increase is importance which is centered in the food sector. This decline is associated with the small marginal propensity to consume food relative to its present importance and to a decrease in food consumption with the increase in median population age. Despite their decrease in relative importance per capita, annual food expenditures are expected to grow from their present level of about $500 to $860 if there is high growth, and to $940 with low growth. This growth of per capita consumption is the smallest of any consumption sector but is seen to be quite substantial. Services increase slightly or stay constant depending on the population assumptions employed.

Finally we examine the differences in allocation of consumption among sectors under different assumptions about population growth. The relative importance of income and median age is critical here. Clothing, for example, has a marginal propensity to consume which exceeds its present share of income. Its share of income thus grows faster for lower population growth due to the accompanying higher per capita income growth. In addition, clothing responds favorably to the higher median age implied by a low birth rate, further strengthening this sector’s relative position. Furniture behaves similarly and its share of the market also is greater with slow population growth. In contrast, housing, gasoline and food display the opposite behavior. In the other subsectors the effects of varying population growth are minor, and the major sectors reflect the patterns of their above mentioned components. Hence, durables rise to take a greater share with low growth and services with high growth, while the aggregate effects of the nondurable categories cancel one another, leaving their shares unchanged. This study is dependent on many assumptions and the results are necessarily very tentative. Nevertheless, they may provide an initial look at the changes due for the consumption sector in the future. We can summarize our main conclusions:

1. Total per capita consumption will grow from $2330 to somewhere in the range from $6550 to $8000 by the year 2020.

2. Median age plays a statistically significant role in the explanation of consumption behavior, and in the light of expected substantial changes in this age, should be included in a model of consumption.

3. The savings rate will rise, leading to a need to discover new investment opportunities, or for a substantial government deficit.

4. Changes in consumption will see durable goods increase in relative importance, services rise slightly or remain constant, and nondurables decrease.

5. Relative prices are found to be significant for durables and services categories and are likely to accent the shift in consumption shares toward durables and away from services.

6. The population growth rate influences consumption in two ways: it changes the median age and per capita income. Given a low population growth rate, there is higher total consumption and a change in the distribution of the sectors toward durables at the expense of services, with little effect on the relative share of nondurables.

**Technical Progress and the Incidence of the Corporation Income Tax**

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**Introduction**

The role of technical progress in determining the incidence of the corporation income tax has been recognized in a number of empirical studies. In fact, in some cases, variables representing changes in productivity and shifts in production function have been specifically included in the analysis (e.g., Gordon [1967], Hall [1964]). Somehow, however, technical progress has been completely ignored in the theoretical literature on the problem of tax-incidence. Recent econometric studies of the aggregate production function show that substantial technical progress has been taking place in the manufacturing sector of the U.S. economy (for example, Solow [1957] and Sato [1970]). Since corporations form a sizable component of this sector, it is important to examine the theoretical and empirical implications of technical progress for the question of the incidence of the corporation income tax. In this paper, we incorporate technical progress into a general-equilibrium model of tax-incidence and analyze several cases of neutral and biased technical progress in the corporate and non-corporate sectors of the economy.

The starting point of our analysis is the well-known two-factor, two-commodity model which was first applied by Harberger (1962) to analyze the incidence of the corporation income tax. In the absence of technical progress, the burden of the tax depends mainly on relative factor intensities and the elasticities of substitution between labor and capital in the two industries. When technical progress is considered, many of the results derived in earlier studies are modified. The most important conclusion to emerge, however, is that demand conditions (especially the elasticity of demand in the taxed industry) now play a crucial role in determining the tax-incidence.

The basic theoretical model is presented in Section II and the subsequent sections deal with technical progress in the taxed industry, the untaxed industry, and in both industries.

**The Model and Some Key Relations**

The model to be presented in this section follows a comparative static approach and estimates how the burden of the tax would be shared when the economy attains a new equilibrium after the tax is imposed. It is assumed that the economy consists of two sectors of production, the corporate sector (C) and the non-corporate sector (Y), which utilize capital (K) and labor (L) in the process of production, and that per-unit net of tax earnings of each productive factor are equalized between sectors. Perfect competition, constant returns to scale, diminishing returns to variable proportions, full employment of factors, inelastic factor supplies
and perfect factor mobility are also assumed. The product and factor prices are initially taken to be unity.

