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**A NEW APPROACH TO ESTIMATE THE
INCIDENCE OF THE CORPORATE INCOME
TAX**

BY

HAROLD A. VASQUEZ-RUIZ

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree
of
Doctor of Philosophy
in the
Andrew Young School of Policy Studies
of
Georgia State University

GEORGIA STATE UNIVERSITY
2012

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ACCEPTANCE

This dissertation was prepared under the direction of the candidates Dissertation Committee. It has been approved and accepted by all members of that committee, and it has been accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Economics in the Andrew Young School of Policy Studies of Georgia State University.

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ABSTRACT

A New Approach to Estimate the Incidence of the Corporate Income Tax

by

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April 2012

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After Harberger published his influential paper in 1962, many authors have assessed empirically whether the incidence of the corporate income tax (CIT) falls on capital owners, consumers, or workers (Krzyzaniak and Musgrave, 1963; Gordon, 1967; Arulampalam et al., 2008). Today, there is little agreement among economists about who bears the incidence of the CIT (Gruber, 2007; Harberger, 2008a,b). The reason for the little convincing evidence is that the econometric models used in the literature ignore that the factors that motivate changes in corporate tax policy are sometimes correlated with other developments in the economy and disentangling those effects from exogenous policy changes requires tremendous effort.

Using annual information at the industry level for the United States, I propose to investigate the consequences of exogenous changes in corporate tax policy. The identification of these exogenous events follows the work of Romer and Romer (2009, 2010), who provide an extensive analysis of the U.S. federal tax legislation using narrative records from presidential speeches and congressional reports, among other documentations. The

results validate the original predictions from Harberger (1995, 2008a). That is, in the short-term, capital owners bear the full burden of the tax. Over time, however, capital owners are able to shift this burden either by raising consumers' goods prices, or decreasing workers' wages. The magnitude of these effects depends on the degree of capital intensity as well as the access to international markets and the availability of substitutes for the industry under consideration.

CHAPTER I

Motivation

“ONLY PEOPLE—NOT GOODS OR ORGANIZATIONS—CAN BEAR THE BURDEN
OF A TAX.”

After Harberger published his influential paper in 1962, many authors have assessed empirically whether the incidence of the corporate income tax (henceforth CIT) falls on capital owners, consumers, or workers (Krzyzaniak and Musgrave, 1963; Gordon, 1967; Arulampalam et al., 2008).¹ Even today, there is little agreement among economists about who bears the incidence of the CIT (Gruber, 2007; Harberger, 2008a,b). The reason for the little convincing evidence on who bears the burden of this tax is that the econometric models used in the literature are not able to account for the different reasons that motivate corporate tax changes. That is, the factors that motivate changes in corporate tax policy are sometimes correlated with other developments in the economy (e.g., financing healthcare reform), and disentangling those effects from exogenous policy

¹Before advancing any further, it is important to clarify a few concepts. Economists use tax incidence analysis to identify how the burden of a tax is distributed across individuals. In this sense, the literature identifies two incidence measures: (i) statutory incidence, which measures incidence in terms of who actually paid—i.e., according to the law—the tax; and (ii) economic incidence, which considers the combined effect of statutory incidence and how real income responds to changes in goods and factor prices when a tax is imposed. These two measures will differ in the presence of tax shifting. Tax shifting occurs whenever some individuals—e.g., in this case corporations—can transfer the burden of the taxes they are supposed to pay through changes in factor rewards and prices (Bruce, 2001, p. 325-26). This study focuses on the economic incidence—henceforth referred only as incidence—of the corporate income tax, unless otherwise specified.

changes requires tremendous effort. In addition, the empirical literature is mostly based on a single-point estimate, or short-run elasticity, of the effect of a tax change on the price of consumer goods and the price of production factors: labor and capital, neglecting the issue of timing and the long term effects.

Most importantly, the empirical literature thus far has ignored that the incidence of a change in the CIT, as predicted in Harberger's model, occurs over time—as investors move some part of the capital stock immediately and the other part just gradually (see Auerbach, 2006, p. 10). Therefore the effect of the CIT on prices will also depend on the short- and long-term ability of capital owners to escape taxation.

To consider an example on how the dynamics of corporate tax changes might work, suppose that the U.S. government decides to impose a tax on the income of oil extracting companies to cover for potential environmental damages from industrial accidents. The initial, or short-term, effect of the tax will be to reduce the profits of oil corporations, harming corporations' owners and stockholders. Over time, as oil extraction becomes less profitable, investors move their capital to other sectors, or countries, where they can obtain a higher return, thus escaping the tax. As less capital is available to build new oil rigs, the industry's supply of oil and demand for workers decline. Therefore, in the long-term, the CIT would result in higher gas prices and lower wages—affecting consumers and workers, economy-wide.

The previous example summarizes the intuition behind Harberger's contribution. Nevertheless, a set of assumptions about production functions and the elasticities of product demands and factor substitutions are required in order to determine the *true* incidence of the CIT. Following this path, general equilibrium (GE) models have been developed since the 1980's, in which economists simulate the tax-expenditure system of a real economy (or group of economies) to analyze how policy changes affect individuals' income and welfare. However, as Harberger indicates, the modeling and calibration to the economy analyzed “must be of high quality,” and given the disagreement about the main parameters that

must be chosen, this constitutes a challenging task. Moreover, these models might not be measuring only the incidence of the CIT, but that of the “entire tax system,” making the incidence analysis unintelligible (Harberger, 2008a, p. 285-86). As of today, the general equilibrium modeling literature is inconclusive regarding who bears the incidence of the corporate income tax.²

The importance of determining the incidence of the CIT is twofold. For equity considerations, the assumptions on the incidence of the corporate tax have crucial implications when policy makers evaluate the progressivity of the tax system. For instance, in a 2007 report entitled “Historical Effective Federal Tax Rates: 1979 to 2005,” the Congressional Budget Office (CBO) showed that the corporate income tax—and the U.S. tax system overall—is moderately progressive. However these calculations rely on the assumption that “corporate income taxes are borne [fully] by owners of capital” (CBO, 2007, p. 3). Thus, in the opposite case that the burden of the CIT is borne by consumers or workers, the CBO’s conclusions will overstate the progressivity of the national tax system.³

On efficiency grounds, the CIT always occupies an important place when policy makers are discussing the introduction of a tax reform. For instance, in a recent article Michael Boskin points to the role the CIT has in promoting efficiency and economic growth: “reducing or eliminating the corporate tax would curtail numerous wasteful tax distortions, boost growth in both the short and long run, increase America’s global competitiveness, and raise future wages” (Boskin, 2010). Yet this assertion supposes that for an open economy with free mobility of capital, the CIT might reduce the reward for investments,

²To cite few examples, Gravelle and Smetters (2006) use an open economy general equilibrium model, calibrated for the U.S. economy and the rest of the world, and claim that capital owners bears the full burden of the CIT. In Harberger’s view, however, some of the “key” parameters used for the calibration are “quite implausible” (Harberger, 2008a, p. 306). On the other hand, Gentry (2007) conducted a review of the open economy GE model literature and concludes that labor and land—as production factors of less mobility—bear the burden of this tax.

³The CBO argument about the progressivity of the CIT is based on estimations of effective tax rates—the ratio of tax liability to income—for each quintile of the income distribution of the population. According to these calculations, in 2005 the lowest quintile of the income distribution has an effective tax rate of 0.4%. This rate increases progressively to 0.5% for the second, 0.7% for the middle, 1.0% for the fourth, and 4.9% for the highest quintile of the income distribution (see CBO, 2007, Table 1).

and its long-term incidence is borne by workers. Kotlikoff and Miao (2010) investigate how the corporate income tax affects the level of business risk in the economy. In this model, entrepreneurs can choose to declare their firms as one of two types: (i) corporate and (ii) private. The former are allowed to trade publicly in capital markets, while for the later public trading is banned. The access to capital markets permits corporate firms to diversify their asset portfolio, thus reducing their level of risk. However, these corporations are subject to the CIT.⁴ Using a simple model in which production depends on labor and managerial skills, they show that the CIT reduces the amount of publicly traded companies on behalf of private entities, thus increasing the level of risk in the economy.

