induces a

deviation from equilibrium welfare which is captured in the Ramsey planner's programming problem. We derive a shadow measure of the social cost of taxation from the deviation of Ramsey equilibrium level of welfare from the first best level of welfare[2].

We calibrate the social cost of the optimal taxes for three settings. First, we consider a labour-only economy with imperfect competition in product market and a single income tax (e.g. average effective tax on households). The first setting is thus representative of an economy with single source of market distortion and single tax instrument. Then to the first setting we introduce labour market imperfection in the form of simple monopolistic wage setting. This setting introduces multiple sources of market distortion but continues with a single tax instrument. Finally, we consider an imperfectly competitive economy with labour and capital and a tax code that assigns distinct taxes to income from factors. This setting allows for multiple tax instruments with a single source of distortion. We consider distortion in the private markets in its simplest and most familiar form, one that stems from having a fixed number of firms in a sector producing imperfectly substitutable intermediate goods[3].

We use a sample calibration in order to verify both the methodology that we propose and the underlying intuitions of our analysis. We find that in an imperfectly competitive economy the optimal taxes are associated with lower social cost relative to that in a competitive economy. Relative to the competitive markets setting in an imperfectly competitive economy with only one source of market distortion, a single optimal tax instrument is associated with 42% lesser welfare cost. If there are more taxes, the economy is associated with 1% lesser social cost relative to its competitive market equivalent. The intuition stems from the simplicity of tax administration. Since a significant part of the social cost is the cost of administering distorting taxes, having more taxes to administer is more costly than having a single tax to administer. We also find that the correspondence between the social cost of taxes and the sources of market distortion depends crucially on the size of market distortion. In general, we find that higher levels of market distortions are associated with lower levels of social cost of taxes. The rate at which the social cost declines can vary between settings with a single source of market distortion and multiple sources of market distortion. With multiple sources of market distortion, we find that the social cost of taxes is 48% less than that in a competitive economy.

[2] With only distorting taxes in the scheme, the planner's welfare maximizing problem involves, in addition to the resource constraint, a constraint that restricts welfare maximizing taxes to be implementable. This added restriction in the planner's problem is associated with a present value cost of a sequence of tax plans, i.e. the discounted social cost of administering the tax policy. Because this measure is related to the excess burden of taxes, we define this measure as the social cost of optimal taxes.

[3] This is in the spirit of Dixit and Stiglitz (1977), Judd (1997) and Guo and Lansing (1999).

The Social Cost of Optimal Taxes.

In order to motivate our main analysis we first present the underlying theory and a sample calibration in a competitive market setting. We consider a very standard one sector neoclassical model of Ramsey taxation (e.g. Ljungqvist & Sargent, 2000, ch.12). The final good (y_t) is produced using labour (n_t) and capital (k_t) as inputs and is traded in competitive market. The resource constraint is[4]:

$$f(k_t, n_t) - c_t - g_t - k_{t+1} + (1-\delta)k_t = 0 \qquad (1)$$

where private consumption, government consumption and investment are denoted by c_t, g_t and i_t, respectively, and $f(.)$ satisfies standard regularity conditions. The government's period t budget constraint is $\tau_{kt} r_t k_t + \tau_{nt} w_t n_t + R_t^{-1} b_{t+1} - b_t - g_t = 0$, where $g_t = \bar{g} > 0$ for each t, b_t denotes the government's indebtness to the private sector, and τ_{it} denotes tax rates for $\iota \in \{k, n\}$. The representative household solves the following problem:

$$\max_{c_t, n_t, k_{t+1}, b_{t+1}} \sum_{t=0}^{\infty} \beta^t u(c_t, n_t)$$

$$s.t. \quad (1-\tau_{nt}) w_t n_t + [(1-\tau_{kt}) r_t + (1-\delta)] k_t + b_t - c_t - k_{t+1} - R_t^{-1} b_{t+1} = 0$$

The utility function satisfies standard regularity conditions. The competitive equilibrium conditions include equilibrium factor prices, optimality conditions from the household's problem, the resource constraint and the transversality condition. Given a preset revenue target, the government chooses the tax rates in order to maximize welfare such that these taxes are feasible and implementable, i.e. the allocation and prices generated by these welfare maximizing taxes satisfy (1) and the competitive equilibrium. One can thus characterize the Ramsey planner's problem as one of choosing an allocation in order to maximize welfare subject to the resource constraint (1) and the following implementability constraint:

$$\sum_{t=0}^{\infty} \beta^t [u_c(t) c_t + u_n(t) n_t] - \Omega^p(c_0, n_0, \tau_{k0}) = 0 \qquad (2)$$

[4] Throughout the paper, we use subscript t to denote the level of a variable at period t, and t in parentheses to denote the value of a derivative at period t.

where $\Omega^p(c_0, n_0, \tau_{k0}) \equiv u_c(0)\{[(1-\tau_{k0}) f_k(0) + (1-\delta)]k_0 + b_0\}$. In order to solve this problem, one can conveniently define a Pseudo-type utility function, or more intuitively, a second best welfare function:

$$G(c_t, n_t, \eta^p) \equiv u(c_t, n_t) + \eta^p [u_c(t)c_t + u_n(t)n_t]$$

where $\eta^p \geq 0$ is the Lagrange multiplier on (3.1). Intuitively, η^p provides a shadow measure of the utility cost of raising government revenues through distorting taxation. Given the Ramsey programming problem if $G^*(.)$ denotes the maximum value of $G(.)$ evaluated in a steady state, $G^*(.) = u^*(.) + \eta^p [u_c^* c^* + u_n^* n^*]$, i.e. the second best level of welfare is equal to the first best level of welfare, $u^*(.)$, less the loss in welfare due to distorting taxes, equal to $\eta^p [u_c^* c^* + u_n^* n^*]$. The loss in welfare is measured in terms of the loss in allocation due to the competitive equilibrium reaction of taxpayers, which is multiplied by the shadow price of taxes, η^p. This multiplier's value is therefore representative of the amount (in terms of consumption) taxpayers are willing pay in order to replace a unit of the distorting tax with a unit of a lump sum tax[5].

If the government's plan includes heavy taxation at the beginning (in order to reduce distorting tax rates in the future), η^p is relatively higher. If Γ^* denotes the maximum value Lagrangian associated with the government's welfare maximization problem, $\Gamma^*_{\tau k0} = \eta^p u_c(0) f_k(0) k_0 > 0$ for all τ_{k0}, as long as $\eta^p > 0$. This explains the celebrated result of zero capital income tax in a steady state, due primarily to Judd (1985) and Chamley (1986). A zero tax on capital income is implementable in the long run only if it is possible to tax capital early, which incurs a high social cost. The idea is to confiscate capital income initially and frontload revenue so that η^p is high, and thereafter reduce capital income tax to zero and use bond financing for future revenue.

Consider a sample characterization of a steady state of the Ramsey equilibrium. Let $u(c_t, n_t) = \ln c_t + [1 - \zeta n_t]$ and $f(k_t, n_t) = \phi k_t^{\theta} n_t^{1-\theta}$, where $\zeta, \phi > 0$, $\theta \in (0,1)$. The time-invariant version of the Ramsey equilibrium includes the following equations in (3):

$$1 - \beta[\theta\phi k^{\theta-1} n^{1-\theta} + 1 - \delta] = 0 \qquad \text{(a)}$$

[5] For instance if the value of this multiplier is high, the social cost of distorting taxes is high but that of lump sum taxes are low, implying that administering the second best tax policy costs relatively higher amounts of forgone consumption.

$$\zeta(1+\eta^p) - c^{-1}(1-\theta)\phi k^{\theta} n^{-\theta} = 0 \qquad \text{(b)}$$

$$\zeta(1+\eta^p) - [c_0^{-1} - \eta^p \Omega^p{}_{c0}](\theta-1)\phi k_0^{\theta} n_0^{-\theta} + \eta^p \Omega^p{}_{n0} = 0 \qquad \text{(c)}$$

$$c + g - \phi k^{\theta} n^{1-\theta} + \delta k = 0 \qquad \text{(d)}$$

$$(1-\beta)^{-1}(1-\zeta n) - \Omega^p(c_0, n_0, \tau_{k0}) = 0 \qquad \text{(e)}$$

where $\Omega^p(c_0, n_0, \tau_{k0}) = c_0^{-1}\{[(1-\tau_{k0})\theta\phi k_0^{\theta-1} n_0^{1-\theta} + 1 - \delta]k_0 + b_0\}$

Proposition 1. There is a unique solution to the system (3) implying that there is a unique set of steady state allocation, taxes and prices associated with the Ramsey equilibrium.

Proof: Solve (3a) for $n^{1-\theta}$, and substitute in (3d) in order to derive $k = \frac{(c+g)\theta\beta}{(1-\beta+\beta\delta-\theta\beta\delta)}$. Then, substitute back in the expression for $n^{1-\theta}$ and solve for n. Substitute for both k and n in (3b) in order to derive $c = \frac{(1-\theta)\phi}{(1+\eta^p)\zeta}\left(\frac{1-\beta+\beta\delta}{\beta\theta\phi}\right)^{\frac{\theta}{\theta-1}}$. Notice that c is unique if the multiplier η^p is unique. One can compute a unique value for η^p using (3b) and (3c) in terms of the initial conditions. For unique c and given g, both k, n and their corresponding prices are unique. The competitive equilibrium condition $(1-\tau_n)(1-\theta)\phi k^{\theta} n^{-\theta} = \zeta c$ gives a unique labour income tax rate. With $\tau_k = 0$, the time-invariant version of the no-arbitrage condition gives R. In order to find the steady state level of government bond, b, evaluate the household's time t budget constraint at time $t+1$, and substitute in the household's first order conditions. This gives the following recursive equation:

$$u_c(t)k_{t+1} - \beta u_c(t+1)(k_{t+2} + R_{t+1}^{-1} b_{t+2} - b_{t+1}) + \beta u_n(t+1)n_{t+1} + c_{t+1} = 0 \qquad (4)$$

The time-invariant version of this equation gives $b = [\beta(R^{-1}-1)]^{-1}[k(1-\beta) + \beta\zeta cn - c^2]$, which is unique. •

The calibrations we perform in this paper refers to the problem of finding parameter values, given some constant growth observations for an actual economy, such that the constant growth behaviour of that model economy matches the growth observations for that actual economy. In line with Cooley and Prescott (1995) we define an *algorithm* as a sequence of steps to numerically compute parameters, given a set of steady state observations of an actual economy. A feature of an algorithm is that at any step parameters whose values have been determined in earlier steps can be used, but parameters whose values have not been determined in earlier steps cannot be used. We

use a representative dataset for calibrating the parameters for our models. We then use these parameters and corresponding steady state observations in order to compute the Ramsey taxes and their associated social cost. Given the algorithm to calibrate the parameters, for a given set of steady state observations there exists a unique set of calibrated Ramsey taxes and their associated social cost. Any change in the steady state observations thus requires recalibration of the parameters which in turns recalibrates the Ramsey taxes and their associated social cost.

