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Taxing Capital in an Imperfectly Competitive Economy

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Abstract:

Evidence of declining trend in OECD economies' income tax rates and the concern of enhancing competition in the US and the EU product markets subtly motivate the question if low income tax rates are optimal in an imperfectly competitive economy. This paper examines optimal income tax policy in a dynamic neoclassical model with monopoly distortions. A capital subsidy, motivated by low private returns to capital, provides strong incentive to invest, but the adverse welfare effect of investment is not perceived by capital owners. Since profit seeking investment worsens second best welfare, and this effect is only perceived by the government, there is a strong motivation to tax capital. The paper presents a numerical characterization of the Ramsey policy and shows that switching to a Ramsey policy involving a capital tax is welfare improving.

Keywords: Optimal taxation, Monopoly power, Ramsey policy.

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

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Taxing Capital in an Imperfectly Competitive Economy

What is the optimal capital tax policy in an imperfectly competitive economy? There is an agreement on one principle --- with monopoly distortions, since output is lower than its optimal level, there must be some form of *Pigovian* element in optimal taxes, such that taxes offset the distortions created by monopoly power. This is the original idea behind Stiglitz & Dasgupta (1971)'s key result that in an imperfectly competitive economy optimal policy should include differential taxes and subsidies to transactions. Judd (1997) qualifies this general principle and argues that capital should be subsidized while labor and consumption should be taxed. Later, Guo & Lansing (1999) establish an ambiguity in capital tax policy. They establish that the long run optimal policy may involve capital tax or capital subsidy depending on the relative strength of profit effect and underinvestment effect. Profit-seeking investment persuades over accumulation of capital which motivates a capital tax, while the underinvestment effect, mainly due to discouraging private returns to capital, motivates the use of investment-boosting subsidy.

The current paper examines the Ramsey (1927) tax policy in a simple dynamic general equilibrium model with an imperfectly competitive sector. The analysis is mainly focused on finding the welfare maximizing level of average effective capital tax rate and the welfare effects of capital tax policy and investment. The model introduces labor supply in both competitive and imperfectly competitive sectors which enables one to examine the capital tax policy with differential labor taxation. The key objective is to explore the optimal policy in light of welfare effects of profit seeking investment. Since monopoly power earns pure profits but induces loss in private return to capital, agents face conflicting demand for investment, and they can never get it right. They over invest in search of profit that distorts welfare directly; this in turns motivates the government to tax capital. On the other hand, under investment, due to low returns to capital, motivates the government to subsidize capital.

This result is perfectly consistent with Guo & Lansing (1999). The current paper sharpens this result by providing the details of the welfare effect of investment. It shows that investment decision affect welfare directly but does not affect the government's motivation to subsidize capital. In other words, and using Guo & Lansing's (1999) terminology, while the underinvestment effect is completely independent of investment decisions, the welfare effect is not and is extremely sensitive. The adverse welfare effect of profit seeking investment is perceived by the government but not perceived by the investors. This creates a strong motivation to tax capital. In addition, the current paper numerically characterizes the welfare effect and the welfare cost of distorting taxes. It also shows that optimal labor tax in the monopoly sector is always lower than optimal labor tax in competitive sector. Finally, it shows that significant welfare gains can be achieved by switching to a dynamic Ramsey policy in an imperfectly competitive economy.

To my understanding, papers on optimal taxation with private market distortions that are of immediate relevance to this paper include Stiglitz & Dasgupta (1971), Diamond & Mirrlees (1971), Judd (1997), Guo & Lansing (1999), Auerbach & Hines Jr. (2001) and Judd (2002). One of the main results of Stiglitz & Dasgupta (1971) is that the optimal commodity tax policy for a monopolistic industry with a bound on profit taxation generally includes both differential taxes and subsidies. Diamond & Mirrlees (1971) argue that the existence of pure profits may require a deviation from the productive efficiency condition implying that taxes should generally be levied on final and not on intermediate goods. Judd (1997) and Judd (2002) establish the idea of subsidizing capital from a combination of these two results. Essentially, Ramsey's idea of designing optimal taxes with minimum disincentive effects and minimum distortions is reminiscent of the relatively recent idea of designing optimal taxes that create smooth intertemporal wedges in allocations. Optimal income taxes should correspond to smooth tax distortions over time, implying that the wedge between marginal rate of substitution (MRS) of consumption and marginal rate of transformation (MRT) of consumption across different dates that is created by an income tax should be uniform over time. A capital tax creates a wedge between MRS and MRT that grows exponentially over time (see Judd (1997) for details). Since a capital tax violates this principle, Judd (1997) and Judd (2002) argue that capital should be subsidized while labor and consumption should be taxed. Later, Guo & Lansing (1999) show that with monopoly profits flowing as a fixed income to households, the government faces conflicting demands for capital subsidy and capital tax. Underinvestment effect due to discouraging private returns to capital demands a subsidy, while the government's strong motivation to tax capital stems from profit seeking investment.

Judd's (1997) capital subsidy result is essentially based on the productive efficiency argument, i.e. the government should not tax capital since capital tax induced wedge in productive efficiency is ever growing. Subsidizing capital is optimal since a capital subsidy can push up the buyer price equal to social marginal cost of capital. If one assumes that profit is separately taxed, and it is possible to tax away all profits through *windfall* taxes, this result is in general technically robust. But if profit tax and capital tax are linked, there is a strong motivation to discourage investment. This is the key assumption of Guo & Lansing (1999), and the current paper. In addition, the current paper extends the Guo & Lansing (1999) result by providing an interpretation of their *two-effect* result from the second best welfare point of view. Any investment that increases profits in the second best equilibrium is welfare worsening. If capital tax and profit tax are linked, subsidizing capital is tantamount to encouraging welfare worsening investment. Government's motivation to tax capital is thus stronger if profit tax and capital tax are linked, an assumption which is not held in Judd's (1997) analysis. With a capital subsidy the effective return to capital would earn additional income in the form of a profit subsidy. Though the distortion effect motivates the use of a subsidy, a capital subsidy is likely to overcompensate capital owners, i.e. a capital subsidy would earn them a higher than optimal real return to capital. In the numerical exercise, this paper shows that the dynamic path of capital tax rates involves high tax for a number periods starting at the initial period, but then gradually converges to a small tax rate. In the steady state, the Ramsey policy therefore involves a capital tax. The calibration also shows that switching to this policy is associated with lower utility cost of taxation and higher levels of consumption, both of which attribute to higher level of welfare.

The policy problem addressed in this paper is one of central importance. The *OECD Revenue Statistics* and various issues of *OECD Observer* suggest that there has been a general tendency amongst the OECD countries to cut the top marginal rates of income taxes and shift the revenue reliance more towards general consumption taxes. While the 1999 OECD average revenue share of consumption taxes was 32%, revenue share of corporate income tax and property tax in the same year were only 9% and 5.5%, respectively[2]. On the other hand, empirical estimates of price mark ups, such as the Bayoumi, Laxton & Pesenti (2004) estimates of 1.23 for the US economy and 1.35 for the Euro area, motivate the concern of designing competition enhancing policy tools. The key question therefore is whether allowing tax favoured treatment to monopoly distorted returns is the optimal policy for imperfectly competitive economies.

Tax reforms in most industrialized countries have shown clear tendency of moving towards simplistic capital tax policy involving lower (or no) amount of direct subsidy to capital and minimum amount of deductions. The main two objectives behind these reforms are *(a)* to encourage competition and innovation amongst firms, and *(b)* to increase the amount of corporation tax revenue. Various incentive schemes including investment tax credits and property related tax shelters have been moderated or abolished in numerous countries, such as Australia, Austria, Finland, Germany, Iceland, Ireland, Portugal, Spain and the USA. Important evidence include the 1986 repeal of Investment Tax Credit Scheme in the USA. More recently, the UK 2006 tax reforms replaced the 0% starting rate of corporation profit tax and the starting marginal relief of corporation profit tax by a single 19% small companies' profit tax for all companies with reported profit of £0-£300,000. The UK reform, for instance, is likely to allow small companies to focus on growing their businesses, increase (and invest) their profits by reducing their administrative burden, and encourage innovations and efficiency gains of their own. This simplification is likely to present a strong competitive challenge to incumbent firms, who are in

[2] The OECD average of the revenue share of personal income tax in 1999 was 26.3%, which of course is a high proportion. Personal income tax revenue involves some revenue from taxing capital at the household level, although it is a minor proportion. The major source of capital tax revenue is the corporate income tax and property tax.

turns prompted to improve productivity. Prior to this reform, the 2004 budget introduced a 19% Non-Corporate Distribution Rate (NCDR) to ensure the incentive was focused on profits retained by small companies. This NCDR was charged on any profits distributed as dividend payments to individuals, rather than retained in the company to fund investment[3].