To empirically determine the incidence of the CIT (and perhaps the reason why previous attempts might have failed), it is necessary to obtain time series information on exogenous changes in policy that allows for the estimation of the short- and long-term effects of tax changes on the price of goods and services produced as well as the price of production factors: rate of return on capital and wage rate.⁵ In the words of Harberger (2008a), however, this could be a challenging task given that “the world never gives us a clear incidence scenario in which we can trace out the consequences of a tax change by simply following the data” (p. 305). Facing to this challenging task, and I think successful, constitutes this research’s major contribution.

To get there, I employ a new and more appropriate methodology that allows for a clearer improved analysis for how the incidence of the CIT is distributed over time among workers, consumers, and capital owners. Using annual information at the industry level for the United States, I investigate the consequences of exogenous changes in corporate tax

⁴The U.S. tax code makes a similar distinction when classifies corporations as “C-corporations” and “S-corporations”—the letters “C” and “S” refer to the corresponding chapters in the legislation. The profits from C-corporations are subject to the corporate income tax. Moreover, dividends from C-corporations are taxed at the individual level when they are distributed to investors. On the other hand, S-corporations do not pay the CIT. Instead, their profits are taxed under the individual income tax when they are distributed among shareholders.

⁵In Harberger’s model, land rent prices are positively with the imposition of the corporate income tax. However, as I will explain in section 2.1.2, the increase in land rent prices is only to compensate for the increasing profits in the Agriculture sector caused by a decline in labor cost.

policy. The identification of these exogenous events are based on the work of Romer and Romer (2009, 2010), who provide an extensive analysis of the U.S. federal tax legislation using narrative records from presidential speeches and congressional reports, among other documentations. That is, by looking at the sources that motivate tax policy changes, this study separates exogenous events in corporate tax policy from other endogenous developments within the economy and, therefore, it obtains a “clean” unconfounded estimate of the incidence of the corporation income tax.

The estimation procedure uses Vector Autoregression (VAR) models. As chapter III explains in more detail, the advantages of using a VAR approach are as follows. First, the VAR specification assumes that all the variables in the system of equations are endogenous, thus solving the simultaneity problem that arises in the literature when estimating factor returns as functions of the CIT. Second, the impulse-response functions (IRF) obtained from the VAR system allow for the dynamic impact analysis of exogenous shocks associated with corporate income tax policy. These dynamic responses tie the short and long run reactions of prices to policy changes in a smooth function that enhances the interpretation of the results. Third, this technique allows to analyze simultaneously the impact of CIT changes on capital owners, consumers, and workers, which represent a big depart from the previous empirical literature which *only* focus on the effect of corporate tax changes on one of these three groups (Krzyszaniak and Musgrave, 1963; Arulampalam et al., 2008; Felix, 2007; Nadja Dwenger and Steiner, 2011).⁶

The results validate the original predictions from Harberger (1995, 2008a,b) on the effect of an exogenous increase of the corporate income tax for a multi-sector open economy. That is, in the short-term, the CIT rises the cost of capital in the corporate sector, thus capital owners bear the full burden of the tax. Over time, as capital re-allocates in the economy, the cost of capital returns to its pre-tax level and the return to capital in the

⁶In section 2.2.3, I present a detailed critique on the empirical literature from its origins until current time.

non-corporate sector (e.g., Agriculture, Services) declines. The tax-wedge created by the CIT is absorbed by workers with the outcome that wages decline almost economy-wide. Finally, the estimations show that in the long-term the CIT changes result in the rise of prices of goods and services in high capital intensive industries (e.g., Transportation & Utilities, Manufacturing). For sectors with a relative low capital income share (e.g., Services) prices decline.

CHAPTER II

Literature Review

2.1 The Harberger model: 45 years of tax incidence analysis

The formal treatment of tax incidence analysis began with Harberger (1962) seminal contribution. This paper provides a theoretical framework for the dissection of the effects of corporate income tax (CIT) changes and derives some inference about the incidence of this tax. Harberger characterizes a two-sector competitive closed economy, divided into corporate (C) and noncorporate (NC) sectors, where each sector produces a unique good employing labor (L) and capital (K) as factors of production. These factors are fixed in total supply to the economy but both are perfectly mobile across sectors. Harberger introduces the CIT as a partial factor tax, i.e., a tax on the earnings of capital in the C sector, on the top of the personal income tax, but not the earnings from the NC sector. He also assumes that the government spends all CIT proceeds in a way that will just counterbalance the reduction in consumption from individuals. When analyzing a CIT change, Harberger considers the long-run effects to be of “greatest theoretical and practical interest,” therefore his model does not focus on the short-term effects of CIT changes. However, Harberger argues that under perfect competition the short-term incidence of the CIT will be “borne out of the earnings of fixed capital equipment in the affected industry” (Harberger, 1962, p. 215), hence capital owners will bear the short-term incidence of this

tax.

Under some standard assumptions for the elasticity of output and factor substitution, this model shows how the incidence of the CIT falls on all capital income, economy-wide, but not only on capital income from the taxed sector. Intuitively, the CIT reduces the rate of return on capital (r) in the C sector, causing investors to move capital to the NC (non-taxed) sector, as factors are perfectly mobile (factor substitution effect). The movement of capital increases the labor to capital (L/K) ratio in the C sector and reduces this ratio in the NC sector, changing the relative return to both factors. The capital stock will continue to flow from the C to the NC sector until the economy-wide rate of return on capital falls enough, relative to the wage rate (w), so that the net-of-tax rates of return across the two sectors is the same. Therefore, the factor substitution effect unambiguously decreases the factor price ratio r/w , worsening capital owners relative to workers.

The CIT also increases the gross-of-tax rate of return to capital, raising the cost of capital to firms in the C sector. This causes the price for the corporate good to increase relative to the noncorporate good and consumers to demand more products from the NC sector. Hence, output in the C sector declines while output in the NC sector rises (output substitution effect). The decrease and increase in output from the corporate and noncorporate sectors, respectively, will affect the r/w ratio depending on whether the corporate sector is labor or capital intensive, compared to the noncorporate. When the C sector is labor intensive, the reallocation of labor and capital from the C to the NC sector causes the r/w ratio to raise because the L/K ratio released from C firms is significantly higher than the L/K ratio employed in NC—which is capital intensive, hence the excess supply of labor relative to capital causes w to fall economy-wide. On the other hand, when the C sector is more capital intensive than the NC sector, the r/w ratio will decline, as the ratio of L/K released from C is smaller than the L/K ratio actually used in the NC sector. That is, labor becomes more scarce, relative to capital, and its price w rises. Therefore, the output substitution effect makes the incidence of the CIT fall in

capital owners or workers depending on whether the C sector is capital or labor intensive, respectively.

Overall, the effect of the CIT on factor prices depends on whether the corporate sector is capital or labor intensive. If the C sector is capital intensive, then both the factor substitution and output substitution effects unambiguously reduce the r/w ratio, hence capital owners bear more of the tax burden compared to workers. Contrarily, if the C sector is labor intensive, then the factor substitution effect works in the opposite direction to the output substitution effect, and the net effect on the r/w ratio depends on the capacity of the factor substitution effect to overcome the output substitution effect.

This model is not only important for its sophistication and rigor for tax incidence analysis but also it removed the wide-spread misconception that corporate taxes were fully shifted to consumers in the form of higher goods prices (Krzyzaniak and Musgrave, 1963; Gillis, 2008). Using observed values of capital and labor shares for the period 1953-55, Harberger (1962) found the U.S. corporate sector to be more labor intensive than the noncorporate sector. Then, he calibrated the model with plausible parameter assumptions for the elasticity of product and factor substitution and consistently showed that capital owners bear about 100% of the incidence of the corporate income tax.

2.1.1 Harberger extensions: (i) the open economy case

To extend the incidence analysis of a CIT change for a two-sector open economy, again divided into corporate (C) and noncorporate (NC) sectors, Harberger (2008a) assumes that one of these sectors has access to trade goods and services in world markets, tradable (T) sector, while the other sells its products in the local market, nontradable (NT) sector. Also, the open economy assumption implies that the net-of-tax rate of return to capital r and the price of tradable goods are both determined in world markets. The fact that r is determined worldwide does not eliminate the possibility of small differences across countries in the net rate of return to capital due to differences in country risk perceptions.

However, Harberger argues that one country's change in the CIT rate will not affect its risk premium and, therefore, the cross-country net rate of return to capital will remain the same as the levels prior the policy change (Harberger, 1980, 2008b). These assumptions are enough to show that all workers and consumers of nontradable products will bear the incidence of the corporation tax.