For the purpose of illustration, we consider a simple calibration of the steady state of this competitive market model using post war US economy data approximately for the period 1960-2008. The set of parameters of the model are $(\beta, \delta, \theta, \phi, \zeta)$. The steady state observations of government consumption-output and bond-output ratios are the ones taken from the Federal Reserve Bank of St. Louis Economic Data-FRED II. In seasonally adjusted real terms this data gives average government consumption to output ratio equal to 0.23, and government bond to output ratio equal to 0.51. Annual data for the US economy's capital stock and investment for the period 1960-1996 are collected from the US Department of Commerce's *Revised Fixed Reproducible Tangible Wealth in the United States*. This gives steady state capital to output ratio equal to 3.31, and investment to output ratio equal to 0.22. These, including profit to output ratio which we use later, are in appendix, table 1.

Given a time endowment normalized to one, Cooley & Prescott (1995) pins down the fraction of worked time to a range of 0.2 to 0.3. For the current study we hold $n = 0.3$ as a benchmark. We consider the annual real interest rate of 4%. Using (3a) this gives $\beta = 0.9615$. The steady state version of capital's law of motion, which with steady state observations of capital-output and investment-output ratio give $\delta = 0.0664$. Next, (3a) gives $r = 0.1064$. Then $k / y = 3.31$ and $r = 0.1064$ pin down $\theta = 0.3523$. The steady state version of the resource constraint gives the consumption-output ratio equal to 0.55. We consider the steady state version of the government budget constraint with zero capital tax (the steady state tax rate in the Ramsey equilibrium), and divide both sides by y. We evaluate the resulting expression for the observed steady state government expenditure to output ratio and bond to output ratio in order to derive $(w\tau_n)/y = 0.8322$. This, together with the steady state equilibrium factor price equations give $(w/y) = 2.159$, and therefore $\tau_n = 0.3823$. Estimate for the Lagrange multiplier, i.e. the social cost of these taxes is $\eta^p = 0.4921$. Once this is calibrated, we verify if this social cost is associated with the optimal tax (i.e. $\tau_n = 0.3823$) that generate allocation and prices which are consistent with the steady state of the competitive equilibrium.

An Imperfectly Competitive Economy with a Single Tax Instrument.

Our main analysis starts with a very simple discrete time model of imperfect competition with a single income tax. We refer to this model as model 1. The final goods sector is perfectly competitive (competitive sector, hereafter), and the intermediate goods sector is imperfectly competitive (monopoly sector, hereafter). The competitive sector produces y_t (the numeraire) using a continuum $j \in [0,1]$ of intermediate goods. The final good is used for private consumption (c_t) and government consumption (g_t). The two technologies are:

$$y_t = \left(\int_0^1 z_{jt}^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}} \tag{5.1}$$

$$z_{jt} = n_{jt}^{\alpha} \tag{5.2}$$

where z_j denotes the level of intermediate good j, $\sigma \in (0,1)$ indexes the degree of monopoly power exercised by suppliers of the intermediate good[6], n_j is working time and $\alpha \in (0,1]$. The representative firm in the competitive sector faces the following sequence of problems:

$$\max_{z_{jt}} \quad \left[\left(\int_0^1 z_{jt}^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}} - \int_0^1 p_{jt} z_{jt} dj \right]$$

where p_j denotes the relative price of intermediate good j. The solution gives the inverse demand function $p_{jt} = y_t^{\sigma} z_{jt}^{-\sigma}$. Firm j in the monopoly sector take the wage rate and prices of other firms as given when choosing price according to $p_{jt} = y_t^{\sigma} z_{jt}^{-\sigma}$ and labour to maximize profits. Firm j's decision problem is:

$$\max_{n_{jt}} \quad [y_t^{\sigma} n_{jt}^{\alpha(1-\sigma)} - w_{jt} n_{jt}]$$

[6] $\sigma \to 1$ represents very low elasticity of substitution between intermediate goods giving higher market power to firms in the intermediate goods sector. $\sigma \to 0$ implies intermediate goods are near perfect substitutes.

Firms producing final goods earn zero profits in equilibrium, i.e. $\left[y_t - \int_0^1 p_{jt} z_{jt} \right] = 0$, which together with $p_{jt} = y_t^{\sigma} z_{jt}^{-\sigma}$ and symmetry implies that $p_{jt} = p_t = 1$ for all j. Moreover, the symmetric equilibrium price implies equilibrium wage rate:

$$w_t = \alpha(1-\sigma) z_t (n_t)^{-1} \tag{5.3}$$

The equilibrium profits for the monopoly sector is given by $\pi_t = z_t[1-\alpha(1-\sigma)]$. The government consumes exogenous $g_t = \bar{g} > 0$ each period and raises the required revenue from taxation of income and profit. We consider a tax code where the government taxes wage income at rate τ_t and profits at a rate $\kappa\tau_t$, where $\kappa \in [0,1]$[7]. The government also trades one period bond to households which pay interest at the rate r_t. The government's period t budget constraint is given by:

$$g_t + b_t(1+r_t) = \tau_t \left[\int_0^1 w_{jt} n_{jt} dj + \kappa \int_0^1 \pi_{jt} dj \right] + b_{t+1} \tag{6}$$

where w_{jt} denotes real wage, and b_t denotes bond. Households are endowed with one unit of time at each period and ownership of firms. Households have identical preferences over consumption and leisure, and they like both. Preferences for the representative household are given by:

$$\sum_{t=0}^{\infty} \beta^t u(c_t, l_t) \tag{7}$$

where $\beta \in (0,1)$ is the subjective discount rate, l_t is leisure and $u(.)$ satisfies standard regularity conditions. The representative household's utility maximization problem is:

$$\max_{c_t, n_t, b_{t+1}} \quad \sum_{t=0}^{\infty} \beta^t u(c_t, n_t)$$
$$s.t. \qquad c_t + b_{t+1} \le (1-\tau_t) w_t n_t + (1+r_t) b_t + (1-\kappa\tau_t)\pi_t$$

[7] Different values of the parameter κ will illustrate the government's fiscal treatment of distributed profits. For instance, $\kappa = 0$ implies profits escape all direct taxation, and $\kappa = 1$ implies profits and wage income are taxed at the same rate.

where b_0 given, and standard non-negativity restrictions apply. In a symmetric equilibrium all firms in the monopoly sector produce the same level of intermediate goods and hire the same amount of labour. The symmetric equilibrium is characterized by the following system (8) for the set of endogenous variables $\{c_t, n_t, b_t, w_t, p_t, \pi_t, z_t, y_t, \tau_t\}$:

$$0 < n_t \leq 1 \quad \text{(a)}$$

$$n_t^{\alpha} = c_t + g_t \quad \text{(b)}$$

$$p_t = 1 \quad \text{(c)}$$

$$-u_n(t) = u_c(t)(1-\tau_t)w_t \quad \text{(d)}$$

$$u_c(t) = u_c(t+1)\beta(1+r_t) \quad \text{(e)}$$

$$\lim_{t\to\infty} \beta^t u_c(t) b_{t+1} = 0 \quad \text{(f)}$$

$$w_t = \alpha(1-\sigma) z_t (n_t)^{-1} \quad \text{(g)}$$

$$\pi_t = n_t^{\alpha}[1-\alpha(1-\sigma)] \quad \text{(h)}$$

$$g_t + b_t(1+r_t) = \tau_t(w_t n_t + \kappa\pi_t) + b_{t+1} \quad \text{(i)}$$

The equilibrium profit to output ratio for this model is linked to the degree of returns to scale in monopoly sector, the price mark up ratio μ, and the parameter σ, such that[8]:

$$n_t^{1-\alpha} = \mu\left(1-\frac{\pi_t}{y_t}\right) \quad (9)$$

We use the primal approach in order to derive the conditions that characterize the Ramsey allocation. Then we look for the tax rate that can implement the second-best wedges. The Ramsey allocation can be characterized by designing a problem where the government chooses the allocation $\{c_t, n_t\}_{t=0}^{\infty}$ in order to maximize (7) subject to the resource constraint (8b) and the implementability constraint:

$$\sum_{t=0}^{\infty} \beta^t [u_c(t)c_t + u_n(t)n_t - u_c(t)(1-\kappa\tau_t)\pi_t] - u_c(0)R_0 b_0 = 0 \quad (10)$$

[8]According to Basu & Fernald's (1997) estimates on typical US industry profit ratio, the value of the price mark up ratio assuming constant returns to scale technology in manufacturing industry is 1.03. Bayoumi. Laxton & Pesenti (2004) present a relatively more recent estimate of mark up ratio equal to 1.23 for the overall US economy and 1.35 for the Euro area. The estimate for the US for instance, assuming that $\alpha = 1$ in the current setting amounts to an estimate of σ equal to 0.186 (for the Euro area it is 0.259). In this model for instance, if the profit ratio is 5% and degree of returns to scale in the intermediate goods sector is 1, $\mu = 1.05$. With $\alpha = 1$, the profit ratio is simply equal to σ.