In addition, several OECD countries have revised the allowances for depreciation of capital equipment that companies can use to cut down on taxable income, bringing them nearer to the actual reduction in the economic value of the equipment. Most OECD countries' top marginal rates of income tax have also been reduced. Table 1A in appendix presents a summary of the change in average effective tax rates (AETR) due to such reforms until year 2000. AETR is a measure of the average capital tax rate imposed on household's income from capital, and thus provides a reasonable approximation of the capital tax rate imposed on a representative agent. The reported AETR estimates are from Carey & Tchilinguirian (2000), who use two methodologies. Both methodologies are presented in appendix, following table 1A. The AETR for capital includes corporate profit taxes, taxes on household capital income and various property taxes. All income generated from labor, social security charges (excluding employers' contribution to private pension funds) and payroll taxes are allocated to AETR for labor. The approximations from both methodologies reflect that the AETR for labor and capital are much higher than AETR for consumption in all five major economies. This clearly shows the historical tendency of high reliance on income taxation for revenue.

The recent trend, however, includes evidence of cutting down corporation tax rates with a purpose of increasing corporation tax revenue. The essential idea is that lower corporation tax rates provide lesser incentives for corporations to hide profits or evade taxes. Examples of this trend include Ireland (38% to 12.5%), Australia (36% to 30%), Denmark (32% to 30%), France (37.8% to 35.4%), Germany (52% to 39%), Iceland (30% to 18%) and the Czech Republic (31% to 26%), of which Iceland, Ireland, Denmark, France and the Czech Republic have experienced immediate effect of an increase in corporate tax receipts. But this increased receipt may well be at the cost of increasing the effective capital tax rate. Due to the cut in corporation tax rates, there has been a mixed response in the effective capital tax rates in these countries. For instance, this figure has increased from 18.6% to 18.7% for Ireland, from 19.2% to 23.1% in Czech Republic, and from 22.9% to 23.6% in France. By contrast, there has been a decline in the effective capital tax rate in Germany (21.1% to 19.9%), while in Australia it has remained unchanged at 28%.

[3] In the UK, the starting rate of corporation tax was introduced in 2000 and reduced from 10% to 0% in 2002. It applied to companies with profits up to £10,000 per year, with marginal relief for companies with profits between £10,000 and £50,000 per year. Above this level, profits were taxed at the small companies' rate of 19% (up to a threshold of £300,000). After the reduction of the starting rate to 0%, concerns were raised that the benefits of the rate were being used by incorporations not intending to grow. Therefore, at Budget 2004 the 'non-corporate distribution rate' (NCDR) was introduced to ensure the incentive was focused on profits retained by small companies. The NCDR charged 19% on any profits distributed as dividend payments to individuals, rather than retained in the company to fund investment.

The reason why this evidence is important for the current discussion is as follows. Although the ambiguity related to designing a competition enhancing capital tax policy remains unresolved (as in Guo & Lansing (1999)), providing tax favoured treatment to capital is not a strong solution either. Cutting capital tax rates, or at its extreme subsidizing capital (as in Judd (1997)) in order to achieve a target revenue or level of welfare is in fact far from simple, since any incentive to capital accumulation in an imperfectly competitive economy is also associated with an incentive to earning more profits. Pure profits from an industry with a fixed number of firms worsen welfare since such profits are associated with intertemporally accumulated deadweight loss of consumption. A competition enhancing optimal policy should discourage profit seeking investment which requires taxing capital. Judd (1997) finds an optimal policy involving capital subsidy primarily because his capital tax and profit taxes are independent. But any change in profit tax code imputes change in effective capital tax rate, and vice versa. Empirical evidence suggests that this change can go either way. This is understandable, since a change in profit tax code induces both an income and a substitution effect in capital allocation, and the net effect on capital tax rate depends on their relative strengths. The key idea is that household's decision to accumulate capital in an imperfectly competitive economy is triggered by a motive to earn higher profits. The current paper argues that since with monopoly distortions productive efficiency condition is already violated, a capital tax is likely to offset the pre-existing distortions. The current paper also shows that the income and substitution effects of profit seeking investment reinforce each other and attribute to loss in welfare. It is, therefore, more intuitive to think of the optimal policy as one that discourages profit seeking and welfare worsening investment, which may result in a lower level of capital accumulation and higher level of consumption.

The Model.

Time t is discrete and runs forever. The final goods sector is perfectly competitive (competitive sector, hereafter), and the intermediate goods sector is imperfectly competitive (monopoly sector, hereafter). Firms in competitive sector produce the final good, y_t (the numeraire), using labor, n_{yt}, and a continuum $j \in [0,1]$ of intermediate goods as inputs. Each firm in monopoly sector is a monopoly producer of a single intermediate good. Firm j combines capital, k_{jt}, and labor, n_{zjt}, to produce intermediate good j at the level z_{jt}. Initial endowment of capital, one unit of time at each period and property rights of firms are owned by each of a continua of measure one of identical infinitely-lived households. The constant returns to scale technology used to produce the final good is:

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

Following Dixit & Stiglitz (1977) the elasticity of substitution between any two intermediate goods is equal to s^{-1}, and for $s \to 0(s \to 1)$ the monopoly sector possesses low (high) monopoly power. The technology for monopoly sector is:

$$z_{jt} = k_{jt}^{\;a} n_{zjt}^{\;1-a}; \qquad a \in (0,1) \qquad (2)$$

The government consumes exogenous g_t of the final good each period and raises the required revenue by taxing households' income from capital, profits, and labor, at rates q_t, kq_t, and t_{st} for $s = y, z$, respectively. The government also trades one period real bonds, and let b_t denote the government's indebtness to the private sector, denominated in time t goods, maturing at the beginning of period t. The government's period t budget constraint is:

$$t_{yt} w_{yt} n_{yt} + t_{zt} \int_0^1 w_{zjt} n_{zjt} dj + q_t \left[\int_0^1 r_{jt} k_{jt} dj + k \int_0^1 p_{jt} dj \right] + R_t^{-1} b_{t+1} - b_t - g_t = 0 \qquad (3)$$

where w_{yt} and w_{zjt} denote real wages, r_{jt} denotes rental price of capital, p_{jt} denotes pure profits from monopoly sector, and R_t denotes the gross rate of return on one-period bonds held from t to $t+1$, denominated in units of time t goods. I will only focus on policy with full commitment. Tax rate on pure distributed profits is linked to the capital tax rate. The tax code that Judd (1997) modelled is a demarcated tax code that specifies tax instruments for corporate profits, savings and investment. Judd (1997) assumes a fixed profit tax rate, which stands instrumental in deriving the optimal policy involving no subsidy to profits but subsidy to capital income. Prior to the current paper, Guo & Lansing (1999) proposes a similar link of capital tax rate and profit tax rate, but uses a rich capital tax code involving accelerated depreciation[4]. In the current setting the capital tax rate is the average effective tax rate on income from capital. The parameter $k \geq 0$ represents the tax treatment of distributed corporate profits. For instance, the restriction $k \in [0,1]$

[4] Guo & Lansing's (1999) tax code involved depreciation allowance as a means to subsidize capital income. Depreciation allowances in excess of economic depreciation are another form of investment subsidy which is in practice, in a rather *generous* fashion, in both the US and the UK tax codes. In the UK, starting from 1972 the initial allowance received by industrial buildings ranged between 40% and 75%. Inventories received tax relief due to high inflation in the 1970s. According to the US corporate tax structure, physical rents from capital are taxed at a constant rate after the allowance of a deduction for depreciation.

in the current setting implies the set of tax treatments $[no\,tax, at\ par\ with\ capital\,tax]$ for distributed corporate profits[5].