The corporate income tax can be viewed as a fixed tax per unit of capital employed in industry $X$. When the tax is levied, the output of $X$ declines, both capital and labor are ejected from industry $X$ and have to be absorbed by industry $Y$ (because we assume full employment). The incidence of the tax depends on how the relative factor shares change as a result of the tax. If the earnings of capital decline by just the amount of the tax revenue (or equivalently, the share of labor in national income remains unchanged), capital bears the entire burden of the tax. The change in relative shares depends on the terms on which the untaux absorbs the "rejects" of the taxed industry. Consequently, variables like the elasticity of demand for $X$ (which determines the extent of the decline in the output of $X$), the initial factor proportions and the elasticity of factor substitution in the two industries will have to be included in our model.

Following Harberger, we assume that demand for each commodity is a function of the relative product prices alone, i.e., $D = D_p(p, \{p\})$, where $p$ stands for price, $D$ for demand and the subscript $i$ denotes the two commodities $X$ and $Y$. The demand functions can be specified in this manner if we assume that when the government spends the tax proceeds, the initial commodity prices do not change, and that the redistribution of income among consumers resulting from the corporate income tax does not change the pattern of demand. Since factors are assumed to be fully employed, the demand functions for $X$ and $Y$ are interdepenent. Once the demand function for one commodity is specified for given prices and full employment income, the demand function for the other commodity can be derived without any additional information. The demand conditions in our model may then be represented by a single equation, namely,

$$X = D_x = D_p(p)$$

Differentiating this equation and remembering that $p_x = p_y = 1$ initially, we obtain

$$dX = Edp_x - dp_y + rac{dX}{dL}$$

where $E$ is the price elasticity of demand for $X$.

The two production functions are given by

$$X = f(X, L, t)$$

$$Y = f(X, L, t)$$

where $X$ and $L$ are the capital and labor inputs in the $k$th industry ($i = x, y$), and $t$ is a shift parameter representing the technological level in each sector. Differentiation of $(2^a)$ yields:

$$dX = f_x dx_x + f_L dx_L + f_t dt$$

where $f_x$ and $f_L$ are the partial derivatives of demand for factors of production $X$ and $Y$. When the factor inputs in $X$ are kept constant,

$$a_x = 1$$

In an industry characterized by perfect competition and a production function homogeneous of degree one, the capital-labor ratio is determined by the factor-price ratio and any bias that may be created by technical progress. Therefore, for industry $X$,

$$X = \frac{X}{L_x} = \frac{K_x}{L_x}$$

$$\frac{dX}{dt} = \frac{dK_x}{dt} - \frac{dL_x}{dt}$$

where $p_x$ and $p_y$ are the price of capital and labor, respectively. Differentiating $(4^a)$ and remembering that initially $p_x = p_y = 1$, we obtain:

$$\frac{dK_x}{dt} = \frac{dL_x}{dt} - S_x(dp_x + T - dp_y) + \lambda_x$$

where $S_x$ is the elasticity of factor substitution in industry $Y$, and $\lambda_x$ is the relative rate of change in the capital-labor ratio in $X$. If only the shift parameter changed, i.e.,

$$\lambda_x = \frac{1}{K_x} \frac{dK_x}{dt}$$

With full employment of capital and labor

$$K_y + L_y = K$$

and

$$L_x + L_y = L$$

The partial derivative notation in the above expression implies that factor prices are being held constant. In other words, $\lambda$ is the Hicks-measure of technical progress.3 It's sign indicates the nature of Hicks-technical progress. If $\lambda > 0$, technical progress is neutral; if $\lambda > 0$, it is capital-using, if $\lambda < 0$, it is capital-saving.

The same procedure can be followed to derive a factor response equation in industry $X$, but here it must be noted that the return to capital is subject to a tax in $X$, and not in $Y$. Let $T$ denote the amount of tax per unit of capital. Then the change in the price of capital including the tax will be $(dp_x + T)$. The change in the price of capital relevant for decision making in industry $Y$, therefore, is $(dp_x + T)$, i.e., the change in price of capital net of tax. The equation for $X$ corresponding to $(3)$ will, therefore, be

$$\frac{dK_x}{dt} - \frac{dL_x}{dt} + \lambda_x$$
\( dp_x = 0 \) \tag{9}^1

where \( p_x \) and \( p_y \) are respectively the relative shares of labor and capital in industry \( Y \).