where $R_0 \equiv (1+r_0)$, and r_0, b_0 and g_t are given. We can express the term $(1-\kappa\tau_t)\pi_t$ in (10) in terms of allocations using (8d), such that

$$(1-\kappa\tau_t)\pi_t = \left[\frac{1-\alpha(1-\sigma)}{\alpha(1-\sigma)}\right]\left[\alpha(1-\sigma)(1-\kappa)n_t^{\alpha} - \kappa\frac{u_n(t)n_t}{u_c(t)}\right] \tag{11}$$

Let $\eta \geq 0$ denote the Lagrange multiplier associated with (10), and define

$$G(c_t, n_t, \eta) \equiv u(c_t, n_t) + \eta[u_c(t)c_t + u_n(t)n_t - u_c(t)(1-\kappa\tau_t)\pi_t]$$

where $(1-\kappa\tau_t)\pi_t$ is defined according to (11). Let $\{\chi_t\}_{t=0}^{\infty}$ denote the sequence of Lagrange multiplier associated with the resource constraint (8b). The Ramsey problem's Lagrangian is:

$$J = \sum_{t=0}^{\infty}\beta^t\{G(c_t, n_t, \eta) + \chi_t(n_t^{\alpha} - c_t - g_t)\} - \eta u_c(0)R_0 b_0 \tag{12}$$

The consolidated first order conditions for the Ramsey optimum due to changes in allocations are:

$$G_n(t) = -\alpha G_c(t)n_t^{\alpha-1} \qquad \forall t \geq 1 \tag{12.1a}$$

$$G_n(0) = [u_{cc}(0)\eta R_0 b_0 - G_c(0)]\alpha n_0^{\alpha-1} + \eta R_0 b_0 u_{cn}(0) \tag{12.1b}$$

We consider a utility function that is separable in consumption and labour, and linear in labour. This assumption is supported by Hansen (1985), among others. We evaluate (12.1a) and (8d) in a steady state and derive the optimal tax rate, given by:

$$1-\tau_t = \frac{u_c(t)\{1+\eta[\kappa+\alpha-\alpha\sigma-\alpha\kappa+\alpha\sigma\kappa]\} + \eta u_{cc}(t)[c_t - (1-\kappa)\pi_t]}{u_c(t)\{1-\sigma+\eta[1-\sigma+\kappa(\alpha)^{-1}-\kappa+\sigma\kappa]\}} \tag{13}$$

If one considers competitive markets in this setting, it is necessary to rerun the Ramsey problem in order to derive the competitive market equivalent of η and the optimal tax rate. We denote the corresponding steady state tax rate by τ_t^p and the multiplier by η^p, and in a steady state of the competitive market equivalent of this model,

$$1-\tau_t^p = \frac{1+\eta^p\{c_t u_{cc}(t)[u_c(t)]^{-1}+1\}}{(1+\eta^p)} \qquad (14)$$

For the remaining two models, we follow the same method of rerunning the Ramsey problem for two sector competitive market settings in order to derive the competitive market analogue of the social cost of optimal taxes and the optimal taxes. This is because for each setting, the dynamic path of tax rates that achieves a Ramsey steady state is different. Given a set of initial conditions and tax rates numerous paths of tax rates can achieve the Ramsey steady state. The quest is therefore choosing the paths that maximize welfare and are implementable. Implementability is ensured by imposing an additional constraint in the planner's optimization problem. Starting from the same initial tax rates (held given), each individual path of tax rates (and bonds) that reaches the Ramsey steady state is associated with a different social cost, i.e. each individual path of tax rates that are implementable in the decentralized equilibrium can induce different levels of forgone utility. Depending on which path of tax rate is chosen, the social cost of these taxes will vary. This intuition holds same for a competitive market economy.

Monopolistic Wage Setting.

We now consider an extension of model 1 with the simplest form of monopolistic wage setting behaviour of workers. Along with the single tax distortion, we introduce two forms of market distortion in our model. We assume that the labour market is imperfectly competitive and subject to monopolistic wage setting, i.e. wages are set with a mark up compared to a fully competitive outcome, leading to a socially suboptimal level of working hours. We will call it model 2.

Assume that households collectively organize in a trade union which acts as a monopolistic wage setter. Wages are set for one period, and the wage-setting behaviour takes into account the static constraint imposed by the labour demand schedule $n_{jt} = n(w_{jt})$. Since firms are small relative to the economy, they are unable to behave in a strategic manner towards the wage setting behaviour. This simplification removes the hold-up problem (which typically arises under firm specific bargaining). We assume that the behaviour of the union is myopic in the sense that the intertemporal feedback effects of wage setting are not taken into account. The union is also assumed not to influence profits which are distributed back to its members. The institutional set up which generates the market inefficiency is taken as given by the government when designing the tax policy, implying that corrective taxes or subsidies are the only channel to address the labour and intermediate goods market distortion. The proportional tax rate on wage in this model is

denoted by τ_t^m. Imposing symmetry, the wage function which is the wage setting constraint for the trade union's maximization problem is:

$$w_t = \alpha(1-\sigma)n_t^{\alpha-1} \tag{15}$$

The wage elasticity of labour demand therefore is $\omega_w = \frac{-1}{[1-\alpha(1-\sigma)]}$. Acting on behalf of its members, the trade union maximizes utility subject to the budget constraints and the labour demand constraint. The mark up of net wages over the marginal rate of substitution between labour and consumption is equal to $\frac{1}{\alpha(1-\sigma)}$, which in turns is equal to $\frac{|\omega_w|}{[|\omega_w|-1]}$.

The implementability constraint for the corresponding Ramsey problem is:

$$\sum_{t=0}^{\infty}\beta^t\left[u_c(t)c_t + \frac{u_n(t)n_t}{\alpha(1-\sigma)} - u_c(t)(1-\kappa\tau_t)\pi_t\right] - u_c(0)R_{b0}b_0 = 0 \tag{16}$$

where $(1-\kappa\tau_t^m)\pi_t = \left[\frac{1-\alpha(1-\sigma)}{\alpha(1-\sigma)}\right]\left[\alpha(1-\sigma)(1-\kappa)n_t^{\alpha} - \kappa\frac{u_n(t)n_t}{\alpha(1-\sigma)u_c(t)}\right]$.

The Pseudo utility function associated with the Ramsey problem is:

$$G^m(c_t, n_t, \eta^m) \equiv u(c_t, n_t) + \eta^m[u_c(t)c_t + \frac{u_n(t)n_t}{\alpha(1-\sigma)} - u_c(t)(1-\kappa\tau_t)\pi_t] \tag{17}$$

The first order condition corresponding to the Ramsey problem for variation in labour supply for $t \geq 1$ is $G_n^m(t) = -\alpha G_c^m(t)n_t^{\alpha-1}, \forall t \geq 1$, where

$$G_n^m(t) = u_n(t)\left\{1 + \frac{\eta^m}{\alpha(1-\sigma)} + \frac{\eta^m[1-\alpha(1-\sigma)]\kappa}{[\alpha(1-\sigma)]^2}\right\} - \eta^m u_c(t)(1-\kappa)[1-\alpha(1-\sigma)]\alpha n_t^{\alpha-1} \tag{18.1}$$

$$G_c^m(t) = u_c(t)(1+\eta^m) + \eta^m u_{cc}(t)\left\{c_t - (1-\kappa)n_t^{\alpha}[1-\alpha(1-\sigma)]\right\} \tag{18.2}$$

In a steady state, the optimal tax rate is given by:

$$1-\tau^m = \frac{u_c\{1+\eta^m[\kappa+\alpha-\alpha\sigma-\alpha\kappa+\alpha\sigma\kappa]\}+\eta^m u_{cc}[c-(1-\kappa)\pi]}{u_c\{\alpha(1-\sigma)^2+\eta^m[1-\sigma+\kappa(\alpha)^{-1}-\kappa+\sigma\kappa]\}} \qquad (19)$$

A Model with Many Tax Instruments.

The final extension of model 1 we consider is one with capital and a set of income taxes. We call it model 3. We go back to our basic assumption that factor markets are competitive. Since we introduce capital and a set of income taxes, we simplify the model by removing government bonds[9]. In this model intermediate goods production requires labour and capital, and final goods production requires intermediate goods and labour. We define leisure in this model as $l_t = 1 - n_{yt} - n_{zt}$. The two technologies are:

$$y_t = \left\{\left(\int_0^1 z_{jt}^{1-\sigma} dj\right)^{\frac{1}{1-\sigma}}\right\}^{\nu} n_{yt}^{1-\nu}, \qquad \nu \in (0,1); \sigma \in (0,1) \qquad (20.1)$$

$$z_{jt} = k_{jt}^{\alpha} n_{zjt}^{1-\alpha}, \qquad \alpha \in (0,1) \qquad (20.2)$$

where $n_{st}, s = y, z$ is working time in sector s, k_t is capital. In addition to time endowment and property rights, households are endowed with a strictly positive amount of capital at $t = 0$. The final good can be consumed or invested. The government's tax instruments are τ_{ns} and τ_k for labour and capital, and $\xi\tau_k$, with $\xi \in [0,1]$ for profits. The resource constraint (with symmetry) is:

$$c_t + g_t + k_{t+1} = k_t^{\alpha\nu} n_{zt}^{\nu(1-\alpha)} n_{yt}^{1-\nu} + (1-\delta)k_t; \qquad \delta \in (0,1) \qquad (21)$$

We denote the wages and the return to capital by w_s and r, respectively. The representative firm in the competitive sector faces the following sequence of problems:

[9] It is simple to understand that adding bonds to the model does not alter any of the analyses to follow. To start with, we could have reconstruct models 1 and 2 as static models without government bonds. But in models 1 and 2, since there is a single income tax the government bond performs the role of an orthogonal policy instrument. Any change in the single tax instrument in models 1 and 2 can be supplemented by a change in government bonds that would keep government's revenue requirement fixed.

$$\max_{z_{jt},n_{yt}} \left[\left\{ \left(\int_0^1 z_{jt}^{1-\sigma} dj \right)^{\frac{1}{1-\sigma}} \right\}^{\nu} n_{yt}^{1-\nu} - \int_0^1 p_{jt} z_{jt} dj - w_{yt} n_{yt} \right]$$