The representative firm in the competitive sector faces the following sequence of problems:

$$\max_{z_{jt}, n_{yt}} \left[\left\{ \left(\int_0^1 z_{jt}^{1-s} dj \right)^{\frac{1}{1-s}} \right\}^n n_{yt}^{1-n} - \int_0^1 p_{jt} z_{jt} dj - w_{yt} n_{yt} \right] \qquad (4)$$

where p_j denotes the relative price of j. The first order conditions associated with *(4)* yields the demand function $p_{jt} = n(y_t)^{1-\frac{1-s}{n}} z_{jt}^{-s} (n_{yt})^{\frac{(1-n)(1-s)}{n}}$ for the jth intermediate good. The profit maximization problem of the jth firm in the monopoly sector is:

$$\begin{aligned} &\max_{p_{jt}, n_{zjt}, k_{jt}} \quad [p_{jt} z_{jt} - r_{jt} k_{jt} - w_{zjt} n_{zjt}] \\ &s.t. \quad z_{jt} = k_{jt}^{a} n_{zjt}^{1-a} \qquad (5) \\ &\qquad\quad p_{jt} = n(y_t)^{1-\frac{1-s}{n}} z_{jt}^{-s} (n_{yt})^{\frac{(1-n)(1-s)}{n}} \end{aligned}$$

I will restrict attention to a symmetric equilibrium where all firms in the monopoly sector produce at the same level, employ the same levels of factors and charge the same relative price, such that $n_{zjt} = n_{zt}$, $k_{jt} = k_t$ and $p_{jt} = p_t$ for all j. The representative household derives utility from consumption and disutility from labor service. Its maximization problem is:

$$\begin{aligned} &\max_{\{c_t, n_{st}, k_{t+1}, b_{t+1}\}} \quad \sum_{t=0}^{\infty} b^t u(c_t, n_{yt}, n_{zt}) \\ &s.t. \quad c_t + k_{t+1} + R_t^{-1} b_{t+1} \le (1-t_{yt}) w_{yt} n_{yt} + (1-t_{zt}) w_{zt} n_{zt} + [(1-q_t) r_t + 1 - d] k_t + b_t + (1-kq_t) p_t \end{aligned} \qquad (6)$$

where $b \in (0,1)$ is the subjective discount rate, $k_0 > 0, b_0$ given, and $d \in (0,1)$ is the capital depreciation rate. The utility function $u : \mathbf{R}_+^3 \to \mathbf{R}$ has standard properties[6].

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[5] In principle, ignoring the possibility of more than 100% tax on distributed corporate profits, the restriction $q_t^{-1} \ge k \ge 0$ would be more appropriate, since $k = q_t^{-1}$ then would represent the case where distributed profits are taxed at the 100% rate. But for most parts of the analysis to follow, I will consider $k \in [0,1]$. This is because although a 100% tax on profits is optimal, it is an impractical policy option.

[6] $u : \mathbf{R}_+^3 \to \mathbf{R}$ is continuously differentiable, strictly increasing in consumption, decreasing in labor, strictly concave, and satisfies Inada conditions, namely $\lim_{c_t \to 0} [u_{ns}(t)]^{-1} u_c(t) = \infty$, and $\lim_{c_t \to \infty} [u_{ns}(t)]^{-1} u_c(t) = 0$ for $s = y, z$.

Definition 1 (Symmetric Equilibrium). A symmetric equilibrium is a 5-tuple of price sequences $\{w_{yt}, w_{zt}, p_t, r_t, R_t\}_{t=0}^{\infty}$ that depends on the government policy $\{t_{yt}, t_{zt}, q_t, b_t\}_{t=0}^{\infty}$ and supports an allocation $\{c_t, n_{yt}, n_{zt}, k_t, z_t, y_t\}_{t=0}^{\infty}$, such that

- given the price system, government policy and $\{g_t\}_{t=0}^{\infty}$, the allocation solves (4), (5) and (6);
- given the price system, allocation and $\{g_t\}_{t=0}^{\infty}$, the government policy satisfies the symmetric version of *(3)*;
- all markets clear in the long run, i.e. allocations satisfy the resource constraint $c_t + g_t + k_{t+1} = k_t^{an} n_{zt}^{n(1-a)} n_{yt}^{1-n} + (1-d)k_t$.

Given $\{g_t\}_{t=0}^{\infty}$, b_0 and k_0, the symmetric equilibrium consists of time path of allocations $\{c_t, n_{yt}, n_{zt}, k_t, z_t, y_t\}_{t=0}^{\infty}$, prices $\{w_{yt}, w_{zt}, p_t, r_t, R_t\}_{t=0}^{\infty}$ and policy $\{t_{yt}, t_{zt}, q_t, b_t\}_{t=0}^{\infty}$, that solves the following system *(7)*:

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

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

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

$$c_t + g_t + k_{t+1} = k_t^{an} n_{zt}^{n(1-a)} n_{yt}^{1-n} + (1-d)k_t \qquad (d)$$

$$p_t = n\,(y_t)^{1-\frac{1-s}{n}} z_t^{-s} (n_{yt})^{\frac{(1-n)(1-s)}{n}} \qquad (e)$$

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

$$w_{zt} = (1-a)n(1-s)(n_{zt})^{-1} y_t \qquad (g)$$

$$r_t = a(1-s)n\,(k_t)^{-1} y_t \qquad (h)$$

$$p_t = (ns)k_t^{an} n_{zt}^{n(1-a)} n_{yt}^{1-n} \qquad (i)$$

$$-u_{ns}(t) = u_c(t)(1-t_{st})w_{st}, \qquad s = y, z \qquad (j)$$

$$b[(1-q_{t+1})r_{t+1} + 1 - d] = R_t = \frac{u_c(t)}{u_c(t+1)} \qquad (k)$$

$$\lim_{T\to\infty} \frac{k_{T+1}}{\Pi_{i=0}^{T-1} R_i} = 0 \qquad (l)$$

$$\lim_{T\to\infty} \frac{R_T^{-1} b_{T+1}}{\Pi_{i=0}^{T-1} R_i} = 0 \qquad (m)$$

$$t_{yt} w_{yt} n_{yt} + t_{zt} w_{zt} n_{zt} + q_t (r_t k_t + kp_t) + R_t^{-1} b_{t+1} - b_t - g_t = 0 \qquad (n)$$

Further to *(7)*, the price mark up ratio can be derived by redefining the monopoly sector firm's problem as one of choosing output to maximize profits. If $TC_t(z_t, w_{zt}, r_t)$ denotes the total cost function for the firm, the first order condition $p_t = (1-s)^{-1} MC_t(z_t, r_t, w_{zt})$ implies that the price mark up ratio is equal to $(1-s)^{-1}$. The profit to output ratio for this model economy is equal to ns, and the three income shares add up to $1-ns$.

Consider a special case with $b_t = 0, \forall t$, and there is an access to lump sum taxes $(\equiv \ell_t)$. This would enable the government implement the first best tax policy which replicates the pareto optimum, i.e. the social planner's equilibrium. The social planner's equilibrium is defined by a system including *(7d&l)* and the followings:

$$u_{ny}(t) = -u_c(t)(1-n)(n_{yt})^{-1} y_t \qquad (8.1a)$$

$$u_{nz}(t) = -u_c(t) n (1-a)(n_{zt})^{-1} y_t \qquad (8.1b)$$

$$b\left[na\, k_{t+1}^{an-1} n_{zt+1}^{n(1-a)} n_{yt+1}^{1-n} + (1-d)\right] = \frac{u_c(t)}{u_c(t+1)} \qquad (8.1c)$$

Proposition 1: The first best fiscal policy is to (a) set zero labor tax in competitive sector, (b) set a uniform labor and capital subsidy in monopoly sector, and (c) impose $\ell_t = g_t + \frac{ns}{(1-s)} y_t [1 - s(1-k)]$ as lump sum tax. The lump sum tax is strictly greater than g_t.

Proof: See Appendix P1.

Tax distortions are minimized under the first best policy that prescribes zero tax in competitive sector and a uniform subsidy to restore monopoly induced wedge between social and private marginal returns to factors. This policy corresponds to the first best since the resulting allocations imitate the pareto optimal allocations. This policy is optimal because the uniform subsidies, paid entirely from the large lump sum tax, do not distort any allocations.

Optimal Taxation.