To work conceptually through this model, first, assume a world with no CIT and for our two-sector open economy suppose the noncorporate sector is tradable (NC-T) while the corporate sector is nontradable (C-NT). Then, the imposition of a CIT will affect neither the price of capital nor will it affect the price of noncorporate products, since both are determined worldwide. Also, it can be shown that the price of labor, economy-wide, will remain unchanged as well. Therefore, the price of the C-NT goods and services will have to raise and consumers of C products will bear the incidence of this tax.¹

When the corporate sector is tradable C-T, the CIT will not affect the net rate of return to capital, nor the world price for the corporate tradable goods, therefore corporations will stay in business if only if they can shift the tax burden to workers, hence wages in the C-T sector will decline until they absorb the full amount of the tax. Since wages must be equalized economy-wide, Harberger (2008a) showed that workers end up bearing more than 100% of the burden of the tax. Furthermore, the drop in wages will cause a reduction in the price of the NC nontradable goods and services, benefiting the buyers of these products. In other words, capital owners and workers will receive a gain from the CIT but only in their roles as consumers of NC nontradable products.²

¹Mathematically, this result can be demonstrated as follows. Harberger (2008a) defines the "price formation equation" for corporate and noncorporate goods as

$$dp_C = \phi_K(dr + t_{KC}) + \phi_L dw \quad \text{and} \quad dp_{NC} = \theta_K dr + \theta_L dw$$

respectively; where dp_C , dp_{NC} , dr and dw are the total change in the price of corporate goods, noncorporate goods, capital, and labor, respectively. t_{KC} is a tax on the income from capital in the corporate sector. The parameters ϕ_K , ϕ_L , θ_K , and θ_L are the shares of K and L in the production cost of the C and NC sectors, accordingly. If the noncorporate sector is tradable, then $dp_{NC} = dr = 0$, hence $dw = 0$ as well. Using this result in the price equation for the corporate nontradable sector, then $dp_C = \phi_K t_{KC}$.

²Similarly, using the price formation equation for the corporate sector previously defined and assuming that the corporate sector is tradable, then $dp_C = dr = 0$, and $\phi_L dw = -\phi_K t_{KC}$. The implication for

This model shows that the incidence of the CIT is born by labor because it is an immobile factor, while capital that is assumed to be perfectly mobile escapes taxation. Also, the country's decision to modify its CIT rate has no effect on the world prices of capital and tradable products, thus we can think of this change as occurring in a small open economy (or a group of small open economies). For the large open economy, Harberger argues this scenario can be analyzed within a two-sector close economy framework, as shown above, and the conclusions will still remain the same: the incidence of the CIT falls on all capital income, in this case worldwide, and not just on capital income from the taxed country. However, capital owners in the large open economy will bear a smaller burden (compared to the burden predicted in the closed-economy model shown in section 2.1) because there is a "very large sponge (world capital market) to help absorb the capital that is being ejected" from the large economy (Harberger, 2008a, p. 293).

2.1.2 Harberger extensions: (ii) Four-sector open economy model

Harberger further advanced the tax incidence analysis by developing a four-sector open economy model that allows to determine the burden of CIT changes in both small and large open economies scenarios (Harberger, 1995, 2008a). The model divides the economy into corporate (C) and noncorporate (NC), tradable (T) and nontradable (NT) sectors, with Manufacturing (T) and Public Utilities & Transportation (NT) representing the corporate side, while Agriculture (T) and Services (NT) represent the noncorporate sectors. Also, Harberger considers the CIT as a tax wedge that affects the preexisting cost structure in the C sector.

The open economy assumption implies that capital (the mobile factor) can easily escape taxation compared to labor, therefore the incidence of the CIT will depend on the size of the economy where the tax is imposed. For the small open economy, the rate of return on capital r is determined in world markets, hence the burden of the CIT

the price of the NC nontradable products is that $dw = -(\phi_K/\phi_L)t_{KC}$, hence $dp_{NC} = -\theta_L(\phi_K/\phi_L)t_{KC}$. That is, the price of the NC nontradable goods and services declines.

lies mostly on workers. On the other hand, for the large open economy, the corporate tax causes a significant movement of capital to international markets, decreasing r , thus capital owners, worldwide, bear the burden of the CIT. Capital owners, however, are not the only ones bearing the burden of this tax because the movement in factor prices might shift some of this burden to consumers and workers as well. These arguments are further developed as follows.

The imposition of the CIT in a small open economy will not release a significant amount of capital to world markets; hence we cannot expect r to decline. In the Manufacturing sector, the wedge imposed by the corporate tax t_{KC} cannot increase the price of manufacturing products p_M because this sector is tradable, therefore Manufacturing wages have to decline to absorb the extra cost added by the tax. This decline in wages is not only in the Manufacturing sector, but economy-wide, therefore consumers will benefit from a decrease in the price for Services p_S , as labor cost decline. Since the Agriculture sector is tradable, the decline in wages does not affect the price for agricultural products p_A , but land rents increases, therefore landowners are benefited.³ The CIT also affects the price in the Public Utilities and Transportation sector p_{UT} —which is corporate and nontradable; however the effect depends on the degree of capital intensity of this sector with respect to Manufacturing. That is, p_{UT} will increase, decrease, or no change depending on whether Public Utilities & Transportation is more, less, or equal capital intensive than Manufacturing. Harberger considers the former more capital intensive than Manufacturing, therefore he concludes that p_{UT} will raise.

For a large open economy, e.g., the United States, the CIT causes a significant amount of capital to flow to both the local noncorporate sector and the international markets, decreasing the rate of return to capital worldwide. This prediction is similar to the closed economy case in the sense that capital owners face the burden of the tax as their income

³Land rent increases because land is considered as a productive factor in the Agriculture sector and “reproducible capital” (K) is assumed to be out of agriculture (Harberger, 2008a, p. 291).

from capital declines. However, the drop in r predicted in the open economy model is significantly lower than predicted in the closed economy case, because international markets absorb part of the capital that has been released. As capital is shifted abroad, labor income will increase relative to capital income, hence foreign workers will gain from this tax, however foreign landowners will lose as land rents also decline.

For the rest of the large open economy, the changes in goods and factor prices will be similar to the small open economy case. Manufacturing prices are determined worldwide, thus p_M will not be affected with the CIT. Again, wages will have to fall economy-wide to absorb the tax wedge inserted by the CIT, and both local landowners and consumers of services will gain from the decline in labor cost. However, the increase in p_{UT} will harm capital and labor owners, but only in their roles as consumers. Harberger indicates that the worldwide decline in r affects all capital markets (including credits, bonds, and others), thus individuals participating in those markets will bear the burden of the CIT as well. For instance, borrowers will benefit from the worldwide decline in the interest rates.

The result that the imposition of the CIT does not affect p_M because this sector is tradable is based on the conjecture that Manufacturing products are homogeneous worldwide. While this might be the case for certain manufactured products (such as steel or electrical wiring) or products from particular sectors (such as Agriculture or Mining), this is a strong assumption for Manufacturing overall. Thus, Harberger extends this model by allowing the local to foreign manufacturing price ratio p_m/p_m^* to increase with a change in the CIT. As expected, if the CIT causes manufacturing—and national—wages to decline, the effect will not be as large as before because the price for manufactured goods rises.

The four-sector open economy model, which Harberger considers as his “own favorite open-economy model” (Harberger, 2008b, p. 305), offers great insight about how the incidence of the CIT is distributed among capital owners, workers, and consumers under

different scenarios: small or large open economies that produce homogeneous or non-homogeneous goods. The main conclusions from Harberger's original two-sector economy model still remain in the sense that as long as capital is mobile between sectors, or countries, a large proportion of the incidence of the CIT will fall on the immobile factors, e.g., labor and land. Also, the mobility of capital does not rule out the possibility for capital owners to bear the incidence of this tax; however, this incidence is considerably reduced as it is distributed across a large number of capital owners worldwide.

The next section presents a survey of the empirical evidence on the incidence of the CIT. This literature centers on the short-term incidence of this tax, ignoring the long-term effects of capital reallocation on the price of goods, services and production factors. The majority of the studies published during the 1960's and 1970's tried to estimate the impact of the CIT on the rate of return to capital, while few of them focused on the effect of the CIT on consumers. The most recent literature developed during the 2007-2011 period, centers the attention on the impact of the CIT on workers. However, As we move through all these studies, it will be shown that the incidence of the CIT still remains unknown in the economics literature.