The profit maximization problem of the j-th firm in the monopoly sector is:

$$\max_{p_{jt},n_{zjt},k_{jt}} [p_{jt} z_{jt} - r_{jt} k_{jt} - w_{zjt} n_{zjt}]$$

$$s.t. \quad z_{jt} = k_{jt}^{\alpha} n_{zjt}^{1-\alpha}$$

$$p_{jt} = \nu(y_t)^{1-\frac{1-\sigma}{\nu}} z_{jt}^{-\sigma} (n_{yt})^{\frac{(1-\nu)(1-\sigma)}{\nu}}$$

The representative household's problem is:

$$\max_{\{c_t,n_{yt},n_{zt},k_{t+1}\}} \sum_{t=0}^{\infty} \beta^t u(c_t, l_t)$$

$$s.t. \quad c_t + k_{t+1} = (1-\tau_{yt}) w_{yt} n_{yt} + (1-\tau_{zt}) w_{zt} n_{zt} + [(1-\tau_{kt}) r_t + (1-\delta)] k_t + (1-\xi\tau_{kt}) \pi_t$$

$$k_0 > 0 \; given$$

Symmetric equilibrium conditions include standard transversality condition and the following system (21.1)

$$0 < n_{yt} + n_{zt} \leq 1 \qquad \text{(a)}$$

$$y_t = z_t^{\nu} n_{yt}^{1-\nu} \qquad \text{(b)}$$

$$z_t = k_t^{\alpha} n_{zt}^{1-\alpha} \qquad \text{(c)}$$

$$c_t + g_t + k_{t+1} = k_t^{\alpha\nu} n_{zt}^{\nu(1-\alpha)} n_{yt}^{1-\nu} + (1-\delta) k_t \qquad \text{(d)}$$

$$p_t = \nu(y_t)^{1-\frac{1-\sigma}{\nu}} z_t^{-\sigma} (n_{yt})^{\frac{(1-\nu)(1-\sigma)}{\nu}} \qquad \text{(e)}$$

$$w_{yt} = (1-\nu)(n_{yt})^{-1} y_t \qquad \text{(f)}$$

$$w_{zt} = (1-\alpha)\nu(1-\sigma)(n_{zt})^{-1} y_t \qquad \text{(g)}$$

$$r_t = \alpha(1-\sigma)\nu(k_t)^{-1} y_t \qquad \text{(h)}$$

$$\pi_t = (\nu\sigma) k_t^{\alpha\nu} n_{zt}^{\nu(1-\alpha)} n_{yt}^{1-\nu} \qquad \text{(i)}$$

$$g_t = \tau_{yt} w_{yt} n_{yt} + \tau_{zt} w_{zt} n_{zt} + \tau_{kt} (r_t k_t + \xi\pi_t) \qquad \text{(j)}$$

$$-u_{ns}(t) = u_c(t)(1-\tau_{st}) w_{st} \quad \text{for } s = y, z \qquad \text{(k)}$$

$$\beta[(1-\tau_{kt+1}) r_{t+1} + 1 - \delta] = u_c(t)[u_c(t+1)]^{-1} \qquad \text{(l)}$$

The implementability constraint associated with this equilibrium is:

$$\sum_{t=0}^{\infty}\beta^t[u_c(t)c_t+u_{ny}(t)n_{yt}+u_{nz}(t)n_{zt}-u_c(t)(1-\xi\tau_{kt})\pi_t]-\tilde{\Omega}(c_0,n_{y0},n_{z0},\tau_{k0})=0 \tag{22.1}$$

where

$$(1-\xi\tau_{kt})\pi_t=\begin{cases}\nu\sigma(1-\xi){k_t}^{\alpha\nu}{n_{zt}}^{(1-\alpha)\nu}{n_{yt}}^{1-\nu}+k_t\dfrac{\xi\sigma}{\alpha(1-\sigma)\beta u_c(t)}\left[u_c(t-1)-\beta u_c(t)(1-\delta)\right] & \text{for } t\geq 1\\ (1-\xi\tau_{k0})(\nu\sigma){k_0}^{\alpha\nu}{n_{z0}}^{\nu(1-\alpha)}{n_{y0}}^{1-\nu} & \text{for } t=0\end{cases} \tag{22.2}$$

and $\tilde{\Omega}(c_0,n_{y0},n_{z0},\tau_{k0})\equiv u_c(0)\{[(1-\tau_{k0})\alpha(1-\sigma)\nu(k_0)^{-1}y_0+(1-\delta)]k_0\}$. The Pseudo utility function is:

$$\tilde{G}(c_t,n_{yt},n_{zt},k_t,\tilde{\eta})\equiv u(c_t,n_{yt},n_{zt})+\tilde{\eta}[u_c(t)c_t+u_{ny}(t)n_{yt}+u_{nz}(t)n_{zt}-u_c(t)(1-\xi\tau_{kt})\pi_t]$$

where $\tilde{\eta}>0$ is the multiplier associated with (22). Let $\{\tilde{\chi}_t\}_{t=0}^{\infty}$ denote the sequence of Lagrange multiplier associated with the resource constraint (22.1d). The Ramsey equilibrium allocations corresponding to model 3 include (21.1d), (22) and the following system (23):

$$\tilde{G}_c(t)-\tilde{\chi}_t=0, \qquad t\geq 1 \tag{a}$$

$$\tilde{G}_{ny}(t)+\tilde{G}_c(t)w_{yt}=0, \qquad t\geq 1 \tag{b}$$

$$\tilde{G}_{nz}(t)+\tilde{G}_c(t)(1-\sigma)^{-1}w_{zt}=0, \qquad t\geq 1 \tag{c}$$

$$\tilde{G}_c(t)-\beta\left\{\tilde{G}_k(t+1)+\tilde{G}_c(t+1)\left[\frac{r_{t+1}}{(1-\sigma)}+(1-\delta)\right]\right\}=0, \qquad t\geq 1 \tag{d}$$

$$\tilde{G}_c(0)-\tilde{\chi}_0-\tilde{\eta}\tilde{\Omega}_c=0 \tag{e}$$

$$\tilde{G}_{ny}(0)+\tilde{\chi}_0(1-\nu){k_0}^{\alpha\nu}{n_{z0}}^{\nu(1-\alpha)}{n_{y0}}^{-\nu}-\tilde{\eta}\tilde{\Omega}_{ny}=0 \tag{f}$$

$$\tilde{G}_{nz}(0)+\tilde{\chi}_0\nu(1-\nu){k_0}^{\alpha\nu}{n_{z0}}^{\nu(1-\alpha)-1}{n_{y0}}^{1-\nu}-\tilde{\eta}\tilde{\Omega}_{nz}=0 \tag{g}$$

$$\tilde{\chi}_0-\beta\left\{\tilde{G}_k(1)+\chi_1[\nu\alpha k_1^{\alpha\nu-1}n_{z1}^{(1-\alpha)\nu}n_{y1}^{1-\nu}+(1-\delta)]\right\}=0 \tag{h}$$

We consider the Ramsey policy in a steady state. The steady state version of the Ramsey equilibrium and the symmetric equilibrium together imply:

$$1-\tau_z = \frac{1}{(1-\sigma)} - \frac{\tau_y}{(1-\sigma)} \tag{24.1}$$

$$1-\tau_k = \frac{1}{(1-\sigma)} + \frac{\tilde{\tilde{G}}_k}{r\tilde{\tilde{G}}_c} \tag{24.2}$$

where

$$\tilde{\tilde{G}}_c = u_c + u_c\tilde{\eta}\left[1+\frac{u_{cc}c}{u_c}\left\{1-\sigma\nu\frac{y}{c}\left[(1-\xi)-(1-\delta-\beta^{-1})r^{-1}\xi\right]\right\}\right]$$

$$\tilde{\tilde{G}}_k = u_c\tilde{\eta}\left[\frac{\xi\sigma}{\alpha(1-\sigma)}(1-\delta-\beta^{-1}) - \nu\sigma(1-\xi)\frac{r}{(1-\sigma)}\right]$$

Equation (24.1) captures the differential taxation result of Stiglitz and Dasgupta (1971). It says that since the intermediate goods sector is imperfectly competitive, it is optimal to set a relatively lower labour income tax in the intermediate goods sector in order to compensate for the loss in income[10]. Equation (24.2) reinterprets the capital tax ambiguity result of Guo and Lansing (1999). It says that the sign of optimal capital tax rate is ambiguous and depends on the relative strength of the two opposing effects. Given the current setting, these effects are the distortion effect and the welfare effect of profit-seeking investment (see Selim, 2010 for further details). The optimal policy may subsidize (tax) capital income if the distortion effect (investment effect) dominates.

Calibration of Models 1 and 2.

We consider the following specification for utility:

$$u(c_t, l_t) = \ln(c_t) + l_t \tag{25}$$

For model 1 and 2, we assume that $l_t = 1-\Lambda n_t$, and $l_t = 1-\Lambda^m n_t$, respectively, where $\Lambda, \Lambda^m > 0$ are constants associated with the marginal disutility of work.. For model 3, $l_t = 1-n_{yt}-\tilde{\Lambda}n_{zt}$. We use annual data for the US economy for a period of 1960-2008[11], taken from the Federal Reserve Bank of St. Louis Economic Data-FRED II. Consider first the calibration for model 1. The steady state of symmetric equilibrium includes:

[10] The optimal τ_z can be computed using the steady state versions of (23c) and (21.1g). For the optimal τ_y, the steady state versions of (23b) and (21.1f) needs to be used together.