Substituting equations (5)-(9) into equations (1)-(4), we obtain the following system of equations:

\[
\begin{align*}
\frac{dX}{K_x} &= E[f_x(dp_x + T)] - L_x dp_y + \alpha_y, \\
\frac{dX}{K_y} &= \alpha_x, \\
\frac{dX}{L_x} &= -S, \quad \text{and} \\
\frac{dX}{L_y} &= S. 
\end{align*}
\]

Equating (1') and (2) and rearranging terms in (3') and (4'), we obtain:

\[
E[f_x T + \alpha_y] - \alpha_x(1 + E) = E[g_x f_x - f_x dp_x] + f_x \frac{dL_x}{L_x} + f_x \frac{dK_x}{K_x} - L_x dp_y + \alpha_y. \tag{10}
\]

The specification of the model is now complete. The government's tax revenue always amounts to \( K_x T \). The change in national income caused by the tax, and measured in terms of \( p_x \), the price of labor, is \( K_x T + (K_y + K_x) dp_x \). If \( dp_y \) is zero, the decline in real national income equals the tax revenue; the prices of labor and capital (net of tax) as also their relative factor shares do not change, hence capital and labor bear the tax in proportion to their initial factor shares. Labor's tax-burden exceeds this if the price of capital (net of tax) rises in the new equilibrium position after the tax \( (dp_x > 0) \), and if \( dp_x = \frac{(K_y + K_x)}{-T} \), the earnings of capital fall by the amount of the tax revenue and the entire burden of the tax is on capital. The incidence of the tax thus, depends crucially on \( dp_x \).

The solution for \( dp_x \) is:

\[
dp_x = \begin{cases} 
E[f_x T + \alpha_y] - \alpha_x(1 + E) & \text{if } f_x > 0 \\
-\lambda_x & \text{if } f_x < 0 \\
S, & \text{if } f_x = 0
\end{cases}
\]

Expansion of (11) furnishes us with:

\[
E[f_x T + \alpha_y] - \alpha_x(1 + E) = \frac{K_x}{L_x} \frac{L_x}{L_x} + \lambda_x + (S, T + \lambda_y)
\]

\[
\begin{align*}
\frac{dX}{K_x} &= \alpha_x, \\
\frac{dX}{K_y} &= -S_x, \\
\frac{dX}{L_x} &= -S_x, \\
\frac{dX}{L_y} &= -S_x.
\end{align*}
\]

The only term reflecting technical progress is \( \alpha_x \) \( \frac{K_x}{L_x} \frac{L_x}{L_x} \) (1 + E) which appears in the numerator of (13). It is obvious that when \( |E| = 1 \) or \( \frac{K_y}{K_x} \frac{L_x}{L_y} \) the term disappears.

This leads to a key conclusion that whenever the demand for the product of the taxed industry is unit elastic, or factor proportions are initially the same in the two industries, technical progress does not affect the problem of tax-incidence.\(^3\)

Several other results can be derived by examining the general solution (13): 1. When factor proportions are initially the same in the two industries, capital's share of the tax burden must exceed its initial contribution to national income. In

\(^3\)It is easy to explain this rather sweeping conclusion. Within the framework of our model the incidence of the tax depends on its effect on the output of the two industries and relative factor prices. When \(|E| > 1\), the proportions of national income spent on the taxed industry remains constant regardless of the level of output; technical progress, therefore, does not matter. Again, when factor proportions are the same, the untaxed industry can absorb labor and capital in the same proportions in which they are released by the taxed industry. Neutral technical progress, by definition, does not alter capital-labor ratios; therefore, it does not affect relative factor prices in this case.

**Technical Progress in the Taxed Industry**

**Neutral Technical Progress**

If technical progress takes place only in industry \( X \), \( \alpha_x = h_x > 0 \). If technical progress is more closely followed Harberger's model, it is interesting to compare (12) with Harberger's general solution. The
this case \( \left( \frac{T}{K} \right) = \left( \frac{T}{L} \right) \), second term alone re-

mains in the numerator of (13) and the first term in the denominator also disappears. 