Given the current setting, a lump sum tax that is higher than government expenditure can impose serious practicality concerns. Impracticality of first best lump sum taxes has been the central motivation of second best, or optimal taxation. Consider the second best scenario, with $b_t \neq 0$. The Ramsey problem is the government's problem of choosing implementable distorting taxes that maximize welfare. The primal approach to this problem is one that characterizes the government's quest of choosing allocations to maximize welfare subject to the resource constraint *(7d)*, and an implementability constraint that ensure that resulting taxes, prices and allocations are consistent with equilibrium system *(7)*. Once the Ramsey problem is solved, the resulting Ramsey allocations, given the initial conditions $\{R_0, k_0, b_0\}$, can be used to recover a sequence of prices $\{w_{zt}, w_{yt}, r_t, p_t, R_t\}_{t=0}^{\infty}$ and policy variables $\{t_{zt}, t_{yt}, q_t, b_t\}_{t=0}^{\infty}$ that will support the Ramsey allocations as a decentralized equilibrium. A formulation convenient for the Ramsey problem is to construct the wealth constraint from the income flow constraint. The wealth constraint of the household is:

$$\sum_{t=0}^{\infty} q_t^o [c_t - (1 - t_{yt}) w_{yt} n_{yt} - (1 - t_{zt}) w_{zt} n_{zt} - (1 - kq_t) p_t] = [(1 - q_0) r_0 + 1 - d] k_0 + b_0 \tag{9.2}$$

where the Arrow-Debreu price[7] is $q_t^o = \left(\prod_{s=1}^{t} R_s \right)^{-1}$, and $\prod_{s=1}^{0} R_s \equiv 1$ is the numeraire which makes $q_0^o = 1$. The representative household chooses $\{c_t, n_{yt}, n_{zt}\}_{t=0}^{\infty}$ to maximize utility subject to *(9.2)*. The consolidated first order conditions are $q_t^o u_c(0) = b^t u_c(t)$ and *(7j)*. The implementability constraint is derived by substituting out taxes, factor prices and Arrow-Debreu price in *(9.2)* using $q_t^o u_c(0) = b^t u_c(t)$, *(7i,j&k)*. This results in:

$$\sum_{t=0}^{\infty} b^t [u_c(t) c_t + u_{ny}(t) n_{yt} + u_{nz}(t) n_{zt} - u_c(t)(1 - kq_t) p_t] - \Omega(c_0, n_{y0}, n_{z0}, q_0) = 0 \tag{9.3a}$$

where

[7] q_t^o is the relative price of the final good in period t in terms of the final good in period zero, so q_0^o is the relative price of the final good in period zero in terms of the final good in period zero.

$$
(1-kq_t)p_t = \begin{cases} ns(1-k)k_t^{an} n_{zt}^{(1-a)n} n_{yt}^{1-n} + k_t \dfrac{ks}{a(1-s)bu_c(t)}\left[u_c(t-1) - bu_c(t)(1-d)\right] & for\, t \geq 1 \\ \\ (1-kq_0)(ns)k_0^{an} n_{z0}^{n(1-a)} n_{y0}^{1-n} & for\, t = 0 \end{cases}
$$

(9.3b)

and $\Omega(c_0, n_{y0}, n_{z0}, q_0) \equiv u_c(0)\{[(1-q_0)a(1-s)n(k_0)^{-1}y_0 + (1-d)]k_0 + b_0\}$

The term $k_t \dfrac{ks}{a(1-s)bu_c(t)}\left[u_c(t-1) - bu_c(t)(1-d)\right]$ in *(9.3b)* for $t \geq 1$ is simply equal $\dfrac{ks}{a(1-s)}(1-q_t)r_t k_t$. Combining it with household's budget constraint implies that the (after tax) effective real return to capital is equal to $\left[(1-q_t)r_t\left\{1+\dfrac{ks}{a(1-s)}\right\}+(1-d)\right]$. A capital subsidy with $k \neq 0$ not only pushes buyer price up to social marginal return, but also pays capital owners an extra compensation. Put differently, an implementable capital subsidy with $k \neq 0$ overcompensates capital owners at the cost of higher debt or higher labor taxes. This is an implementable policy where a capital subsidy attains socially optimal level of capital accumulation if and only if profits are not taxed or subsidized, i.e. if and only if $k = 0$. This policy, however, does not discourage profits and does not encourage competition. Later it is shown that the Ramsey policy supports a capital subsidy that attains socially optimal level of capital with a complete confiscation of profits.

The Ramsey problem is to choose allocations to maximize welfare subject to constraints *(7d)* and *(9.2)*. Let $\Phi \geq 0$ denote the Lagrange multiplier associated with *(9.2)*. Define the second best welfare function as:

$$
V(c_t, n_{yt}, n_{zt}, k_t, \Phi) \equiv u(c_t, n_{yt}, n_{zt}) + \Phi[u_c(t)c_t + u_{ny}(t)n_{yt} + u_{nz}(t)n_{zt} - u_c(t)(1-kq_t)p_t]
$$

(9.4)

where $(1-kq_t)p_t$ is defined by *(9.3b)*. Let $\{c_t\}_{t=0}^{\infty}$ be the sequence of Lagrange multiplier on *(7d)*. The second best level of welfare is equal to first best level of welfare less the loss in welfare due to after tax profits and distorting taxes. The loss in welfare is measured in terms of loss in allocations due to symmetric equilibrium reaction of taxpayers, which is multiplied by the shadow price of taxes Φ. This multiplier's value is representative of the amount in terms of consumption taxpayers are willing pay in order to replace a unit of distorting tax with a unit of lump sum tax. The Ramsey equilibrium conditions are *(7d)*, *(9.3)* and the followings:

$$V_c(t) - c_t = 0, \qquad t \geq 1 \qquad (9.5a)$$

$$V_{ny}(t) + V_c(t) w_{yt} = 0, \qquad t \geq 1 \qquad (9.5b)$$

$$V_{nz}(t) + V_c(t)(1-s)^{-1} w_{zt} = 0, \qquad t \geq 1 \qquad (9.5c)$$

$$V_c(t) - b\left\{V_k(t+1) + V_c(t+1)\left[\frac{r_{t+1}}{(1-s)} + (1-d)\right]\right\} = 0, \qquad t \geq 1 \qquad (9.5d)$$

$$V_c(0) - c_0 - \Phi\Omega_c = 0 \qquad (9.5e)$$

$$V_{ny}(0) + c_0(1-n)k_0^{an} n_{z0}^{n(1-a)} n_{y0}^{-n} - \Phi\Omega_{ny} = 0 \qquad (9.5f)$$

$$V_{nz}(0) + c_0 n(1-n)k_0^{an} n_{z0}^{n(1-a)-1} n_{y0}^{1-n} - \Phi\Omega_{nz} = 0 \qquad (9.5g)$$

$$c_0 - b\left\{V_k(1) + c_1[na\, k_1^{an-1} n_{z1}^{(1-a)n} n_{y1}^{1-n} + (1-d)]\right\} = 0 \qquad (9.5h)$$

The Ramsey equilibrium taxes satisfy *(9.5)* and generate allocations and prices that are consistent with equilibrium *(7)* and implementability constraint *(9.3)*. The presence of profits in the implementability constraint *(9.3)* implies that investment in physical capital induces a direct effect on second best welfare, though this effect is not perceived by capital owners. Return to investment in physical capital perceived by the households is characterized by the Euler equation:

$$u_c(t) - b\, u_c(t+1)\left[(1-q_{t+1})r_{t+1} + 1 - d\right] = 0 \qquad (9.6a)$$

Return to investment in physical capital perceived by the government is characterized by:

$$V_c(t) - b\, V_c(t+1)\left[\frac{V_k(t+1)}{V_c(t+1)} + \left(\frac{r_{t+1}}{1-s} + 1 - d\right)\right] = 0 \qquad (9.6b)$$

Ramsey equilibrium taxes are chosen such that *(9.6b)* is consistent with *(9.6a)*. The government's perception includes the term $\frac{V_k(t+1)}{V_c(t+1)}$. Since the function $V(.)$ represents a measure of (second best) welfare in the Ramsey equilibrium, the derivatives $V_k(t+1)$ and $V_c(t+1)$ represent the marginal effect of capital accumulation and consumption on second best welfare. Their ratio, therefore, is a measure of the relative effect of investment in physical capital on second best welfare. To illustrate it further, consider proposition 2 with the following:

$$V_k(t+1) = \Phi\left[\frac{ks}{a(1-s)}\left\{u_c(t+1)(1-d) - b^{-1}u_c(t)\right\} - ns(1-k)u_c(t+1)\frac{r_{t+1}}{(1-s)}\right] \qquad (9.6c)$$

Proposition 2: In the Ramsey equilibrium, any additional investment worsens welfare. This effect is perceived by the government but not perceived by investors.

Proof: See Appendix P2.

The marginal effect of investment on second best welfare, represented by *(9.6c)*, can be decomposed into substitution and income effects of investment. The substitution effect is $\Phi\frac{ks}{a}\left[-u_c(t+1)(1-q_{t+1})\frac{r_{t+1}}{1-s}\right]$, which represents the loss in welfare due to the margin of loss of a period ahead consumption. Since the final good is used for consumption and investment, additional investment requires substituting consumption for further capital stock. If, say, profit tax is equal to q (i.e. $k=1$), profit seeking investment reduces next period's consumption by an amount $\frac{s}{a}\left[-u_c(t+1)(1-q_{t+1})\frac{r_{t+1}}{1-s}\right]$, which characterizes the government's perceived deviation from second best consumption level. Since the multiplier Φ represents the utility cost of distorting taxes, Φ adjusted deviation in welfare represents a utility measure of the loss in welfare. If profits are not taxed or subsidized at all, the income effect, i.e. $\left[-\Phi ns\ u_c(t+1)\frac{r_{t+1}}{(1-s)}\right]$ characterizes the government's perceived loss in welfare due to loss in private return to capital. Any $k\in(0,1)$ in *(9.6c)* implies that both these effects are strictly negative, and therefore reinforce each other to lower welfare. Thus any additional investment lowers welfare.