[11] We use this dataset as a representative dataset in order to carry out a numerical experiment of our proposed methodology. The calibration is therefore only a numerical characterization of our methodology.

$$c + g = n^{\alpha} = y \tag{26.1}$$

$$-\Lambda c = (1-\tau)\alpha(1-\sigma)n^{\alpha-1} \tag{26.2}$$

$$\pi = y[1-\alpha(1-\sigma)] \tag{26.3}$$

$$g = \tau[\alpha(1-\sigma)(1-\kappa)+\kappa]n^{\alpha} - br \tag{26.4}$$

$$\beta = (1+r)^{-1} \tag{26.5}$$

The set of parameters for the model is $(\beta, \alpha, \sigma, \kappa, \Lambda)$. We use an interest rate value of 4% which is consistent with $\beta = 0.9615$. Working hours estimate is set at 0.3. According to its specification, the parameter κ stands for the fiscal treatment of profits and is equal to the ratio between the profit tax rate and the labour tax rate. The profit tax in this model is the tax that households pay on distributed profits. McGrattan & Prescott (2005) estimate a tax rate on corporate distributions for the US and the UK economy, which is the personal income tax rate on dividend income if corporations make distributions to households by paying dividends. We use their period average estimate of 17.4% for 1990-2000 for the US economy. For the average effective tax rate on household income for the US economy, we use a value of 22.6% from Carey & Tchilinguirian (2000). This pins down $\kappa = 0.76991$.

One can pin down the parameter σ in either of the two ways. First, one can simply assume $\alpha = 1$, which pins down σ equal to the profit to output ratio. The second way is to use price mark up estimates from the literature and derive an estimate of σ consistent with the mark up value, which in turn will pin down α consistent with both the profit ratio and the mark up value. We follow the latter. From the literature, an interesting observation is the range of estimates for the price mark up ratio, which for the US economy ranges from as low as 1.03 in Basu & Fernald (1997) to as high as 1.23 in Bayoumi et al. (2004). There are even higher estimates of this ratio for particular industries of the US, as may be found in detail in Martins et al. (1996). For the current model, we choose $\mu = 1.12$ as the price mark up ratio, which is the Martins et al. (1996)'s 1970-1992 average estimate for the US industries producing differentiated goods. Given (26), the profit ratio and the already pinned down parameters, $\mu = 1.12$ pins down $\alpha = 0.99734$. The decentralized equilibrium condition (26.3) pins down $\sigma = 0.10763$.

For model 2, the baseline wage mark up estimate is therefore equal to 1.12, which is very close to the recent estimate of 1.16 for the US economy, as in Bayoumi et al. (2004). For $g = 0.23$, and the remaining pinned down parameter values, (26) gives baseline estimate for Λ and Λ^m, equal to

2.8075 and 2.4987, respectively. The baseline parameter values for models 1 and 2 are summarized in appendix, table 2a.

With (25), the decentralized equilibrium and (26.2), the steady state of the Ramsey equilibrium for model 1 implies:

$$\frac{c}{y}\left\{\frac{\Lambda n[1+\eta+\frac{\eta}{\alpha(1-\sigma)}\kappa\{1-\alpha(1-\sigma)\}]}{\alpha[1+\eta(1-\kappa)\frac{\pi}{c}]}\right\}+\frac{\eta(1-\kappa)\{1-\alpha(1-\sigma)\}}{[1+\eta(1-\kappa)\frac{\pi}{c}]}=1 \qquad (27)$$

For model 2, similar steps of algebra find the condition:

$$\frac{c}{y}\left\{\frac{\Lambda^m n[1+\frac{\eta^m}{\alpha(1-\sigma)}+\frac{\eta^m}{\{\alpha(1-\sigma)\}^2}\kappa\{1-\alpha(1-\sigma)\}]}{\alpha[1+\eta^m(1-\kappa)\frac{\pi}{c}]}\right\}+\frac{\eta^m(1-\kappa)\{1-\alpha(1-\sigma)\}}{[1+\eta^m(1-\kappa)\frac{\pi}{c}]}=1 \qquad (28)$$

We derive the steady state calibrated value of η and η^m from (27) and (28), respectively. According to our baseline calibration, $\eta=1.097$ and $\eta^m=1.202$, i.e. given $\sigma=0.10763$, the social cost of Ramsey taxes is relatively higher in an economy with two sources of market distortion. Relative to the competitive goods' market Ramsey tax, Ramsey tax in model 1 incurs 42% less social cost in terms of forgone consumption. For model 2, the social cost is about 48% less than its competitive market analogue. These relative measures allow one to realize the social desirability of Ramsey taxes in imperfectly competitive economies.

Given the baseline parameter values and the social cost of taxes, we calibrate the Ramsey taxes for model 1 and model 2. We also calibrate the competitive market analogue tax rate[12]. These are summarized in appendix, table 2b. The calibrated optimal tax rate for model 1 is equal to 62.03%, and its competitive market analogue optimal tax rate is equal to 65.01%. For model 2, the baseline parameter values gives the optimal tax rate equal to 63.28%, and its competitive goods market analogue optimal tax rate is equal to 69.21%. We conduct a sensitivity analysis of our key results (the social cost and the optimal tax rate) for both models for changes in the key parameters of the model, and the baseline statistics which we use to pin down the parameters of the models. These are presented in figure 1.

[12] With competitive market setting profit ratio, σ and κ are zero, which is why it is necessary to reconstruct the implementability constraint and rerun the Ramsey problem.

We present the sensitivity of the social cost of optimal taxes and the sensitivity of optimal taxes for different values of κ and σ in figure 1 and figure 2. A higher degree of monopoly power is associated with a relatively lower utility cost of distorting taxes, which holds for both models. Put intuitively, this means households facing higher monopoly distortions would be more willing to accept a distorting tax as a corrective device. For higher values of the parameter σ, the optimal tax rate continues to be lower. We do not find any sensitivity of the optimal tax rates for changes in κ, implying that the government's optimal choice of tax rate is completely independent of its fiscal treatment of profits. This is not surprising, since profit tax as modelled here distorts the welfare margin only through an income effect. Since household's allocation decisions are not affected at the margin by κ, the government is able to choose optimal tax rate without any concern of its fiscal treatment of profits. We also present the sensitivity of the social cost of optimal tax and the optimal tax for a plausible range of labour supply, consumption-output ratio and profit-output ratio, values for which were initially chosen in order to pin down the baseline parameter values. When we vary these statistics, we recalibrate all corresponding parameters.

The sharp decline in optimal tax rate for extremely high values of σ indicates that with elastic demand for intermediate goods (and elastic demand for labour in the wage setting model), monopoly distortions create compounding effect in the wedge between the social and the private returns to labour, and it becomes optimal to cure its more than proportionate distortions with more than proportionate decrease in tax rates. Higher distortions therefore necessitate a more *Pigovian* role of distorting taxes, which incurs a relatively lesser social cost. Following this intuition, for the monopolistic wage setting model the multiplier effect is much larger.

Calibration of Model 3.

For simplicity, we will assume $\tilde{\Lambda} = 1$. Through this we abstract from the possibility of having different marginal disutility of work across sectors[13]. The decentralized equilibrium at steady state for model 3, with $l_t = 1 - n_{yt} - \tilde{\Lambda} n_{zt}$ in (25), and $\tilde{\Lambda} = 1$, includes:

$$y = k^{\alpha\nu} n_z^{\nu(1-\alpha)} n_y^{1-\nu} = c + g + \delta k \qquad (29.1)$$

[13] The US Bureau of Labour Statistics survey reports suggest that injury related incidence per 100 workers varies greatly across different industrial sectors of the US economy, and incidence rates are relatively higher in goods producing sector as compared to the service producing sector. This evidence is in strong support of $\tilde{\Lambda} \neq 1$. On the other hand, as in Huffman and Wynne (1999), the assumption that disutility from work can be different across sectors requires specification of the intratemporal labour adjustment cost in utility function. In its simplest form, such utility functions are non-linear in labour which complicates the tractability of results in the Ramsey equilibrium due to second order and cross derivatives of labour. We follow a standard approach by assuming zero adjustment cost of labour and unitary marginal rate of substitution of labour across sectors.

$$w_y = (1-\nu)(n_y)^{-1} y \tag{29.2}$$

$$w_z = (1-\alpha)\nu(1-\sigma)(n_z)^{-1} y \tag{29.3}$$

$$r = \alpha(1-\sigma)\nu(k)^{-1} y \tag{29.4}$$

$$\pi = (\nu\sigma) y \tag{29.5}$$

$$c = (1-\tau_y)(1-\nu)(n_y)^{-1} y \tag{29.6}$$

$$c = (1-\tau_z)(1-\alpha)\nu(1-\sigma)(n_z)^{-1} y \tag{29.7}$$

$$\beta[(1-\tau_k)\alpha(1-\sigma)\nu(k)^{-1} y + 1 - \delta] = 1 \tag{29.8}$$

$$g = \tau_y w_y n_y + \tau_z w_z n_z + \tau_k (rk + \xi\pi) \tag{29.9}$$

For model 3 the set of parameters is $(\alpha, \nu, \sigma, \xi, \beta, \delta)$. The parameter β is pinned down similarly, as in previous calibration. We use McGrattan & Prescott (2005)'s period average estimate for 1990-2000 for US corporate tax rate, which is 17.4%, and Carrey & Tchilinguirian (2000)'s estimate of average effective tax rate on capital income for the US economy, which is 27.3%. This pins down $\xi = 0.6373$. Capital's share of final output is set equal to 0.36, an approximation that is consistent with long run US data, and also frequently used in relevant literature[14]. With (29.2), (29.3) and (29.4), this pins down $\nu = 0.7351$, $\sigma = 0.1496$, and $\alpha = 0.5759$. The calibrated value for the parameter σ yields the price mark up ratio equal to 1.175. Given the target statistics, the steady state version of capital's law of motion pins down $\delta = 0.0664$. These baseline values are summarized in appendix, table 3a.