2.2 Empirical evidence on the incidence of the Corporate income tax

2.2.1 The debate between Krzyzaniak & Musgrave vs Cragg, Harberger, & Mieszkowski

After Harberger published his seminal paper in 1962, Krzyzaniak and Musgrave (1963) (henceforth referred to as K-M) published one of the most controversial studies attempting to empirically estimate the incidence of the corporation income tax by applying time series regressions.⁴ Using annual data from 1935 to 1959 for U.S.'s industries, they estimate that

⁴Before K-M, other studies addressed empirically the incidence of the CIT, including Lerner and Hendriksen (1956) and Clendenin (1956). Lerner and Hendriksen analyzed the effect of changes in the

an increase in the corporate tax rate has a positive and significant impact on the gross-of-tax rate of return on corporate capital.⁵ After running different econometric specifications, K-M find that the elasticity of the rate of return on corporate capital with respect to the corporate tax rate is significantly greater than one, therefore the corporation income tax is more than 100% shifted. This result implies that capital owners significantly benefited, in after-tax income terms, from an increase in the corporation income tax rate.⁶

The results from Krzyzaniak and Musgrave (1963) were immediately questioned based on their model inability to account for other factors that may explain the positive and significant correlation between the tax changes and the rate of return on corporate capital (Goode, 1966; Slitor, 1966). The strongest critics to K-M model were Cragg et al. (1967) (henceforth referred to as C-H-M), who demonstrated that the K-M's estimates were positively biased. According to C-H-M, the high positive correlation between the tax variables and the gross rate of return on capital is due to "other important forces" that influenced the economic environment—including World War II, the Korean War, and the mobilization years, causing profit rates to be considerably high when the government increased the tax rate (Cragg et al., 1967, p. 813). In addition, C-H-M argued that the non-tax explanatory variables introduced in the Krzyzaniak and Musgrave (1963) model are not able to account for cyclical factors that affected the high correlation between profit rates and the tax rates; therefore, they claimed that the relationship found in K-M was completely spurious.

To prove their arguments, Cragg et al. (1967) re-estimated K-M's model introducing

corporate tax rate on the rate of return on investment for all profitable corporations in the manufacturing sector for the years 1927 to 1952. Cledenin conducted a similar study for the years 1926 to 1952. These authors did not find evidence of short- or long-run shifting of the corporation income tax.

⁵K-M use data at the industry level as well as at the firm level. The industry data includes Manufacturing, Pulp and Paper, Rubber, Leather and Hide Products, Food and Kindred Products, and Stone, Clay, and Glass Products. The firm level data is divided into 26 steel companies, and 12 textile companies. They also excluded from the sample the years from 1943 to 1947 because they argued this period is characterized by "abnormal conditions," including price controls, high level of government expenditures, among other reasons (see Krzyzaniak and Musgrave, 1963, p. 68-69).

⁶The 95% confidence limit estimated in this study gives a degree of shifting between 111% to 157% (see Krzyzaniak and Musgrave, 1963, p. 46).

two additional regressors: (i) the employment rate E_t as a proxy for the business cycle, or demand fluctuations in the economy, and (ii) a dummy variable W_t to account for the high level of government intervention in the economy during the mobilization and war years.⁷ C-H-M admitted that the introduction of these new covariates cannot correct for all the sources of the biasness because the employment rate might be endogenous. Furthermore, they demonstrated that the inclusion of the pressure variable E_t will overstate the shifting coefficient model hence resulting in an upper bound for the degree of tax shifting; however, the bias in Krzyzaniak and Musgrave (1963) should be attenuated it. After introducing E_t , C-H-M found the coefficient on the tax variable to be considerably less than one (indicating less than 100% shifting of the CIT), and when they controlled for the war years, this coefficient was even negative and not statistically significant.⁸

In 1970, K-M wrote an article responding to all the criticisms from Cragg et al. (1967). Basically, the authors recognized that their tax shifting estimates might be biased, but they argued that it is still significant and thus there was no evidence suggesting that this bias is of considerable magnitude. K-M also agreed that the non-tax variables used in their model may fail to fully control for the current demand pressures and the business cycle. However, they pointed out that the employment variable used in C-H-M study is endogenous, therefore it is inappropriate for the estimation; also, despite the fact that the introduction of the year dummy variable significantly reduced the coefficient on the tax variables, this result only suggest that “the model does not permit us to choose between the hypotheses of zero and full shifting,” instead of rejecting the shifting hypothesis at all (Krzyzaniak and Musgrave, 1970, p. 770).

⁷C-H-M defined the employment rate as $E_t = (1 - \mu_t) \times 100$, where μ_t is the unemployment rate; and $W_t = 1$ if $t = [1941, 1942, 1950, 1952]$, or zero otherwise.

⁸The degree of tax shifting found in C-H-M depends on the definition of the tax variable employed in their specifications. When using the ratio of tax liability to capital stock L_t , they show that the tax shifting coefficient estimated in K-M study is reduced from 1.511 to 1.024, after the introduction of E_t . This coefficient is reduced further to 0.60 and becomes statistically insignificant when both E_t and W_t are added as regressors. When the tax variable is defined as the ratio of tax liability to gross-of-tax profits—i.e., the average tax rate, the estimated degree of tax shifting is significantly reduced from 0.481 to -0.101, being also insignificant across most of the specifications (see Cragg et al., 1967, p. 817-18).

Finally, as indicated above, the Krzyzaniak and Musgrave (1963) model was severely criticized in many econometric aspects, including errors in variable measure bias, omitted variable bias, multicollinearity, misspecification, and lack of theoretical framework. However, this model was the center of discussion in corporate tax shifting for more than a decade and, therefore, the subsequent empirical literature was based on replications and improvements to K-M's work, applied to both U.S. and international data. Overall, the next generation of models tried to control for demand pressure and increasing productivity variables, employed multi-equation and panel data regressions, or used disaggregated data at the firm level to estimate the shifting of the CIT. However, as discussed in the next section, economists still have not find agreement on the question of who bears the final incidence of the corporation income tax.⁹

2.2.2 Other empirical studies: the literature of the late 1960's and 1970's

After the work of Krzyzaniak and Musgrave (1963), many authors proposed new approaches to empirically estimate the incidence of the corporation income tax. Gordon (1967) indicated that the K-M model was not derived from a theoretical framework and it also failed to control for increases in demand pressures. Therefore, he proposed a theoretical model where a representative manufacturing firm follows a mark-up pricing behavior to maximize profits and introduces capacity utilization measures. The model is estimated with industry level data for the years from 1924 to 1962 by non-linear regression methods, and he finds no evidence of short-term shifting of the corporation income tax.¹⁰

⁹For the case of India, Laumas (1966) estimated the K-M model and found a degree of CIT shifting of 107%. However, Rao and Rao (1971) used a modified version of K-M, with lagged values of the tax variables, estimated by OLS and they did not find evidence of shifting of the CIT for Indian corporations. Roskamp (1965) estimated a version of K-M model similar to Rao and Rao (1971) for the case of West Germany, during the period from 1949 to 1962, and found a degree of shifting ranging between 108% to 140%. For United Kingdom, Davis (1972) estimated the K-M model, for the years 1949 to 1964, and concluded that there is no shifting of the CIT. Spencer (1969) added a pressure variable to the K-M model—the ratio of actual to potential GDP, and he found a degree of tax shifting between 100% to 124% in Canadian's manufacturing corporations, for the period 1935-39 and 1948-64. For more details and discussions on these models refer to Sahni and Mathew (1976, p. 65-77).

¹⁰Krzyzaniak and Musgrave (1968) indicates that Gordon's failure to integrate the tax variable into one of the behavioral equations—e.g., price or wage, invalidates his model to explain the shifting of the

Oakland (1972) also used annual data on U.S. manufacturing industries for the years 1930-1968 to analyze the effects of corporate income taxes on the rate of return to capital. The novelty of this paper is that it defines the rate of return on capital as a function of technological progress, capital intensity, and the short-run fluctuations in output. He uses the labor to capital ratio as a measure of capital intensity, the ratio of actual to potential output (or capacity utilization) to control for the effects of demand fluctuations on the profit rate, and assumes a constant rate of technological progress.¹¹ Oakland did not find evidence of short-run shifting of the CIT; the introduction of the tax rate does not increase the explanatory power of the model, so he concludes that Krzyzaniak and Musgrave (1963) mistakenly attribute to the tax variable the effects of technological progress and business cycle fluctuations on the rate of return on corporate capital.