The solution simplifies to 

\[ dp_x = \frac{TS_y K_x}{S_x K_x + S_y K_y} \]

which is negative because \( S_x \) and \( S_y \) are negative but \( K_x \), and \( T \) are positive.  

2. When the two industries use capital and labor in the same proportion, demand conditions do not affect the problem of tax incidence at all. Hence, these considerations are immaterial as long as the untaxed industry uses labor and capital in the same proportion as the taxed industry. The result is obvious from the general solution (13) because whenever \( \frac{K_x}{K_y} = \frac{T_x}{L_x} \), all terms containing \( E \) disappear from both the numerator and the denominator. 

3. When the taxed industry uses capital intensive and the demand for its product is price elastic, capital's share of the tax burden exceeds its initial contribution to national income. In this case, \( |E| < 1 \), \( K_x \) is greater than \( L_x \), and all the terms in the numerator are negative; hence \( dp_x \) must be negative. Q.E.D. When \( |E| = 1 \), the result still holds: the third term in the numerator of (13) vanishes but the other terms are negative, hence \( dp_x < 0 \). 

4. When labor and capital are used in the fixed proportions in both industries, the incidence of the tax depends on the elasticity of demand for the taxed commodity and the relative capital-labor ratios in \( X \) and \( Y \). 

In this case, \( S_x = S_y = 0 \) and (13) reduces to 

\[ dp_x = \frac{T_x T_y}{K_x} - \frac{\alpha_y (1 + E)}{E (K_x - f_x)} \]  

(15) 

When \( |E| = 1 \), the expression simplifies further to \( dp_x = -\frac{T_x T_y}{K_x} \), which is negative when the taxed industry is relatively capital-intensive (\( f_x < f_y \)), and conversely.  

This conclusion is reinforced when \( |E| < 1 \), because the second term in (15) will have the same sign as the first. The sign of \( dp_x \), however, could be reversed if \( |E| > 1 \). 

5. When elasticity of demand is unity, capital bears more of the tax than labor relative to their initial factor shares if \( |S_y| > |S_x| \). In this case, \( S_x f_x (\frac{T_x}{K_x}) \) and other negative terms dominate the only positive term in the numerator, namely \( E (\frac{T_x}{K_x} - f_x) \) and \( dp_x < 0 \). However, when \( |E| > 1 \), this is not a sufficient condition for \( dp_x < 0 \); now \( (\alpha_y) - \frac{T_x}{K_x} = \frac{\alpha_x}{K_x} \) and the other additional positive terms in the numerator of (1) and the sign of \( dp_x \) is not independent of the factor proportions in the two industries. 

6. In the absence of technical progress, labor can bear more of the tax than its initial share in national income, only if the taxed industry is relatively labor intensive. When technical progress is taking place, this is a necessary condition only if the demand is unit elastic or inelastic. 

The above result holds if \( dp_x > 0 \). The denominator of (13) is positive, the second term in the numerator is negative, the entire numerator can be positive only if the first and/or the third terms are positive. 

\[ \frac{\alpha_y (K_x - L_x)}{K_y} \]  

when \( \frac{K_x}{L_x} \leq \frac{L_x}{K_x} \) which is true if \( \frac{K_x}{L_x} = \frac{L_x}{K_x} \), i.e., \( X \) is labor-intensive. When \( |E| < 1 \), this also ensures that 

\[ \alpha_y (\frac{T_x}{K_x} - f_x) (1 + E) > 0. \]

When \( |E| = 1 \), the third term in the numerator (13) disappears and the first term is positive only if \( X \) is labor-intensive. When there is no technical progress \( \alpha_y = 0 \) and the same result follows, Q.E.D. 

A corollary of the above result is that when technical progress occurs at sufficiently rapid rate (\( \alpha_y \) substantially greater than zero), and demand for \( X \) is elastic (\( |E| > 1 \)), \( dp_x \) can be positive even if the taxed industry is relatively capital-intensive. 