In order to restrict $\tau_t^{\,k} \leq 1$ in the calibration, we impose the additional restriction $\beta(1-\delta) \leq 1$. This is consistent with the steady state version of (21.1l). With baseline parameter values, $r = 0.1087$. In a steady state, the Ramsey equilibrium condition (23d) is:

$$\tilde{G}_c - \beta\left\{\tilde{G}_k + \tilde{G}_c\left[\frac{r}{1-\sigma} + 1 - \delta\right]\right\} = 0 \tag{30}$$

Using the pinned down parameters and $r = 0.1087$, (30) calibrates $\frac{\tilde{G}_k}{\tilde{G}_c} = -0.0213$. With (25), and $\tilde{\Lambda} = 1$,

$$\tilde{G}_c = \frac{1}{c}\left[1 + \tilde{\eta}\sigma\nu\frac{y}{c}\left\{(1-\xi) - (1-\delta-\beta^{-1})r^{-1}\xi\right\}\right] \tag{31.1}$$

[14] In model 3 the three income shares add up to $1-\nu\sigma$, which is simply one minus the profit ratio.

$$\tilde{G}_k = \frac{1}{c}\tilde{\eta}\left[\frac{\xi\sigma}{\alpha(1-\sigma)}(1-\delta-\beta^{-1}) - \nu\sigma(1-\xi)\frac{r}{(1-\sigma)}\right] \qquad (31.2)$$

It is straightforward to verify that the term $\frac{\tilde{G}_k}{\tilde{G}_c}$ is strictly negative[15]. With $\frac{\tilde{G}_k}{\tilde{G}_c} = -0.0213$, and (31), it is straightforward to derive $\tilde{\eta} = 0.9890$. Rerunning the calibration with competitive markets gives $\tilde{\eta}^p = 0.9992$. This implies that relative to a competitive markets setting, implementing the optimal taxes in an imperfectly competitive economy incurs 1.02% less social cost in terms of forgone consumption.

The quantitative findings for model 3 are summarized table 3b. Table 3b summarizes the calibrated Ramsey policy and the associated social cost for baseline parameter values. Our findings suggest that for the baseline parameter values we choose the long run optimal policy for the government involves tax on all income and no subsidy. The calibrated optimal tax rates are approximately equal to 2%, 31% and 41% for capital income, labour income from intermediate goods sector, and labour income from final goods sector, respectively.

We conduct a sensitivity analysis of our key results for a range of values for the key parameters and the statistics which we use in order to pin down baseline parameter values, and these are presented in figure 3. These suggest that economic agents prefer the Ramsey policy than the first best policy for high price mark up ratio. This is perfectly consistent with our previous findings, as in fig 1. This is simply because the Ramsey policy compensates for monopoly distortion and induces lesser welfare cost than a heavy lump sum tax. Higher degree of monopoly power results in higher losses of output and drives a larger wedge between the social and the private returns to factors, which in turn distorts the work and investment incentives. Although a first best subsidy can be used to compensate the wedge, a heavy lump sum tax in addition reduces disposable income. In absence of a lump sum tax, the Ramsey policy diversifies the excess burden of taxes through different tax instruments, which imply that the social cost of distorting taxes becomes relatively lower. Once again we find no correspondence between the optimal tax rates and changes in the parameter ξ.

We find that for $\sigma \in (0, 0.17)$, the relative effect of investment dominates the distortion effect of monopoly power which motivates the optimal policy that involves a tax on capital income. The peak of capital income tax is around 20% which is for very low value of σ. For any $\sigma > 0.17$,

[15] The term $\frac{\tilde{G}_k}{\tilde{G}_c}$ is the (steady state) relative effect of investment on second best level of welfare. In figure 3 we present the sensitivity of this term for different values of capital stock.

the optimal policy involves a subsidy to capital income. Although high degrees of monopoly power are associated with high profits, they are also associated with larger wedges between the social and the private returns to factors which results in larger loss in output. For high degrees of monopoly power, the rate of increase in the wedge between the social and the private marginal return to capital is much larger than the rate of increase in welfare effect of investment.

Concluding Remarks.

This paper presents estimates of the social cost of optimal taxes in a class of general equilibrium models of imperfect competition. The social cost concept we use is somewhat similar to that of a present value of the excess burden of distorting taxes. In general, it simply measures a discounted loss in net benefits, expressed in terms of consumption, from private use of resources that results when a distorting tax and monopoly distortions prevent markets from attaining efficient output levels. This total excess burden is the loss in well-being of taxpayers over which they would suffer if a lump sum tax were used to collect revenues. A lump sum tax would not prevent the attainment of efficiency because it has no substitution effect. For the class of imperfectly competitive economies we consider, a lump sum tax or its equivalent (100% profit tax, say) would motivate the optimal policy that involves subsidies to transactions (and no tax) in order to correct the monopoly distortions. Such a setting would incur even a lower social cost of taxes. Given a fixed revenue requirement, our measure of the social cost is actually the present value of a stream of efficiency-loss ratio of a tax or a set of taxes, implying that in an imperfectly competitive economy taxes induce relatively lesser efficiency loss.

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Tables:

Table 1: Statistics for calibration.

Description	Value
Government consumption to output ratio.	0.23
Profit to output ratio.	0.11
Bond to output ratio.	0.51
Capital to output ratio.	3.31
Investment to output ratio.	0.22

Source: Federal Reserve Bank of St. Louis Economic Data-FRED II, 1960-2008, and Revised Fixed Reproducible Tangible Wealth in the United States, US Department of Commerce.

Table 2a: Baseline parameter values for models 1 and 2.

Parameter	Description	Value
β	Subjective discount rate.	0.9615
α	Degree of returns to scale in intermediate goods sector.	0.9973
σ	Inverse of the elasticity of substitution.	0.1076
κ	Fiscal treatment of profits.	0.7699
Λ	Value of marginal disutility of work (model 1).	2.8075
Λ^m	Value of marginal disutility of work (model 2).	2.4987

Table 2b: Optimal tax rates and social cost of taxes for models 1 and 2.

	τ^p (Competitive goods market)	η^p (Competitive goods market)	τ (Ramsey, $\sigma = 0.1076$)	η (Ramsey, $\sigma = 0.1076$)
Model 1	0.6501	1.921	0.6203	1.097
Model 2	0.6921	2.327	0.6328	1.202

Table 3a: Baseline parameter values for model 3.

Parameter	Description	Value
β	Subjective discount rate.	0.9615
δ	Capital depreciation rate.	0.0664
α	Share parameter for capital in intermediate goods sector.	0.5759
ν	Share parameter for intermediate goods in final goods sector.	0.7351
σ	Inverse of the elasticity of substitution.	0.1496
ξ	Fiscal treatment of distributed profits.	0.6373

Table 3b: Calibrated optimal tax rates and the social cost of taxes for model 3.

	Capital income tax (τ_k)	Sector z labour income tax (τ_z)	Sector y labour income tax (τ_y)	Social Cost $(\tilde{\eta})$
Ramsey Policy	0.0206	0.3611	0.4653	0.9853

Figure 1: Sensitivity analysis for model 1's η and τ .

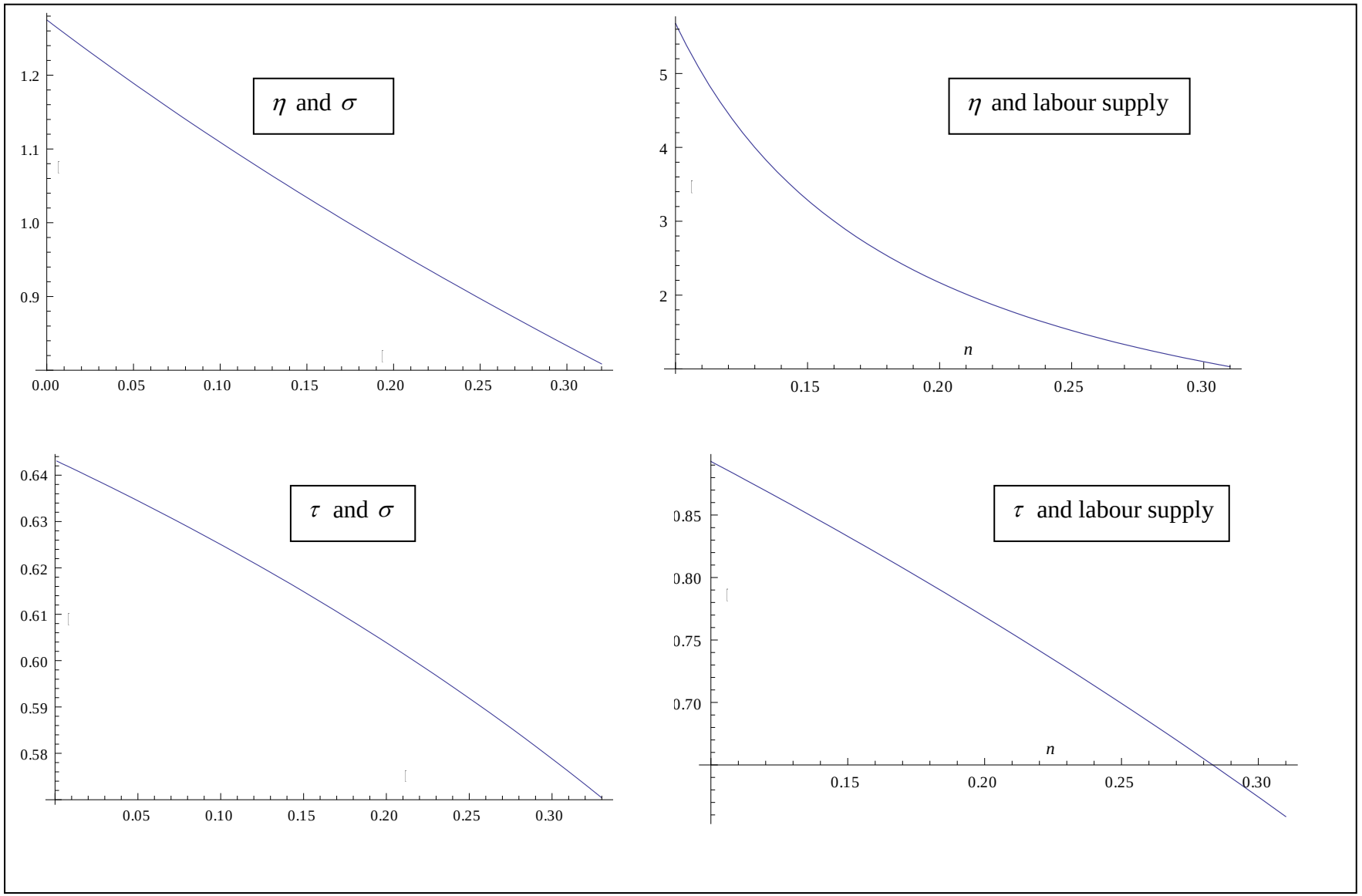


Figure 1: Sensitivity analysis for model 1's η and τ .