Dusansky (1972) argues that manufacturing firms are heterogeneous and operate in different markets under a variety of demand conditions, hence the construction of models based on the maximization of an objective function for a representative firm, such as Gordon (1967) and Oakland (1972), is misleading. Further, the approach results in a “naïve specification” to empirically estimate the shifting of the corporate income tax (Dusansky, 1972, p. 359). Therefore, he suggests a multi-equation and multi-goal model where firms attempt to achieve, simultaneously, three major goals: (i) a profit goal (ii) an inventory goal, and (iii) a sales effectiveness goal. Dusansky specifies a set of structural equations to represent this behavior.¹² Dusansky’s study covers the period from 1925 to 1962, and the model is estimated by two-stage least squares for U.S. manufacturing
CIT.

¹¹Specifically, the rate of technological progress is assumed to be an exponential function of time, i.e., $A = e^t$, where t is the calendar time minus 1929. Alternatively, he uses the output to capital ratio, $A = (Y/K)$, a measure of capital productivity, to allow for technological changes in production (see Oakland, 1972, p. 240-41).

¹²This model contains a total of sixteen equations, from which eight are intent to capture the firm behavior, including equations for the rate of return on capital, tax liability, manufacturing inventory, sales, wages, output productivity, labor supply and the price level. There are six equations representing macroeconomic variables, including output, consumption, gross investment, other investments, imports and the interest rate. The remaining are identities.

industries.¹³ He concludes that when cyclical variables are considered and modeled as endogenous, as opposed to how they were handled in previous studies (Cragg et al., 1967; Gordon, 1967), the results still support the conclusion of about 100% short-term shifting of the corporate income tax.

To this point, the empirical literature on the incidence of the corporate tax centered on estimating profit equations (either in reduced- or structural-form), disregarding other possibilities of tax shifting, e.g., forward shifting or backward shifting. In 1979, Sebold proposed a simultaneous equation model to address this gap. His model is estimated by two-stage least square method with annual data from the corporate manufacturing sector, on an establishment basis, for the periods 1931-41 and 1946-70.¹⁴ He omitted the years from 1942 to 1945 due to the high degree of the U.S. government intervention during the Second World War, and he also truncated the sample to 1970 based on the imposition of wage and price controls in the economy in 1971. Sebold finds that 154% of the tax is forward shifted as higher consumer prices, whereas 80% is backward shifted as a reduction in both labor (33%) and input prices (47%); therefore, he concludes that 69% of the burden of this tax is shifted.¹⁵

2.2.3 Recent evidence: the late 1990's and 2000's

In the 1980s, the empirical literature on this subject was virtually abandoned. The research on the incidence of the corporation tax was focused on general equilibrium models, in which the Harberger (1962) model is modified to introduce new assumptions, including multiple sectors, substitutability among goods produced, imperfect mobility of factors,

¹³In the first stage, Dusansky estimate all endogenous variables in the rate of return equation as a linear function of the exogenous covariates in the system, which are also considered as instruments. Then, in the second stage, the rate of return equation is estimated (see Dusansky, 1972, p. 366).

¹⁴Sebold (1979) presents a system of eight equations, including profits, producer price, demand function, wage, employment, input price, depreciation, and retention rate equation—which is defined as one minus the effective tax rate. He introduces this retention rate into the manufacturing price, wage, input price, and depreciation equations to test the hypotheses of forward and backward shifting of the CIT.

¹⁵There is a remaining negative portion of the tax effect that he identifies as “depreciation effect” (5%), which cannot be considered part of the forward or backward shifting measures (Sebold, 1979, p. 407-8).

unemployment, life time income, and firm's financial decisions (Slemrod, 1983; Miyagiwa, 1988; Fullerton and Rogers, 1993; Gravelle and Kotlikoff, 1989, 1993).¹⁶

In 1998, Dye empirically analyzes the incidence of the corporate income tax on investors, workers, and consumers using financial statement data from Standard & Poor's 1996 Compustat Annual Data tapes for U.S. firms in the manufacturing sector. She uses three time series specifications, estimated by simple OLS regressions, to determine if corporate taxes have a significant impact on the returns to corporate equity, profit margins, and labor compensation, for the years 1977 to 1996. She finds that the coefficient on the tax variable is significant and has the desirable sign in both the profit margin and the return on equity specifications, therefore concluding that the corporate tax is borne by consumers and investors. Also, since she finds that the estimated coefficient of the tax variable in the labor compensation specification is not statistically significant, she concludes that "the burden of the tax is borne by at least two players, shareholders and consumers" (Dye, 1998, p. vii). However, Dye does not make any effort to correct for the potential bias induced by economic fluctuations and/or the relationship between corporate profits and the amount of tax paid.

As the evidence on the effect of corporate taxes on the rate of return on capital appeared to be contradictory, more recent studies are using international data to focus on the effect of corporate income taxes on wages.¹⁷ For instance, Hassett and Mathur (2006) employ a panel data with seventy-two countries for the years 1981-2003 to estimate a fixed-effect model that controls for time covariates as well as macroeconomic and institutional variables, including trade, inflation, and the strength of labor unions. They find that

¹⁶I do not cover general equilibrium studies in this review. However, the Congressional Budget Office (CBO) published a comprehensive survey regarding this literature. The CBO's survey concludes that the short-term incidence of the corporate income tax might be born by capital owners—stockholders and investors, whereas the long term incidence is partly shifted to immobile factors, e.g., labor and land (Rogers, 1996, p. 27). However, Gentry (2007) also reviewed the evidence provided by general equilibrium models and concluded that the wide spectrum of answers in this framework only suggest that the burden of the CIT remains as an empirical question.

¹⁷For a survey in this literature see Gentry (2007, p. 4-15).

one percentage increase in the corporate tax rate decreases average wages by 0.95%.¹⁸ Moreover, the response on wages to changes is significantly larger in small countries than large ones, thus they conclude that corporate taxes might be negatively affecting wages through a decrease in the amount of capital investment per-worker.

Felix (2007) focuses on how the degree of economic openness might affect the incidence of the corporate tax on wages. She uses panel data that covers thirty countries, for the period 1979-2002, from the Luxembourg Income Study (LIS). This dataset contains individual and household information on income, expenditures, demographics, labor market outcomes and taxes. She specifies a log-linear random-effect regression that allows for individual characteristics to analyze the impact of the average corporate tax rate as well as the interaction between average taxes and economic openness on annual gross wages. Her evidence supports that a 10% increase in corporate taxes reduces average annual gross wages about seven percent.

Arulampalam et al. (2008) modify the efficient bargaining model of McDonald and Solow (1981) and introduce a corporate income tax to analyze the process in which firm managers and union workers bargain over both wages and employment. The idea is that the corporate tax reduces the share of profits that are available for bargaining, therefore any attempt of managers to keep a certain rate of return would result in shifting some of the tax to workers. To assess the effect of the corporate tax, they specify a log-linear dynamic equation in which the wage rate depends on the value added and the tax liability per worker, company specific fixed- and time-effects, and a vector of variables associated with wage bargaining, including alternative wages and workers union density. For the estimation, they employ the Arellano and Bond (1991) and Blundell and Bond (1998) GMM-methods, to control for company-specific unobserved heterogeneity, in a sample of more than 55,000 companies located in the European Union for the years 1996 to 2003.¹⁹

¹⁸Hassett and Mathur (2006) estimates for the degree of shifting range between -84% to -119% across different specifications.

¹⁹Arulampalam et al. (2008) employ the Arellano and Bond (1991) method using the lagged levels of

Their estimates shows that one dollar increase in the CIT reduces the wage rate by 0.96 cents and 0.92 cents in the short- and long-term, respectively.

Although these studies use different international databases and empirical methods, it is noticeable that they all find a strong and significant impact of corporate income taxes on wages. This contrast with the previous studies developed during the 1960's and 1970's, which were not able to arise to a consensus. However, there are a few important points that are worth mentioning. First, these studies seem to measure short-term effects of the corporate income tax on wages. Thus, the fact that these studies suggest almost 100% shifting in the short-term is not in line with the prediction of theoretical models, such as in Harberger (1962, 1995), which suggest that the short term incidence of the tax might fall on capital owners, while the impact of the corporate tax on wages come after the capital stock has been adjusted in the economy.