Ramsey Policy.

For tracking analytical results, assume $u:\mathbf{R}^3_+\to\mathbf{R}$ is separable in consumption and labor, and linear in labor, i.e. $u_{cns}(t)=u_{nsc}(t)=u_{nsns}(t)=u_{nsnl}(t)=0$, $s,l=y,z,$ and $l\neq s$. This assumption is consistent with Hansen (1985). Assume also that there exists a $T\geq 0$ for which $g_t=\bar{g}$ for all $t\geq T$, and solution to the Ramsey problem converges to a time-invariant allocation. Solving *(9.5)* and *(8)* for steady state allocations yield:

$$1-t_z=\frac{1}{(1-s)}-\frac{t_y}{(1-s)} \qquad (9.7a)$$

$$1-q=\frac{1}{(1-s)}+\frac{V_k}{rV_c} \qquad (9.7b)$$

where

$$V_c = u_c + u_c \Phi \left[1 + \frac{u_{cc} c}{u_c} \left\{ 1 - s\, n \frac{y}{c} \left[(1-k) - (1 - d - b^{-1}) r^{-1} k \right] \right\} \right]$$

$$V_k = u_c \Phi \left[\frac{ks}{a(1-s)} (1 - d - b^{-1}) - ns(1-k) \frac{r}{(1-s)} \right]$$

Proposition 3: The steady state Ramsey policy is to set lower labor tax in monopoly sector, and a capital tax or subsidy depending on the relative strengths of the monopoly distortion effect and the welfare effect of investment. If the distortion effect (welfare effect) dominates, the long run optimal policy involves a capital subsidy (a tax).

Proof: See Appendix P3.

Both *(9.7a)* and *(9.7b)* are consistent with competitive market analogue, i.e. for $s \to 0$, $t_z \to t_y$ and $q \to 0$. By contrast, since $s \in (0,1)$ the optimal labor tax for the monopoly sector is the sum of two elements, namely, the first best subsidy, and the price mark up adjusted optimal labor tax for the competitive sector. Due to monopoly distortions, the private marginal return to labor in the monopoly sector is lower than the social marginal return. It is therefore optimal to set the labor tax rate for this sector lower than a competitive sector's labor tax such that the distorted efficiency margins are corrected. This is the differential taxation principle, consistent with Stiglitz & Dasgupta (1971).

The two effect result of optimal capital tax is perfectly consistent with the finding of Guo & Lansing (1999), and the current interpretation draws insights from the welfare effects of second best capital taxation. The first effect which is due to monopoly distortions is simply equal to the first best subsidy; in other words, it is one minus the price mark up. This is the amount lost in private marginal returns and is analytically equivalent to the underinvestment effect in Guo & Lansing (1999). Interestingly, this effect is completely independent of the level of investment, but the only motivation to subsidize capital is due to this effect. The welfare effect of investment stems from profit seeking investment. Since the loss in welfare is not perceived by households, investment is tempting for higher profits. This effect motivates the government to use a capital tax and discourage profit seeking investment. This is because $\frac{V_k}{V_c} = \frac{1}{b} - \left[\frac{r}{(1-s)} + (1-d) \right]$, and in a zero profit competitive market equilibrium V_k would equal zero. By contrast in the presence of pure profits, the welfare effect of investment in terms of consumption good is strictly negative. The Ramsey policy for capital taxation is therefore determined by the relative strengths of these two effects. If the welfare effect (distortion effect) dominates the distortion effect (welfare effect), the Ramsey policy is a capital tax (a capital subsidy).

The equilibrium cost of capital in this setting is determined by total distortion created by the interaction of taxation and monopoly power. Since the before tax return to capital is equal to $(1-s)$ times the marginal product of capital, the after tax return to capital is equal to $(1-s)(1-q)$ times the marginal product of capital. This simply implies that monopoly distortion acts like a second (and privately imposed) tax rate on capital income. If for instance, s = 0.15, a 18% capital subsidy reinstates socially optimal outcome by setting $(1-s)(1-q)$ = 1. But since profit tax in linked to capital tax, a capital subsidy must be accompanied with a profit subsidy, and a policy encouraging welfare worsening profits cannot be optimal. This is because the net effective return to capital includes an additional term $\frac{ks}{a(1-s)}$, implying that any capital subsidy not only pushes private return up to social marginal return to capital, but also provides additional profit income. Proposed earlier by Judd (1997), a trivial solution is to tax profits separately at 100% rate and subsidize capital. This result can be recovered from the current setting, as summarized in Proposition 4.

Proposition 4: If profits are taxed at a given rate, the steady state Ramsey policy involves a capital subsidy if and only if profits are taxed at 100% rate. The optimal capital subsidy with 100% profit tax replicates first best allocation of capital.

Proof: See Appendix P4.

Ramsey capital subsidy can be implemented if one replaces the endogenous profit tax with a given profit tax and if and only if one allows for full confiscation of profits at each point in time. This is tantamount to saying that the Judd (1997) result is equivalent to the first best tax policy that prescribes homogenous subsidy to monopoly distorted private returns at the expense of a large lump sum tax equivalent (the windfall tax).

Proposition 5: The steady state Ramsey policy does not involve zero capital tax.

Proof: See Appendix P5.

Allocations which are consistent with a zero capital tax result are not implementable in *(7)*. Put differently, the distortion effect and the welfare effect do not completely cancel out each other. This important result is based on proposition 2. Since the household's perception of the return to investment is always different from the government's perception, investors will never get the right amount invested, which is why a zero capital tax cannot be implemented.

Calibration and Numerical Results.

The calibration is only representative of a numerical characterization of the analytics presented in this paper. I use 1960-2002 data from the US economy. The time period is considered to be one year which is consistent with frequency of revision of fiscal decision. The calibration estimates, for a given initial tax policy, the path of tax rates that achieves a new steady state allocations and Ramsey taxes. For utility, it is assumed that $u(.)$ follows lottery argument of Hansen (1985):

$$u(c, n_y, n_z) = \frac{c^{1-g}}{1-g} + [1 - n_y - z\ n_z] \qquad \textit{(9.8)}$$

The set of parameters for the model is (a, n, s, k, b, d, g, z). The parameters (a, n, s, k, b, d) are pinned down to match the steady state characteristics identified from the US data. The parameter g is chosen from Cooley & Prescott (1995). The parameter z is normalized to 1. This gives the baseline values for the set of parameters. I assume that the US economy is in a steady state under the current tax system. This steady state corresponds to taxes and allocations which will be treated as the taxes and allocations for $t = 0$ for calibrating the model. In order to pin down the parameters, I will use the steady state ratios of the US economy based on US data for time period 1960-2002. These statistics are from annual data of the US economy's real output, government consumption, government debt and corporate profits for the period 1960-2002, collected from the *Federal Reserve Bank of St. Louis Economic Data*-FRED II, summarized in table 2A in appendix. 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*. The series for capital and investment include business equipment and structures, residential components and consumer durables. This data gives average government consumption to output ratio equal to 0.23, profit to output ratio equal to 0.11, bond to output ratio equal to 0.51, capital to output ratio equal to 3.31, and investment to output ratio equal to 0.22. These steady state ratios will be part of the set of initial allocations. Current average effective tax rates for the US economy are chosen from Carrey & Tchilinguirian (2000), equal to 27.3%, 22.6% and 6.1% for capital income, labor income and consumption, respectively. Given these allocations and the parameters, I will solve the following system of equations *(9.9)* representing a decentralized equilibrium at $t = 0$.