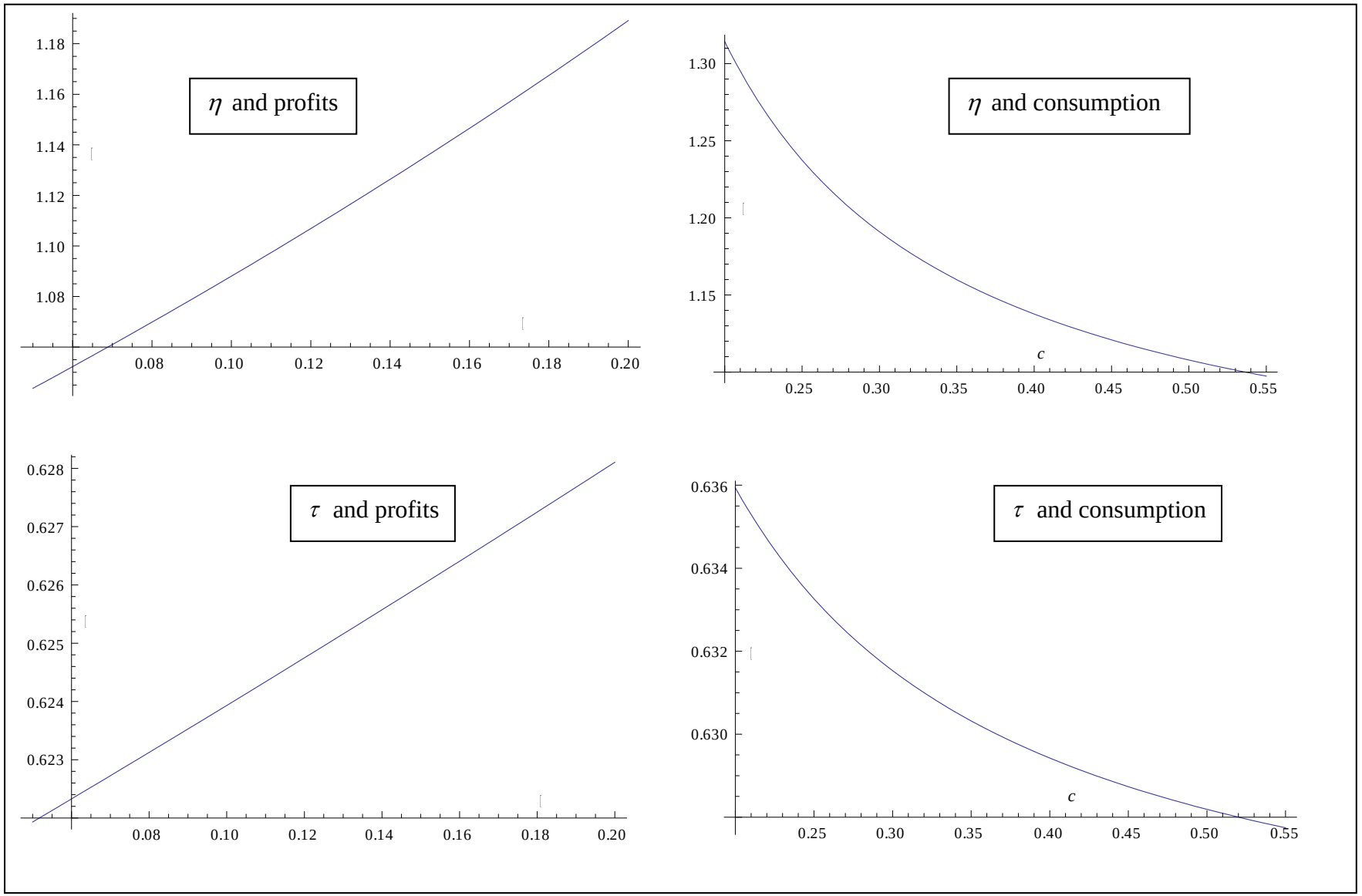


Figure 2: Sensitivity analysis for model 2's η^m and τ^m.

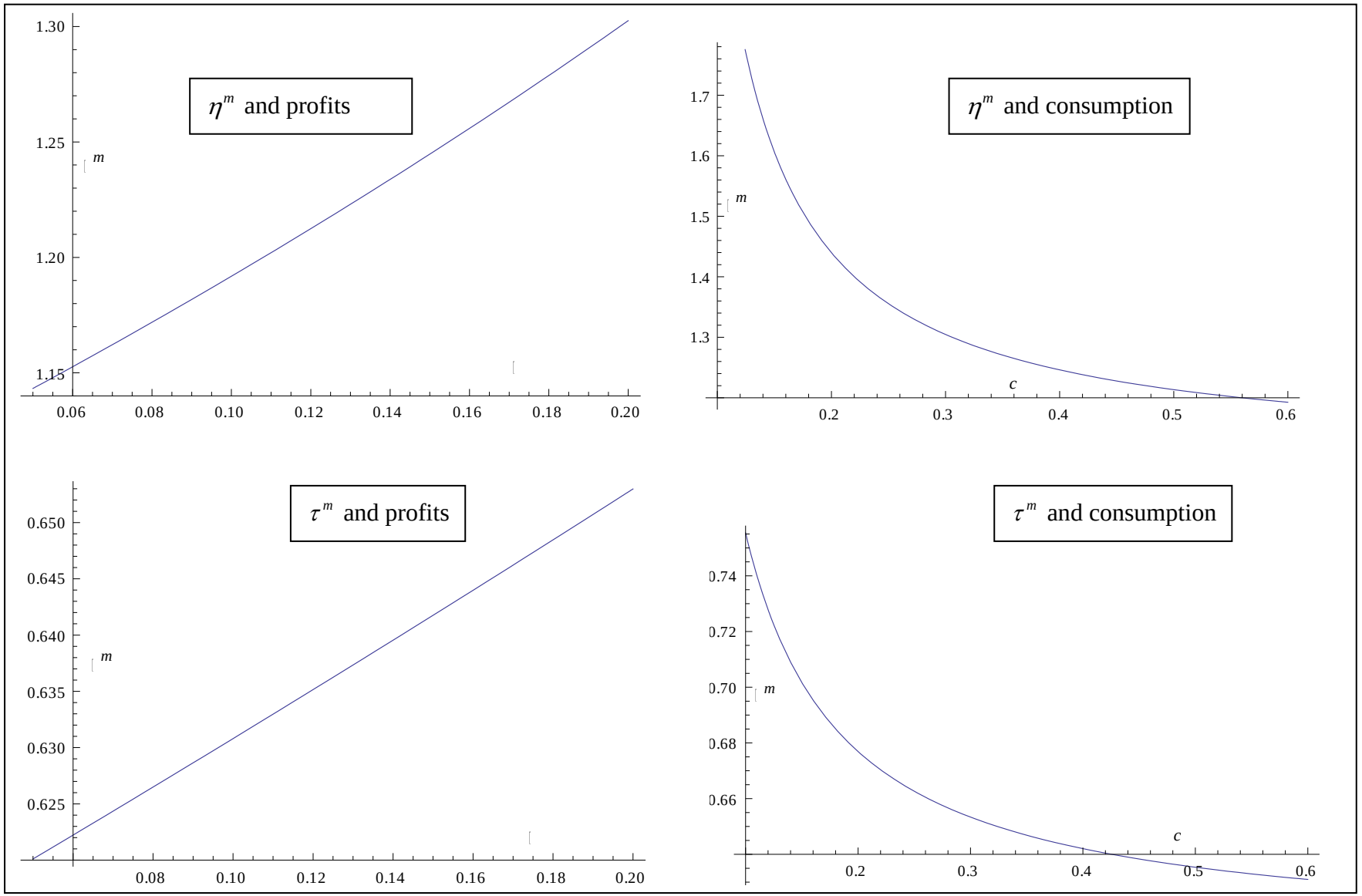


Figure 2: Sensitivity analysis for model 2's η^m and τ^m.