The time period of these studies seems to be too short to capture long-term effects of tax policy—seven years of data in Arulampalam et al. (2008), thus it is difficult to expect many permanent changes in policy during this time span. Also, there is not a significant effort in these studies to address the problem of endogeneity between wages and corporate taxes (besides Arulampalam et al. (2008), who employ the GMM estimator), therefore the econometric techniques proposed are incurring in the same failures as the studies developed after 1960's.²⁰

More recently, Nadja Dwenger and Steiner (2011) have argued that the literature has omitted essential employment factors when assesing the true tax burden of the corporate income tax on labor. That is, previous studies only consider the bargaining results and its effect on the wage rate but neglected the ensuing employment effect. For instance, if

the variables as instruments for the endogenous differences in the first-difference model. However, they argued that they prefer the Blundell and Bond (1998) estimator because the levels of the instruments are weak predictors of the differenced endogenous variables when the time series are highly persistent. The advantage of the later estimator, according to the authors, is that it combines the moment conditions for the model in first differences with the moment conditions for the model in levels.

²⁰For more discussion on these studies refer to Gentry (2007, p. 13-16).

employment changes can affect the total wage bill, this may offset the effect of corporate taxes on the wage rate, thus overstating the true burden on labor. They correct this problem by using a pseudo-panel data from Germany for the period 1998 to 2006 and estimating an IV-model to control for the endogeneity induced by firm-specific tax rate. Their incidence calculations indicate that an increase in \$1 euro of corporate tax collections would reduce the wage bill by 0.47 euro, thus labor bears approximately 53% of the incidence of the CIT. When they estimated the incidence of the CIT without considering employment changes, they find a 100% shifting of the CIT.

Table 2.1: Summary of Findings on the Incidence of the Corporate Income Tax

Incidence	No Shifting	Shifting < 100%	Shifting > 100%
On Capital	C-H-M (1967)		K-M (1963)
	Gordon (1967)		Laumas (1966) ^{a,*}
	Oakland (1972)		Raskamp (1965) ^{b,*}
	Rao & Rao (1971) ^{a,*}		Spenser (1969) ^{d,*}
	Davis (1972) ^{a,*}		
On Wages		Sebold (1979)	Hasset et. al (2006) ^e
		Deveraux (2008) ^e	
		Felix (2007) ^e	
		Dwenger & Steiner (2011) ^f	
On Prices			Sebold (1979)
			Dusanski (1972)

Note. K-M: Krzyaniak and Musgrave (1963); C-H-M: Cragg et al (1967).

^{*}Application or modification of the K-M model; ^aIndian corporations; ^bWest Germany; ^cUnited Kingdom; ^dCanada; ^eMulti-country panel data; ^fGermany panel data.

Table 2.2: Empirical Literature on the Incidence of the Corporate Income Tax

Author	Methodology	Data	Incidence	Result
Krzyaniak & Musgrave (1963)	Time series	(a) Industry level, annual from 1935-1959 ^a	$ROE_t = \frac{\pi}{e}$	Shifting $\geq 100\%$
	IV estimation	(b) Firm level, 1936-1959.	$RCK_t = \frac{\pi}{K}$	
Cragg, Harberger & Mieszkowski (1967)	K-M (1963) plus cyclical variables	K-M (1963)	K-M (1963)	No shifting
Sebold (1979)	Reduce form model, 2SLE	Annual data 1931-41 & 1946-70, Manufacturing sector ^b	Profit, prices, and wages	Consumers (154%) and labor (80%)
Gordon (1967)	Non-linear regressions	SOI data for 1924-1962 for 2-digits code manufacturing industries	$RCK_t = \frac{CF}{K}$	No shifting
Oakland (1972)	Time series regression	U.S. Manufacturing, annual for 1930-1968	$RCK_t = \frac{\pi}{K}$	No shifting
Dusanski (1972)	2ELS estimations	Oakland (1972), 1925-1962	$RCK_t = \frac{\pi+i}{K}$	Shifting $\geq 100\%$
Hassett & Mathur (2006)	Panel data, fixed effects	Annual for 72 countries; period 1981-2003	Wages (w)	1% increase in CIT $\downarrow w$ by 0.8% to 1.19%
Felix (2007)	Panel data, fixed effects	Annual for 30 countries; period 1979-2002.	Wages (w)	10% increase in CIT $\downarrow w$ by 7%
Arulampalam et al. (2008)	Panel data, GMM Arellano & Bond	Firm level data, annual for 55,082 European companies	Wages (w)	Shifting from 96% to 92%
Dwenger & Steiner (2011)	Panel data, IV method	Firm level, annual for 1998-2006	Wages (w)	Shifting = 53%

Note. ETR : Effective tax rate; TL : tax liability; π : profits before tax; K : capital stock; e : equity; CF : cash-flow (profits plus depreciation amortization, and interest payments) RCK : return on capital; ROA : return on assets; ROE : return on equity.

^aThe 1943-1947 period is excluded based on price controls & other government interventions. ^bYears for World War II are omitted.

CHAPTER III

Modeling and Estimation Approach

3.1 Modeling approach

This section models the effect of the corporate income tax for a large and open multi-sector economy. The approach extends Harberger (1995, 2008a)'s four sector economy and also follows very closely the General Equilibrium models of Gravelle and Smetters (2006) and Randolph (2006).

There is a large open economy (e.g., United States) which freely trades with the rest of the world (ROW). The economy is divided into eight sectors, each producing goods and services using labor, capital, and land (in Agriculture). The supply of these factors is fixed in the economy. The production functions have constant return to scale and are well behaved (i.e., concave, twice differentiable, etc.). There is free mobility of factor of productions, but only capital is mobile worldwide. There are eight sectors in the economy producing goods and services of which only two are non-corporate (Agriculture and Services), six are corporate, and four are tradable: two with perfect demand substitutes and two with imperfect substitutes.

The Mining sector (Corporate) produces tradable and homogeneous goods—e.g., gold, iron, zinc, etc.—for which its price is determined at international markets. To simplify the analysis, it is standard in the literature to consider the production from a sector with

these characteristics as the numeraire. Therefore, the price formation equation for Mining is given by:

$$dp_{MG} = 0 = \theta_{L,MG}dw + \theta_{K,MG}(dr + t_{CK}) \quad (3.1)$$

where, dp_{MG} , dw , dr are the total changes in the price for mining products, in the wage rate, and in the return to corporate capital, respectively; t_{CK} is the tax on corporate capital and the term in parenthesis ($dr + t_{CK}$) represents the cost of corporate capital, or C_k ; the parameters $\theta_{L,MG}$ and $\theta_{K,MG}$ measure the income, or cost, shares of labor and capital for the mining sector, respectively, the price for mining products is fixed, $dp_{MG} = 0$, because it is determined worldwide.

The assumptions of perfect competition and free mobility of factors imply that the wage rate needs to decline economy-wide to offset the higher cost of capital:

$$dw = -\frac{\theta_{K,MG}}{\theta_{L,MG}}(dr + t_{CK}) \quad (3.2)$$

Equation 3.2 says that the drop in wages depends on the degree of capital intensity of the Mining sector. That is, the larger the income share of capital in Mining $\theta_{K,MG}$, higher will be the drop in wages necessary to absorb the tax wedge created by t_{CK} . Table 3.1 shows estimates for the capital income shares across different industries. My estimates of the capital income shares for U.S. industries (column 3) are very similar to those reported in Acemoglu and Guerrieri (2008) (column 2), which suggests that the capital income shares are very stable across different time periods and industry classifications. Since the share of capital income in Mining ($\theta_{K,MG} = 68\%$) is significantly higher than the share of labor income, the decline on the wage rate is expected to be large.

The Manufacturing and Finance sectors both produce non-homogeneous tradable goods and services, respectively. (Perhaps given the technological advances in the U.S. economy compared to the ROW). Therefore, the price formation equation of these sectors

Table 3.1: Industry Capital Shares Estimates

Industry	Acemoglu (2008) ^a	Vasquez (2011) ^b
1. Agriculture ³	—	74%
2. Mining	66%	68%
3. Transportation & Utilities	—	51%
Transport. & Warehousing	35%	—
Utilities	77%	—
4. Construction	32%	31%
5. Manufacturing	—	36%
Durable goods	27%	—
Nondurable goods	47%	—
6. Wholesale & Retail Trade	—	44%
Wholesale Trade	46%	—
Retail Trade	42%	—
7. Finance, Insurance, & Real Estate	—	75%
Finance & Insurance	45%	42%
8. Services ⁴	33%	34%
9. All sectors	—	43%
Private sectors	—	47%

Note. Industry classification is based on SIC system.