**Biased Technical Progress** 

If technical progress is not neutral, \( \lambda_y (T_x = \frac{T_y}{K_y} - \frac{T_x}{K_x}) \) is added to the numerator of (13). This term is positive if technical progress is capital-using, and negative if it is labor-using (or capital-saving). **On a priori grounds**, it is clear that capital-saving technical progress would tend to increase the burden of tax on capital: for a given reduction in the output of the taxed industry, more capital would now be released and other things equal, in the new equilibrium, the untaxed industry would be able to absorb it only at a lower relative price of capital. 

Many conclusions derived above are altered by the introduction of bias in technical progress. The first one to change is the general result stated earlier, i.e., when the elasticity of demand for the taxed commodity is unity, or the factor-ratios in the two industries are equal, technical progress does not affect the incidence of the tax. 

Now, even if \( |E| = 1 \) and 

\[ \frac{K_x}{L_x} = \frac{K_y}{L_y} \]  

will appear in the numerator of (13) and affect \( dp_x \). If technical progress is capital saving, it reinforces all cases in which \( dp_x \) tends to be negative. When \( \lambda_y > 0 \), things are different, but this case can be analyzed easily by comparing \( \lambda_y \) with \( S_x \). In the numerator of (12), \( \lambda_y \) and \( S_x \) appear as follows: 

\[ \frac{S_x T + \lambda_y}{S_x T + \lambda_x} \]

If other terms in (12) lead to the conclusion that \( dp_x < 0 \) and \( \lambda_y > 0 < \frac{S_x T}{S_x T} \), this conclusion still holds and capital's burden of the tax would be greater than its initial contribution to national income. 

**Technical Progress in the Untaxed Industry** 

When technical Progress occurs only in industry \( Y \) and is neutral, \( \lambda_y = \alpha_y = \lambda_x = 0 \),
and the general solution (12) simplifies to

\[
E_KT + \alpha_T \left( \frac{K}{K} - \frac{L}{L} \right) + S_T \left[ \frac{K}{K} + \frac{L}{L} \right] - S - \frac{\left[ \frac{K}{K} + \frac{L}{L} \right]}{\left( \frac{K}{K} - \frac{L}{L} \right)} = 0
\]

(16)

When factor proportions are the same in the two industries, (16) is a special case of (13) which has been discussed in detail in the preceding section. However, when the two industries do not use labor and capital in the same ratio initially, the results are different. Elasticity of demand for the taxed commodity (especially its absolute value) does not play an important role in determining the incidence of the tax anymore. Many conclusions presented in the preceding section will now hold under much weaker conditions. For example, the first point in that section states that the percentage increase in capital intensive industries of \( \frac{K}{K} - \frac{L}{L} \); and \( S \) are negative, hence, all the terms in the numerator of (16) are negative and \( dp_K < 0 \).

When \( |E| = 1 \), (16) reduces to (16) except for an additional term in the numerator, \( \alpha_C \left( \frac{K}{K} - \frac{L}{L} \right) \). The additional term, however, always has the same sign as the first term in the numerator of (13) (because \( \alpha_C > 0 \); therefore, it affects only the magnitude and not the sign of \( dp_K \). For example, to continue with the case of the taxed industry being capital intensive, when \( |E| = 1 \), neutral technical progress in industry \( X \) does not affect the tax-burden on capital, but when technical progress happens in industry \( Y \), \( dp_K \) is more negative and capital suffers more.

When technical progress is not neutral, \( \lambda \) is added to the numerator of (16) with a positive or a negative sign. In the above example of a capital intensive taxed industry, capital would bear a still greater burden of the tax if technical progress in industry \( Y \) is capital-saving \( \lambda < 0 \) and vice versa. Barring extreme (and extremely unlikely) values of \( \lambda \), the results would not change much and must be true mutatis mutandis, the remarks made above apply.

**Technical Progress in Both Industries**

Assuming that technical progress is neutral, (12) can be rewritten as follows:

\[
E_KT + \alpha_T \left( \frac{K}{K} - \frac{L}{L} \right) + S_T \left[ \frac{K}{K} + \frac{L}{L} \right] - S - \frac{\left[ \frac{K}{K} + \frac{L}{L} \right]}{\left( \frac{K}{K} - \frac{L}{L} \right)} = 0
\]

(18)

When \( \alpha_C > \alpha_T \), and \( \frac{\alpha_C}{\alpha_T} \left( \frac{K}{K} - \frac{L}{L} \right) \) is unambiguously negative, whatever the level of \( E \); this negative term results in a further rise in capital's share of the tax burden.