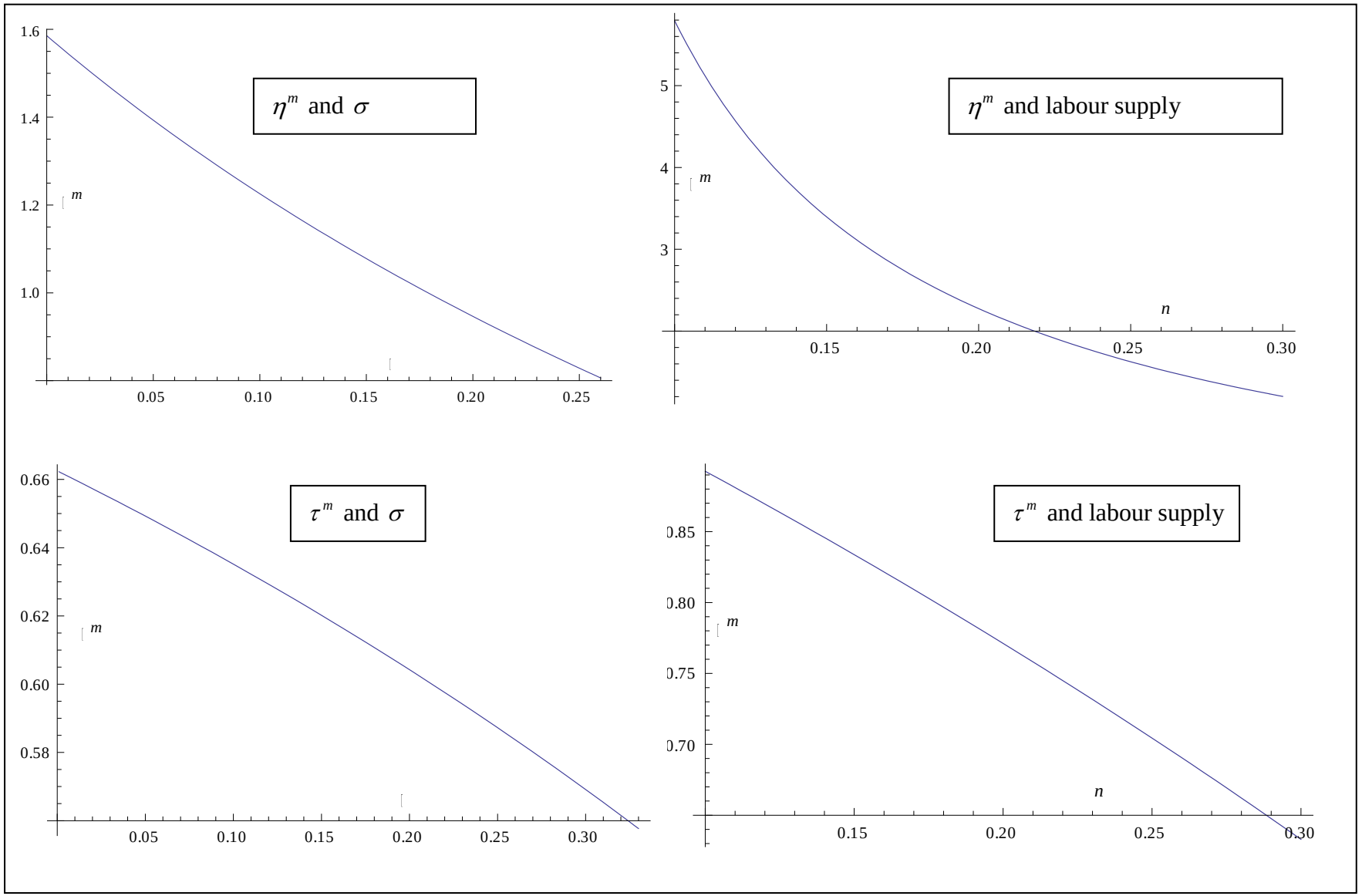


Figure 3: Sensitivity analysis for model 3.

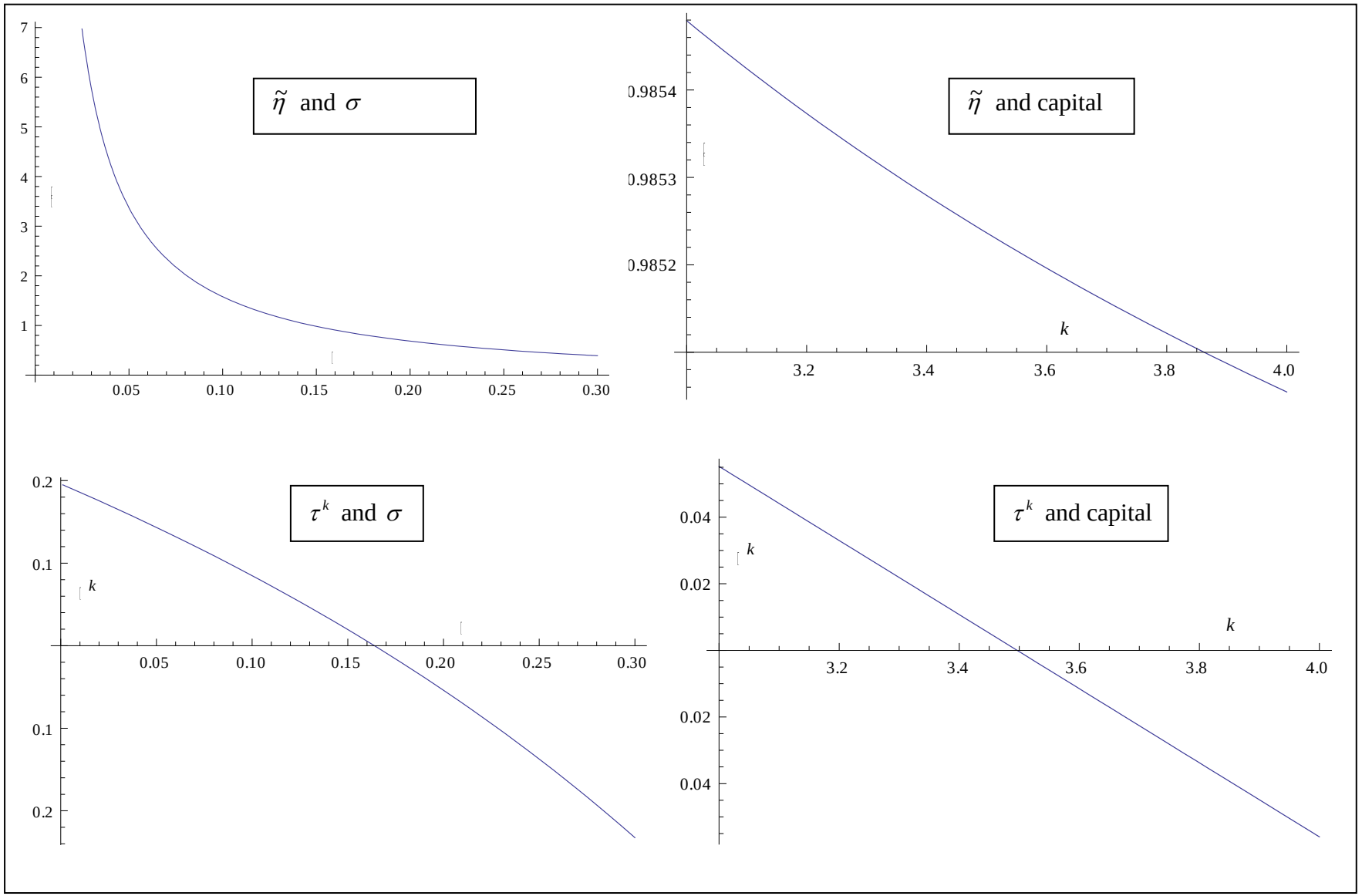


Figure 3: Sensitivity analysis for model 3 continued.

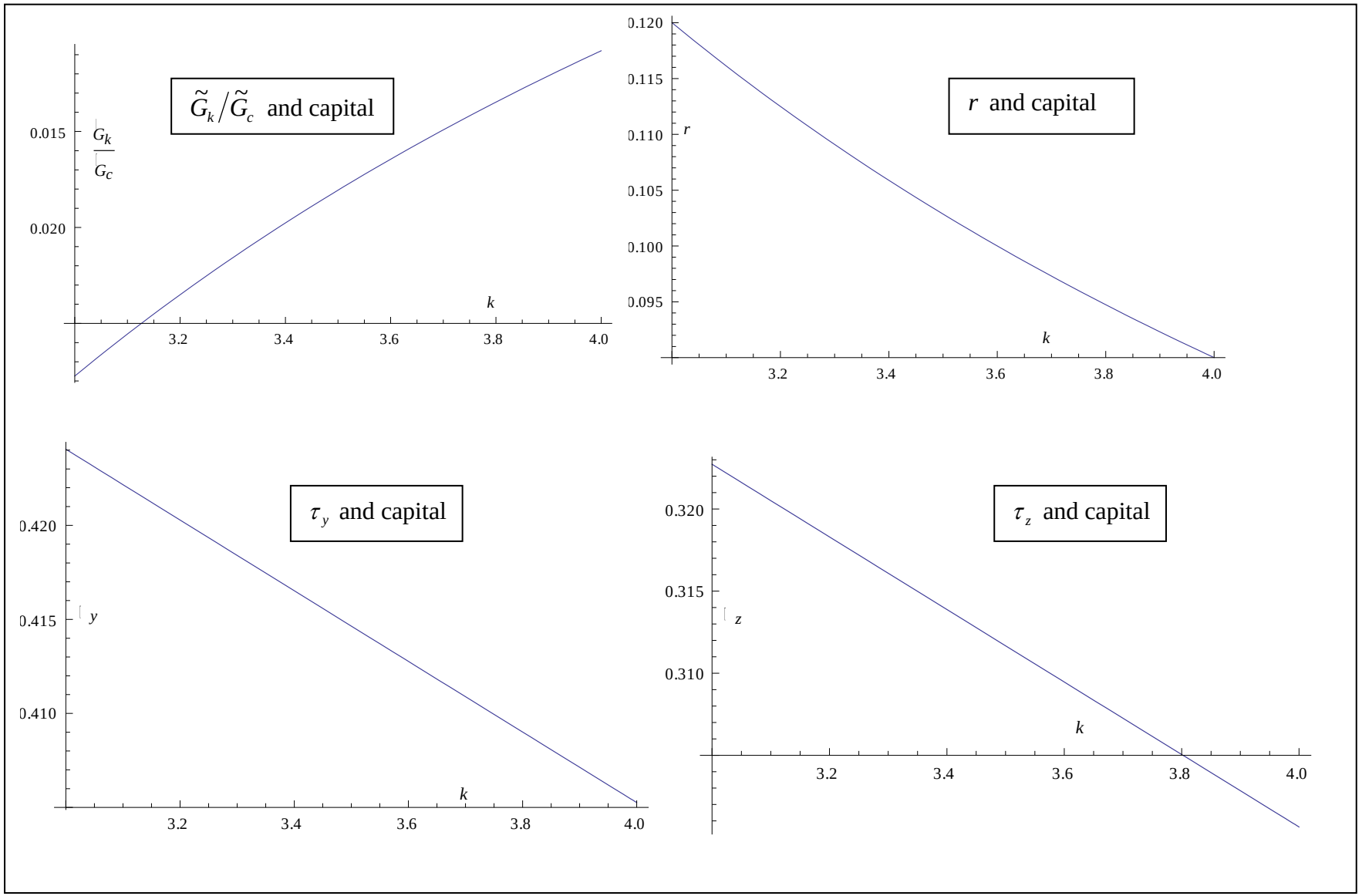


Figure 3: Sensitivity analysis for model 3 continued.