^aAverages for 1987-2005. Adapted from Acemoglu & Guerrieri (2008), Table 1, pg. 486.

Estimates based on the NAICS system. ^bAverages for 1945-2007. Estimates based on the SIC.

^cThe large magnitude in Agriculture is explained by the land income share, which is part of the capital income share (see Valentinyi and Herrendorf, 2008).

^dIn Acemoglu & Guerrieri (2008) refers to “other services except government.” In Vasquez-Ruiz (2011) refers to Services as classified in the SIC.

will be:

$$dp_i = \theta_{L,i}dw + \theta_{K,i}(dr + t_{CK}) \quad (3.3)$$

for $i = \text{Manufacturing, Finance}$. In both sectors, the labor cost and capital cost will change by the same magnitude as the changes produced in the numeraire sector, e.g., Mining. That is, wages will decline with the tax, while the cost of corporate capital will rise. Thus, p_i will increase (or decrease) if the income share of capital in sector i is significantly larger (smaller) than the share of income for labor, compared to the numeraire.

The rest of the corporate sectors are Wholesale & Retail Trade, Construction, and

Utilities & Transportation. They all produce non-tradable goods and services and, therefore, their prices will react according to equation 3.3. As in Harberger (1995, 2008a), I will expect that the price for the Utilities & Transportation sector will rise due to its large capital income share.

The two non-corporate sectors are Agriculture and Services. The former is assumed to produce tradable and homogeneous goods, while the later only operates in the local market. Following Harberger (1995, 2008a), Agriculture produces using capital, labor, and land, therefore:

$$dp_{AG} = 0 = \theta_{L,AG}dw + \theta_{K,AG}dr + \theta_{Land}dl \quad (3.4)$$

where $\theta_{Land,AG}$ and l are the share of income to land and the land rent, respectively.¹ Equation 3.4 implies that land rent will change according to:

$$l = -\left(\frac{\theta_{L,AG}}{\theta_{Land}}dw + \frac{\theta_{K,AG}}{\theta_{Land}}dr\right) \quad (3.5)$$

As capital flows from the corporate to the non-corporate sector, its rate of return (r) declines. The wage rate also drops in Agriculture, according to equation 3.2 above. Therefore, the corporate income tax causes an increase in the land rent prices, thus benefiting landowners. Based on the same arguments, prices for the Services sector (non-corporate and non-tradable) will decline:

$$dp_S = \theta_{L,S}dw + \theta_{K,S}dr \quad (3.6)$$

¹Valentinyi and Herrendorf (2008) estimated the capital income share for Agriculture in 54%, of which 18% corresponds to land income share. They also present estimates for capital income shares in other sectors, including Manufacturing (33%) and Services (34%); see table 1, pg 826.

3.2 Estimation procedure

The disagreements in the extensive literature on this subject about who bears the burden of the CIT show that measuring the incidence of this tax is a challenging task. One of the reasons that could explain such significant differences in both results and opinions is that the econometric models used in this literature might not be adequately analyzing the effects of policy changes; for example, a change in the corporate income tax might be biased because the estimated parameters from these time series regressions are not invariant to the structural changes in the economy caused by policy making (Lucas, 1976, p. 20). That is, the parameter that supposedly determines the degree of corporate tax shifting might not only reflect the effect of a change in the corporate tax but also the adaptation (or reaction) of corporations to the environment that could be motivating such policy change. Therefore, the conclusions derived from previous empirical models might be misleading.

In general, the factors that motivate CIT changes are often correlated with other developments in the economy, such as a decline in economic activity, and therefore separating these effects from exogenous policy changes can be very difficult. Moreover, the estimates of the incidence of the CIT based on time series regression models might reflect shocks to the private sector that are not the result of policy decisions. For instance, during the period considered, a shock might cause corporations to optimally change financing decisions to reduce tax liabilities—e.g., a switch from equity to debt financing, or corporations might simply decide to change pricing and hiring strategies in response to the economic situation.

Thus far, the econometric models and techniques used to estimate the incidence of the CIT have failed to separate those effects. For instance, the early time series studies of Krzyzaniak and Musgrave (1963), Gordon (1967), and Oakland (1972), among others, do not make any distinction between the corporate tax changes that results from exogenous

policy decisions and the tax changes that arise from endogenous economic events. More obviously, the results from these models seem to be very susceptible to the control variables included, as well as the sample period chosen. In addition, these studies claim to estimate the short-term incidence of the corporation tax based on the implausible assumption that the capital stock is immobile across sectors during the period under consideration—which in some cases is more than twenty years. The more recent empirical evidence, based on panel data estimations, also considers all changes in the tax variable as policy changes. Further, few authors attempt to offer short- and long-run estimates of the incidence of the CIT. However, this distinction is not always clear since the time period analyzed is no more than five or seven years (see Arulampalam et al., 2008).

To isolate the effects of policy changes from events occurring within the economy, a number of authors are using a new technique based on the identification of exogenous events that alter fiscal policy through the examination of narrative records. For instance, Ramey and Shapiro (1998) use narrative records from historical accounts and *Business Week* and identify exogenous events leading to military build-ups to analyze the effects of government purchases in the economy—i.e., GDP, interest rates, hours worked, and consumption of durables and nondurable goods. Also, based on Ramey and Shapiro (1998) exogenous events, Edelberg et al. (1999) and Burnside et al. (2004) determine the effects of government purchases on employment, real wages, and residential investment.²

More recently, Romer and Romer (2009, 2010) use narrative records from presidential speeches and congressional reports to identify tax policy changes that are not systematically correlated with developments within the economy during the postwar era. These authors provide a comprehensive analysis of more than 50 federal tax legislations in the United States for the period 1945-2007 and determine the effect of tax policy changes on U.S.'s economic activity—i.e., GDP, consumption, investment, and imports. The Romer

²The events referred to in Ramey and Shapiro (1998) are the Korean War (1950Q3), Vietnam War (1965Q1), and Carter-Reagan buildup (1980Q1).

and Romer (2009) exogenous events have been applied by a number of authors investigating the effect of fiscal policy on the U.S. economy. For instance, Merterns and Ravn (2011) develops a new narrative measure of exogenous tax changes using the changes in personal and corporate income tax identified in Romer and Romer (2009) plus controlling for measurement errors and present new estimates on the effect of tax policy on the economy. Also, Barro and Redlick (2011) use the narrative records from both Ramey (2009) and Romer and Romer (2009) to estimate government spending and tax multipliers.

I propose a similar approach to determine who bears the short- and long-term incidence of the corporate income tax. Specifically, using exogenous events in corporate tax policy, this paper analyzes the effects of corporate tax changes on the rate of return to capital, consumers' good prices, and wages. The identification of exogenous corporate tax changes is based on the work of Romer and Romer (2009), among other reports and documents. The estimation strategy employs a Vector Autoregression (VAR) model, as popularized by Sims (1980). This model provides a description of the dynamic interrelations between multiple time series included in a vector.

There are several advantages from the VAR model approach. First, the VAR model does not require introducing restrictions, besides lag-length restrictions, imposed by the theory about the relationships that we are describing, treating all variables as endogenous. For this reason, VAR models are sometimes referred to as atheoretical models. Since there is still no consensus about who bears the burden of the corporate income tax, this offers a significant advantage because this estimation method basically allows the data to “speak freely” (Hoover et al., 2008, p. 254). More importantly, this characteristic does not rule out the possibility that we can formulate and test “hypotheses with economic content” (Sims, 1980, p. 16). Further, the estimation of *impulse-response functions*, an important component of Vector Autoregressions, will allow to assess in a simple graph the short- and long-term effects of corporate tax changes on the variables of interest. Finally, given certain conditions, VAR models can be easily estimated through OLS regressions.