$$c_0 + g_0 + k_1 = k_0^{an} n_{z0}^{n(1-a)} n_{y0}^{1-n} + (1-d)k_0 \qquad \textit{(a)}$$

$$i_0 = k_1 - (1-d)k_0 \qquad \textit{(b)}$$

$$y_0 = k_0^{an} n_{z0}^{(1-a)n} n_{y0}^{1-n} \qquad \textit{(c)}$$

$$g_0 + b_0 = t_0 (w_{y0} n_{y0} + w_{z0} n_{z0}) + q_0 (r_0 k_0 + kp_0) + t_{c0} c_0 + R_0^{-1} b_1 \qquad (d)$$

$$p_0 = n (y_0)^{1-\frac{1-s}{n}} (k_0{}^{a} n_{z0}{}^{1-a})^{-s} (n_{y0})^{\frac{(1-n)(1-s)}{n}} \qquad (e)$$

$$\left(\frac{c_0^{-g} (1+t_{c1})}{c_1^{-g} (1+t_{c0})} \right) = R_0 = b[(1-q_1) r_1 + 1 - d] \qquad (f)$$

$$-1 = \frac{c_0^{-g}}{(1+t_{c0})} (1-t_0) w_{s0} \qquad \text{for } s = y, z \qquad (g)$$

$$(1+t_{c0}) c_0 + k_1 + R_0^{-1} b_1 = (1-t_0)(w_{y0} n_{y0} + w_{z0} n_{z0}) + [(1-q_0) r_0 + (1-d)] k_0 + b_0 + (1-kq_0) p_0 \qquad (h)$$

$$w_{y0} = (1-n)(n_{y0})^{-1} y_0 \qquad (i)$$

$$w_{z0} = (1-a) n (1-s)(n_{z0})^{-1} y_0 \qquad (j)$$

$$r_0 = a (1-s) n (k_0)^{-1} y_0 \qquad (k)$$

$$p_0 = (ns) y_0 \qquad (l)$$

The equilibrium *(9.9)* is a $t = 0$ version of *(7)* with a consumption tax t_{c0} and sector indifferent labor tax , i.e. $t_{z0} = t_{y0} = t_0$. This is to make the $t = 0$ version of the model a close imitation of the current US tax policy. I will assume that the US economy switches to a Ramsey policy involving no consumption tax and differential labor tax from $t = 1$. This requires recursive solution of the Ramsey equilibrium defined by *(7d)*, *(9.3)* & *(9.5)*, and symmetric equilibrium *(7)* for $t \geq 1$ until tax rates, allocations and prices converge to a new steady state. The process of recursive solution assumes that there is zero exogenous growth in output, implying that all intertemporal changes in allocations are due to variable tax rates during transition which alters the relative prices. Thus the transition to new steady state is consistent with revenue neutral taxation (since government revenue is fixed each period). The tax smoothing stems from the intertemporal allocation of government bonds, implying that the dynamic allocation response and price changes are purely due to changes in tax rates which alter the incentives to consume, save and borrow. In order to avoid confiscatory taxation of capital, the following restriction is imposed in the Ramsey problem:

$$\frac{c_t^{-g}}{(1+t_{ct})} - b(1-d) \frac{c_{t+1}^{-g}}{(1+t_{ct+1})} \geq 0, \qquad t_{ct} = t_{c0} \; at \; t = 0, t_{ct} = 0 \; for \; t \geq 1 \qquad (10.1)$$

The calibration is therefore aimed at imitating the transition to new steady state if the fiscal setting of the economy is switched to Ramsey policy involving no consumption tax, sector specific labor tax and capital tax. In other words, given the current tax policy, the calibrated tax rates will represent the path of tax rates on capital income and labor income that are required to implement the dynamic Ramsey tax policy. This requires a description of the economy in terms of its current and future tax policy. The decentralized equilibrium *(9.9)* will be held as representative of the allocations and prices due to the current tax policy, and it will be assumed that these rates are expected, with probability one, to remain at these levels forever. The new policy is announced at $t = 0$ and is carried through $t \geq 1$.

The baseline parameter values are presented in table 2B in appendix. The parameter b is consistent with annual real interest rate of 4%. The value of the parameter k stands for the fiscal treatment of profits and is the ratio between tax on distributed profit and capital tax. The tax on distributed profits for the US economy, from McGrattan & Prescott (2005)'s period average estimate for 1990-2000, is 17.4%. The parameter k is pinned down combining McGrattan & Prescott (2005)'s estimate of 17.4% and Carrey & Tchilinguirian (2000)'s estimated average effective capital tax rate for the US economy. In order to pin down the production parameters, one needs to assume that there is a fixed proportion of income that flows to one factor. The income shares of capital and labor in the current setting add up to 0.89 (one minus the profit ratio). I set capital's share of final output equal to 0.36, an approximation consistent with long run US data, and also frequently used in relevant literature (see for instance Cooley & Prescott (1995)). This is consistent with (n, s, a) = (0.73, 0.15, 0.57).

The calibrated value for the parameter s yields the price mark up ratio equal to 1.17, which is a reasonable approximation of the range of values typically used in established literature, such as the ones presented in Martins, Scarpetta & Pilat (1996), Basu & Fernald (1997) and Bayoumi *et al.* (2004). Using the target statistics one can pin down d. This specifications, and the given initial tax rates are consistent with n_{z0} = 0.15, n_{y0} = 0.44, w_{z0} = 1.69, w_{y0} = 0.59, r_0 = 0.10, k_1 = 3.26, which can be verified by solving *(9.9)* for allocations and prices, given $c_0, k_0, b_0, p_0, t_0, q_0$ and baseline parameter values. The recursive solution of the Ramsey equilibrium and the symmetric equilibrium can be complicated. This is because for each feasible Ramsey tax policy, the resulting allocations and prices must be consistent with symmetric equilibrium. Thus each set of Ramsey allocations and prices generating from a Ramsey equilibrium tax rate must also satisfy symmetric equilibrium *(7)* for all $t \geq 1$. In principle, for a fixed Φ numerous tax combinations can solve the Ramsey equilibrium for a set of allocations and prices, but not all these are consistent with *(7)*. The implementable tax policy for all $t \geq 1$ is a dynamic path of taxes that solves the Ramsey equilibrium such that the resulting dynamic path of allocations and prices along with the path of taxes are consistent with symmetric equilibrium *(7)* for all $t \geq 1$. Therefore, implementability requires that for $t \geq 1$ Ramsey tax rates at each point in time generates allocations and prices that satisfy the representative household's budget constraint with equality (the government's budget constraint will hold with equality by Walras' Law). For this type of solution first it is necessary to calibrate Φ, i.e. the present value Lagrange multiplier associated with the implementability constraint. Calibrating Φ is rather simple; it requires solving *(9.5e)* and *(9.5f)* for the initial allocations and prices, which results in Φ = 0.206. Note that with *(9.8)*:

$$V_c(t) = c_t^{-g} + \Phi\left[-g\, c_t^{-g} + c_t^{-g} + ns(1-k)y_t g\, c_t^{-g-1} + \frac{k_{t-1}ks}{a(1-s)b} g\, c_{t-1}^{-g-1} - \frac{k_t ks}{a(1-s)}(1-d) g\, c_t^{-g-1}\right] \tag{10.2}$$

$$V_k(t) = \Phi\left[\frac{ks}{a(1-s)}\left\{c_t^{-g}(1-d) - b^{-1}c_{t-1}^{-g}\right\} - ns(1-k)c_t^{-g}\frac{r_t}{(1-s)}\right] \tag{10.3}$$

Solve *(9.5h)*, *(9.5e)* and *(9.5a)* equivalent Ramsey equilibrium conditions with *(10.1)*, and substitute for $V_c(0), V_c(1), V_k(1)$ from *(10.2)* and *(10.3)* in order to derive c_1 = 0.616. This is the implementable consumption allocation for $t=1$ that is generated by a Ramsey capital tax for $t=1$. This allocation and its corresponding prices must be consistent with both *(9.6a)* and *(9.6b)* for $t=1$. This set of allocations and its corresponding prices satisfy Ramsey equilibrium and symmetric equilibrium *(7)* for $t=1$, implying that factor prices, labor supply for $t=1$ and capital stock for $t=2$ are w_{z1} = 1.68, w_{y1} = 0.59, r_1 = 0.11, n_{z1} = 0.16, n_{y1} = 0.44, and k_2 = 3.14. In order to solve for Ramsey allocations, prices and taxes for $t>1$, one needs to consider only *(9.5a-d)* and *(7)* for for $t>1$. The same recursive solution process in *(9.5a-d)* and *(7)* can be repeated for $t>1$ until tax rates, allocations and prices converge to some constant, i.e. until the dynamic system converges to a new steady state.

The dynamic path of Ramsey taxes that achieve a new steady state is summarized in table 3. It presents the first best tax rates, and the dynamic path of tax rates if the policy is switched to a Ramsey policy involving no consumption tax, sector specific labor taxes and a capital tax. The first best tax policy is computed for given initial tax rates. This policy is time invariant. The lump sum tax equivalent required to implement this policy is equal to 35% of initial output level. The computation of dynamic path of Ramsey taxes suggests that the process of convergence is relatively slow. A current switch to Ramsey policy requires 8 years to reach the new steady state level of labor taxes (a 2% subsidy in monopoly sector, a 14% tax in competitive sector) and capital tax (12%). This switch requires taxing capital at 100% rate for 5 years starting from the initial period, and then reducing the rate to 22% and to 12%. In the first year, labor in monopoly sector receives a 35% subsidy. This rate drops to 11% in the second year and continues to drop thereafter until it reaches its steady state level of 2%. Labor in competitive sector gets a low tax in the first year but high tax in the second year. From the third year this tax rate starts to decline until it reaches its steady state level of 14%. The new steady state level of consumption ratio is 0.64 and capital stock is 2.25, with factor prices w_z = 1.68, w_y = 0.59, and r = 0.16. The new Ramsey policy results in a steady state level of higher consumption and lower capital per worker.