None of the above results, however, will hold if \( |E| > 1 \) and \( \alpha_C < \alpha_T \).

When technical progress is non-neutral, the general solution is given by (12) and two new terms, \( \lambda \) and \( \lambda \left( \frac{K}{K} + \frac{L}{L} \right) \), are added to the numerator of (17). These terms measure the bias in technical progress. Recall that when \( \lambda > 0 \), the tax-burden on capital is capital-saving. Consequently, to ensure full employment of capital in the new equilibrium after tax, the price of capital would have to decline more; hence, \( ceteris paribus \), the tax burden of capital increases.

1. When the taxed industry is relatively capital intensive, simultaneous technical progress in both industries increases capital's share of the tax burden if the taxed industry has an inelastic or unit elastic demand. It was proved earlier [section III, result (3)] that whenever neutral technical progress takes place in the untaxed industry also, a new term \( E_N \left( \frac{K}{K} - \frac{L}{L} \right) \) is added to the numerator of \( dp_K \). This term is negative whenever the taxed industry is capital-intensive; therefore, capital's share of the tax burden goes up.

2. When technical progress in the untaxed industry occurs at a rate faster than equal to that in the taxed industry, the above result holds regardless of the magnitude of \( E \). The third term in the numerator of (17) can be rewritten as

\[
E_KT + \alpha_T \left( \frac{K}{K} - \frac{L}{L} \right) + S_T \left[ \frac{K}{K} + \frac{L}{L} \right] - S - \frac{\left[ \frac{K}{K} + \frac{L}{L} \right]}{\left( \frac{K}{K} - \frac{L}{L} \right)} = 0
\]

(19)

If our analysis of tax incidence is correct, the correlation income tax provides the corporate sector with a strong incentive to introduce capital-saving innovations. In this context, it is interesting to note that Sato's recent work supports the hypothesis that technical progress in the manufacturing sector of the U.S. economy has been of the capital-using type. Our results suggest that the bias in technical progress might be explained, at least partially, by efforts of corporations to escape the burden of the corporation income tax.

Our analysis, thus, has some interesting implications for the theory of induced inventions which suggest that when the price of a factor rises, the producers have an incentive to introduce innovations which economize on the use of that factor (see Hicks 1932 and Ahamed 1966). Since the


corporation income tax, in effect, raises the price of capital to the taxed industry, this argument implies that producers in the taxed industry would be induced to introduce capital-saving technical progress. However, this a priori conclusion is modified when other variables suggested by the general equilibrium approach presented in our paper are taken into account, and, as shown before, capital owners (or producers), ceteris paribus, tend to benefit from the introduction of capital-using technical progress.

In the absence of technical progress, capital could benefit from the corporation income tax only if the corporate sector is labor-intensive. When technical progress is introduced, it ceases to be a necessary condition if the corporate sector faces an elastic demand curve; capital can gain (labor's share exceeding its initial contribution to national income) even if the taxed industry is capital intensive. Relative factor intensities alone, however, are not sufficient to determine the incidence of the corporate income tax.

References


1. outline the basic structure of the relevant portions of the model and the role of immigration in the model;
2. examine and explain the results of simulation experiments with the model;
3. explore a simple policy option to offset the macroeconomic effects of immigration as simulated in the model; and
4. comment briefly on some different interpretations of the results for the formulation of immigration policy.

The basic finding from this research is that an increase in the level of net immigration in the model raises the unemployment rate and marginally lowers constant dollar per capita Gross National Expenditure (GNE) averaged over the simulation period. We also illustrate in this report that these effects may be offset in the model by a policy of increased government spending and indicate some qualifications to the results.

In section two we discuss in some detail the structure of the relevant portions of the model and particularly the role of immigration in the model. In section three we present the results of the basic simulation experiments and in section four we show how a complementary increase in government spending can be used to offset the effects observed. In the final section (five) we make some concluding remarks.

The Role of Immigration in the Model

CANDIDE Model 1.0 is a very detailed representation of the Canadian economy.

References