Importantly, it leaves leisure unchanged. This amounts to a 17% increase in consumption level as compared to the initial level, implying that it requires 17% more consumption to make the taxpayers indifferent between the old and the new tax policy. If the policy is switched to the Ramsey policy, the level of second best welfare (i.e. $V^*(c^*, n_y{}^*, n_z{}^*, k^*, \Phi)$) increases from 2.65 (in the old policy) to 2.78 (in the new policy, after 8 years). This is tantamount to a 5% welfare increase in 8 years. This increase in welfare is measured with the same Φ since Φ is time invariant and the old policy's steady state represents the time 0 state of the new policy. It simply states that a 5% welfare increase in 8 years makes taxpayers indifferent between continuing with the old policy and choosing to switch to a new policy.

The idea that there are welfare gains from switching to Ramsey policy is reinforced in figure 4A. In particular, figures 4A, 4B and 4C presents the efficiency of Ramsey policy for a range of values for the parameters s and k [8]. The utility cost of distorting taxes, Φ, is a measure of social cost of taxation, i.e. the amount in consumption (or utility) taxpayers are willing to give up in order to get rid of a distorting tax. The declining value of the utility cost of Ramsey taxes (for high values of s) in figure 4A suggests that economic agents prefer Ramsey policy than first best policy for high price mark up ratio. Ramsey policy compensates for monopoly distortions and induces lesser welfare cost than a heavy lump sum tax. Higher degrees of monopoly power results in higher losses of output and drives a larger wedge between social and 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. The Ramsey policy for high degrees of monopoly power diversifies the tax burdens and reduces the social cost of distorting taxes. With excessively high degrees of monopoly power households are willing to pay lesser amount in terms of consumption goods to replace one unit of distorting tax by one unit of lump sum tax. Not surprisingly, this is also true for higher values of the parameter k, as in figure 4C. The more the tax on distributed profits, the less is the government's reliance on taxing other transactions. Consequently, for high values of the parameter k the welfare cost of Ramsey taxes is low, and Ramsey taxes are preferred over lump sum tax. For any level of k the steady state capital tax policy is unchanged, implying that government's tax treatment of profits cannot influence its choice of capital tax rate. Changes in s however affects the steady state level of capital tax rate.

[8] Note that varying s or k requires recalibrating Φ. In addition, varying s requires recalibrating n and a.

Concluding Remarks.

The paper examines the optimal capital tax policy in a simple two sector general equilibrium model of imperfect competition. It shows that imperfect competition and existence of pure profits creates a conflicting demand for investment. This is mainly why capital owners either over invest or under invest. Capital owners over invest in search of pure profits, but cannot perceive the adverse welfare effect of investment. On the other hand, private returns to capital are low which requires subsidy to capital in order to push the return up to socially optimal level. The government therefore is motivated to use a subsidy or a tax to capital depending on the relative strength of distortion effect and welfare effect. The distortion effect motivates the use of a capital subsidy, while the relative effect of investment on welfare supports the use of a capital tax. This result is perfectly consistent with the main result of Guo & Lansing (1999). In addition, the current paper establishes that any investment in monopoly distorted equilibrium is welfare worsening, since both substitution and income effect of additional investment are negative and jointly attribute to loss in future consumption. One way to compensate capital owners may be to completely tax away profits and subsidize capital income. If taxing away profits in each period is impractical, the Ramsey policy involving a capital tax can discourage profit seeking investment and can induce welfare gains. For an empirically plausible set of parameters which are consistent with long run characteristics of the US economy, it finds that the optimal policy involves a capital tax. It also finds that this policy results in higher consumption and lower capital per worker, but leaves leisure unchanged, all of which contribute to a gain in welfare level.

For high degrees of monopoly power Ramsey taxes induce lesser welfare cost since they neutralize the distortions created by monopoly pricing. Both monopoly power and income taxes induce distortions in allocations and are associated with significant welfare costs. In a recent paper Jonsson (2004) presents a quantitative analysis of the US economy's welfare costs due to monopoly power and taxation, and reports the steady state estimates of the welfare cost of imperfect competition in product market and distorting taxes are 48.26% and 12.79%, respectively. Moreover, based on the computed welfare cost approximations, Jonsson (2004) establishes that in an economy with imperfectly (perfectly) competitive markets labor taxes are more (less) distorting than capital taxes. From this point of view, the current paper's key finding of a nonzero limiting capital tax/subsidy in principle is less distorting than what it would have been if markets were perfectly competitive.

The model avoided much of game theoretic complexities by specifying market distortions in a simple reduced form. This reduced form specification is not based on a completely specified model of market structure and conduct. Nevertheless, one can conveniently map this form of market distortions to several alternative specifications of imperfect competition. The market distortions and equilibrium profits in the current setting is entirely based on the assumption that there is, at each point in time, a fixed number of firms operating in the monopoly sector who exploit the imperfect substitutability between intermediate goods. Since there is no fixed cost, pure profits is likely to lead to entry which will reduce the flow of profits to households. But even if one imposes free entry and steady state zero profits, their will be accumulated welfare distortions along the transition, which will motivate a capital tax to discourage profit seeking investment.

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Appendix: Proofs of propositions.

P1: Proof of Proposition 1.

Set $b_t = 0$ and add ℓ_t to the right hand side of *(7n)*. Compare *(7f, g, h, j, k)* with *(8.1)* to derive $t_{yt} = 0, t_{zt} = q_t = \frac{-s}{(1-s)} < 0$. Substituting for these taxes in *(7n)* with ℓ_t yields:

$$\ell_t = g_t + \frac{ns}{(1-s)} y_t [1 - s(1-k)]$$

which is strictly positive, and strictly greater than g_t. •

P2: Proof of Proposition 2.

It is straightforward to show from *(9.5a)* and *(9.5d)* that $V_c(t) > 0$ for all t. From *(9.6c)*, the term $\{u_c(t+1)(1-d) - b^{-1}u_c(t)\}$ is strictly negative as long as $q_t \le 1$. Hence, $V_k(t) < 0$ for all t, i.e. profit seeking investment directly distorts welfare at each point in time. This effect is not perceived in *(9.6a)*, i.e. household's Euler equation does not capture this effect. •

P3: Proof of Proposition 3.

For any $s \in (0,1)$, $(1-s)^{-1} > 1$. Equation *(9.7a)* implies $t_z < t_y$. Furthermore *(9.7b)* implies for $s \in (0,1)$ the two effects which determine the sign and magnitude of q are $\frac{-s}{1-s}$, which represents the monopoly distortion effect, and $\frac{V_k}{rV_c}$, which is a measure of the relative effect of investment on second best welfare. Since $V_k < 0, V_c > 0$, the term $\left(-\frac{V_k}{rV_c}\right)$ is strictly positive. If the relative effect of investment on second best welfare is stronger (weaker) than the monopoly distortion effect, the long run optimal policy involves a capital tax (a capital subsidy). •

P4: Proof of Proposition 4.

Say the fixed rate of profit tax is t_{Π}. Denote the Lagrange multiplier on implementability constraint by $\overline{\Phi}$. With t_{Π}, the welfare effect of investment is $V_k(t+1) = -\overline{\Phi} u_c(t+1) n s (1-t_{\Pi}) \frac{r_{t+1}}{1-s}$, and its level in steady state is:

$$V_k = -\overline{\Phi} u_c n s (1-t_{\Pi}) \frac{r}{1-s} \qquad (P4a)$$

Equation *(P.4a)* implies that $V_k = 0$ and $q = \frac{-s}{1-s}$, if and only if $t_{\Pi} = 1$. •

P5: Proof of Proposition 5.

Say not, and say for some implementable allocations Ramsey equilibrium policy prescribes $q = 0$. *(9.7b)* and steady state version of *(9.6a)* imply:

$$q = 1 - \frac{1}{r}\left[\frac{1-b(1-d)}{b}\right] \qquad (P5a)$$

With $q = 0$, *(P4a)* implies $b^{-1} = [r + 1 - d]$, which contradicts *(9.6a)*. •

Appendix: Tables & Figures.

Table 1A: Average Effective Tax Rates (in per cent), 1991-97.

	Capital Tax[a]		Labor Tax		Consumption Tax	
	Mendoza *et al.* (1994)	Carrey & Tchilinguirian (2000)	Mendoza *et al.* (1994)	Carrey & Tchilinguirian (2000)	Mendoza *et al.* (1994)	Carrey & Tchilinguirian (2000)
USA	27.3	31.1	26.7	22.6	5.2	6.1
UK	31.9	38.4	23.7	21.0	16.7	16.9
Japan	24.1	32.6	28.3	24.0	6.0	6.7
OECD	22.0	26.6	36.8	33.4	16.5	17.1
EU	21.2	25.1	42.8	36.8	19.3	18.7

a: These estimates are based on gross operating surplus.
Source: Carey & Tchilinguirian (2000). 'Average Effective Tax Rates on Capital, Labor and Consumption', *OECD Economics Department Working Papers No. 258.*

AETR using Mendoza, Razin & Tesar (1994) methodology:

$$AETR(capital) = \frac{t_H(I_{UB}) + T_{corp} + T_{prop} + T_{tran}}{OS}$$, where

$t_H \equiv Effective HH\ tax\ ratio = \dfrac{T_{HH}}{(I_{UB} + W)}$, and

$I_{UB} \equiv$ Net unincorporated income from capital transactions, or precisely

$I_{UB} \equiv OSPUE + PEI$, with

$OSPUE =$ Unincorporated business income (inc. rentals from owner-occupied housing)

$PEI =$ Interest, dividends and investment receipts.

$T_{HH} \equiv$ Tax revenues on income, profits and capital gains of households.

$T_{corp} \equiv$ Tax revenues on income, profits and capital gains of corporations.

$W \equiv$ Wages and salaries of dependent employment.

$T_{prop} \equiv$ Tax revenues from immovable property.

$T_{tran} \equiv$ Tax revenues from financial and capital transactions.

$OS \equiv$ Net operating surplus of the overall economy, or precisely,

$OS = GDP - WSSS$, with $WSSS =$ Total compensation of employees.

AETR using Carey & Tchilinguirian (2000) methodology:

$$AETR(capital) = \frac{t_H(I_{UB} - W_{self} - S_{self} - b\,S_U) + T_{corp} + b\,S_U + T_{prop} + T_{tran}}{OS - W_{self} - S_{self}}$$, where

$t_H \equiv Effective HH\ tax\ ratio = \dfrac{T_{HH}}{(I_{UB} - S_{self} + W - S - S_U)}$,

$I_{UB}, T_{HH}, T_{corp}, W, T_{prop}, T_{tran}, OS$ are same as before, and

$W_{self} \equiv$ wage bill of self employed, or precisely $W_{self} = N_{self}\dfrac{(W-S)}{N}$, with

$N_{self} \equiv$ Number of self em ployed.

$N \equiv$ Number of dependent employed.

$S \equiv$ Employees' Social Security Contribution.

$S_{self} \equiv$ Social Security Contribution of the self employed.

$S_U \equiv$ Unallocated Social Security Contribution.

$b \equiv$ share of capital income in household income, or precisely, $b = 1 - a$, with

$a \equiv$ share of labor income in household income, and

$$a = \frac{(W - S + W_{self})}{(I_{UB} - S_{self} + W - S)}$$

Table 2A: Steady state ratios for the US economy, 1960-2002.

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

Table 2B: Baseline parameter values.

Parameter	Description	Value
b	Subjective discount rate.	0.96
d	Capital depreciation rate.	0.06
a	Production function parameter.	0.57
n	Production function parameter.	0.73
s	Inverse of the elasticity of	0.15
k	Fiscal treatment of distributed	0.63
g	Utility function parameter	0.64
z	Utility function parameter	1.0

Table 3: The dynamic path of tax rates (First best and Ramsey).

Policy		Dynamic path of tax rates (t)										
		1	2	3	4	5	6	7	8	9	10	20
First Best Policy	t_z	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
	t_Y	0	0	0	0	0	0	0	0	0	0	0
	q	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17	-0.17
Ramsey Policy	t_z	-0.35	-0.11	-0.10	-0.06	-0.06	-0.05	-0.02	-0.02	-0.02	-0.02	-0.02
	t_Y	0.08	0.31	0.22	0.19	0.19	0.14	0.14	0.14	0.14	0.14	0.14
	q	1	1	1	1	1	0.22	0.22	0.12	0.12	0.12	0.12

$t_z \equiv$ labor tax rate in monopoly sector.

$t_y \equiv$ labor tax rate in competitive sector.

$q \equiv$ capital tax rate.

Fig 4A: Utility cost of taxes vs. sigma.

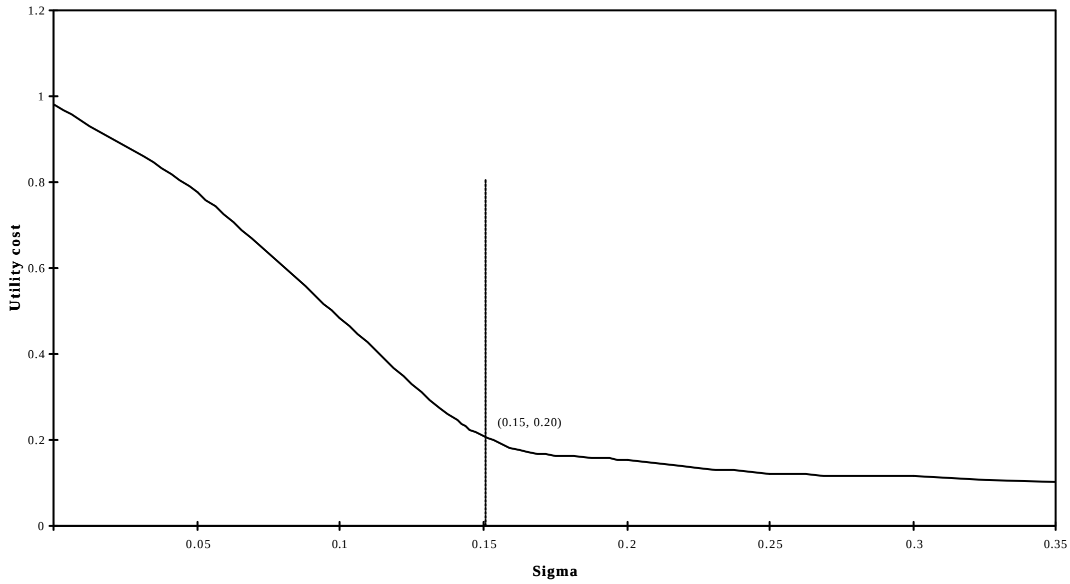

Fig4B: Capital Tax vs. sigma

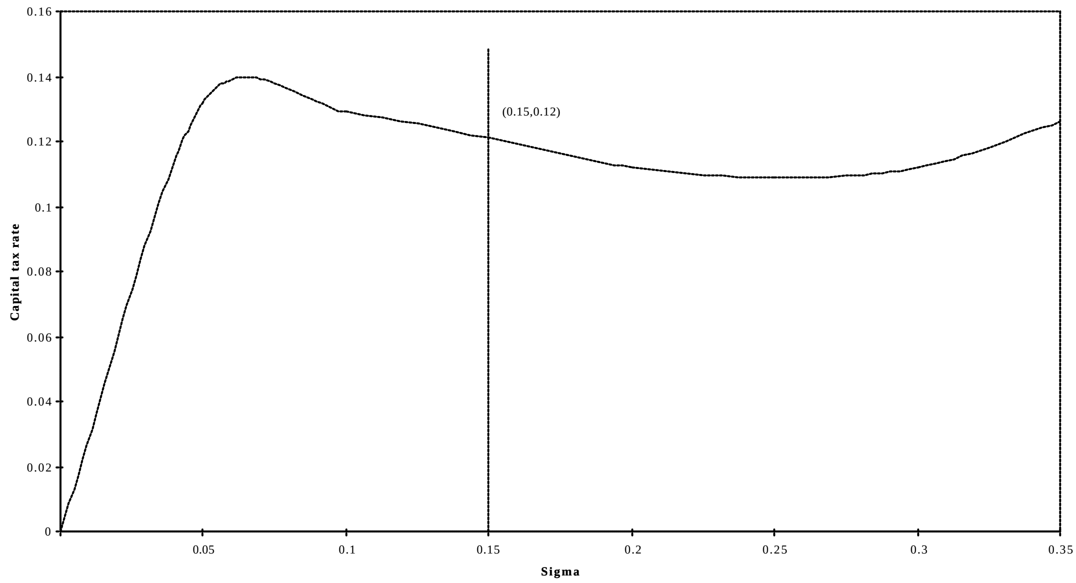

Fig 4C: Utility cost of taxes and capital tax rate vs. kappa