The estimated VAR model is represented as:

$$\mathbf{X}_t = A(L)\mathbf{X}_{t-1} + B(L)\mathbf{D}_t + \epsilon_t \quad (3.7)$$

where $A(L)$ and $B(L)$ are finite vector ordered polynomials in nonnegative powers of the lag operator, L . \mathbf{X}_t is a vector of endogenous regressors, \mathbf{D}_t is a vector representing the exogenous changes in the corporate income tax, or Romer & Romer shocks, and ϵ_t is a vector of error terms, or shocks. Particularly, $\epsilon_t \sim \text{i.i.d. } N(\mathbf{0}, \mathbf{\Omega})$. The vector \mathbf{X}_t includes variables that measure the rate of return on corporate capital RCK_t , the average tax rate ATR_t , wages W_t , and the price of goods and services P_t . Due to the limited sample size (at most 63 observations for each industry), I sometimes substitute ATR_t for other regressors, such as the real gross domestic product GDP_r_t , or the output gap as it is standard in the literature.³

The vector \mathbf{D}_t is of particular interest because it contains the exogenous corporate tax policy changes. As mentioned in section 4.2, the exogenous policy changes are measured using an indicator variable that identifies the dates in which these shocks occurred. That is, $\mathbf{D}_t = 1$ if an exogenous policy change (either a tax increase or decrease) in the CIT occurred in year t , and 0 otherwise. Therefore, the response of the endogenous variables in \mathbf{X} to a exogenous change in corporate tax policy will be given by the polynomial expansion of $[\mathbf{I} - \mathbf{A}(L)]^{-1}\mathbf{B}(L)$.⁴

Alternatively, for a particular equation in (3.7), it is possible to obtain the impulse-response function to show the effect of a shock in the j th variable at time t on the value of the i th variable at time $t + s$, once the effects of all other variables in the model are controlled for—e.g., consider the effect of a shock in the average tax rate, ATR_t , on the

³The output gap is calculated as the difference between GDP_r and its time trend, with the trend calculated using a Hodrick-Prescott filter.

⁴This approach also allows to test for asymmetries in tax policy changes: (i) corporate tax rate increases and (ii) corporate tax rate decreases. Refer to section 4.2 to see the years for which D_t represents exogenous increases or decreases in the CIT.

rate of return to corporate capital, RCK_{t+s} . For this purpose, we write the VAR model in equation (3.7) as a linear function of past innovations:⁵

$$\mathbf{X}_t = \mu + \epsilon_t + \Psi_1 \epsilon_{t-1} + \Psi_2 \epsilon_{t-2} + \dots \quad (3.8)$$

where each matrix Ψ_s measures the effect of ϵ_t on the future observation \mathbf{X}_{t+s} . That is,

$$\frac{\partial \mathbf{X}_{t+s}}{\partial \epsilon_t'} = \Psi_s; \quad (3.9)$$

Thus, the (i, j) element of Ψ_s measures the impact of a one-unit change in the innovation of the j variable at t (ϵ_{jt}) on the i th variable at time $t + s$ ($\mathbf{x}_{i,t+s}$), holding all the other innovations at all dates constant.

⁵Equation (3.8) is known in the literature as the moving average (MA) representation of a VAR model.

CHAPTER IV

The Data

There are two major components that comprise this data set: prices and tax policy changes. For prices, I calculate and obtain information on the rate of return on corporate capital, the wage rate, and the prices of goods and services across eight major U.S. industries. The tax policy variable is based on the exogenous fiscal shocks in the corporate income tax recorded in Romer and Romer (2009, 2010), in the Statistic of Income (SOI) annual reports, among other documentations. Other control variables are also included and they are described below. The sample period for this study runs from 1945 to 2007, and the frequency is annual.

The industry classification is based on the Standard Industrial Classification (SIC) system for the years from 1945 to 1997, and the North American Industry Classification System (NAICS) from 1998 onwards. The information is compiled for eight major industries: (i) Agriculture, forestry, and fishery (henceforth referred to as Agriculture); (ii) Mining and quarrying (Mining); (iii) Construction; (iv) Manufacturing; (v) Public Utilities and Transportation (Utilities); (vi) Wholesale & Retail (Trade); (vii) Finance, insurance, real estate and lessors of real property (Finance); and (viii) Services. In order to make both classification systems comparables, I had to “bridge” the series from the NAICS to the SIC system using weights calculated from the U.S. Census Bureau.¹

¹The methodology to construct the bridge between NAICS and SIC is fully explained in the U.S.

4.1 Bridge from NAICS to SIC

In 1997, the change from the SIC system to the new industrial classification system based on the NAICS considerably affected the comparability of the time series with those of prior years. Table 4.1 shows the major changes to the industrial classification as well as some of the adjustment employed to harmonize (or bridge) the NAICS series with the SIC series. With the introduction of the NAICS, the number of major industries, or 2-digit code industries, significantly expanded from eight sectors (column 1) to nineteen sectors (column 2). Therefore, it was necessary to bridge the new NAICS system to the prior 1997 SIC system in order to obtain a data set from 1945 to 2007 based only in one system: the SIC classification system (column 3). Also, whenever it was impossible to retrieve a NAICS subsector and add it back to the corresponding SIC sector, I calculated industry weights to make the proper adjustments. These weights were constructed using the ratio of the value of receipts for a particular subcategory to the total value of receipts of the 2-digit industry classification reported in the 1997 Census.²

Table 4.1 explains the bridge process. While some major industries were not virtually affected with the switch from SIC to NAICS—e.g., Agriculture and Mining, particular care should be taken comparing industries such as Manufacturing, Transportation & Utilities, and Services, among others, which are sectors with similar titles in both NAICS and SIC, but composed of different sub-sectors. For instance, table 4.1 shows that the Agriculture sector was unaffected after the introduction of the NAICS system. The Mining sector, titled “Mineral Industries” in the SIC, only required a minor change with the NAICS system, because it now excludes part of industries classified under the Professional, Scientific and Technology Services sector: geophysical surveying and mapping services for metal mining, oil and gas extractions, and non metallic mineral mining. These three

Census Bureau’s website (see Census, 1997) as well as in section 5 of the 1998 Statistic of Income annual report (IRS, 1998).

²The total value of receipts includes “the total sales, shipments, receipts, revenue, or business done by establishments within the scope of the economic census,” Census (1997).

Table 4.1: Bridge Between NAICS and SIC: 1945 - 2007

1987 SIC (8 Industries: prior 1997)	1997 NAICS (19 Industries: 1997-onwards)	Bridge: NAIC to SIC (8 Industries: 1997-onwards)
1. Agriculture	1. Agriculture	1. Agriculture
2. Mineral Industries	2. Mining	2. Mining Mining from NAICS +0.1% of Prof. Scientific & Tech
3. Manufacturing	3. Manufacturing	3. Manufacturing Manufacturing from NAICS +Publishing Industries (Inform.) +0.3% of Other Services
4. Transp., Communic., and Utilities	4. Transp. & Warehousing	4. Transp., Communic., and Utilities
...	5. Utilities	Transp. & Warehousing (NAICS)
⋮	6. Adm. & Support	+ Utilities
8. Service Industries	7. Information	+ Waste Manag. (Adm. & Support)
	...	+ Telecommunications (Inform.)
	⋮	+ ...
	19. Other Services	⋮
		8. Service Industries

subcategories, unreported in the Statistic of Income (SOI) report's tables, represent 0.1% of the total receipts in Professional, Scientific and Technology Services.

To build the Manufacturing sector series based on the SIC system, I took the new Manufacturing series from the NAICS system and added the "Publishing Industries" subcategory, which under the NAICS is part of the new 2-level digit code "Information" industry. I also added 0.3% of the total value of receipts from the "Other Services" industry to account for data from auxiliary establishments not included with the new manufacturing data. These adjustments were performed until the bridge between NAICS and SIC was completed for all sectors.

4.2 Tax policy variable: Romer & Romer shocks

Romer and Romer (2009, 2010) analyze more than fifty tax reforms, from 1945 to 2007, and classified all tax policy changes for the post war era in four major categories attending their motivation: (i) spending-driven, (ii) countercyclical, (iii) deficit-driven, and (iv) long-run growth. The spending-driven fiscal policies are motivated by changes in government spending (e.g., raise taxes to finance a war), while countercyclical tax policy changes intend to return output to its normal trend (e.g., a tax cut to fight a recession). Both of these actions are considered “endogenous tax changes.” On the other hand, deficit driven actions are taken to tackle a current government deficit, while long-run tax policy changes are intended to promote economic growth as well as efficiency and fairness in the tax system. These later two policy actions are classified as “exogenous tax changes.”³

To illustrate the Romer and Romer (2009, 2010) procedure, let’s consider four policy changes, each corresponding to one of the motivations defined above:

- **Revenue Act of 1950.** The motivation for this policy was to raise taxes to cover for defense spending related to the Korean War. This tax policy took the form of increases of marginal tax rates on individuals and corporations. In the *Letter to Committee Chairmen on Taxation of Excess Profits*, President Truman stated:

“After the communist aggression in Korea last summer, the Congress recognized the need for greatly increasing the Government’s revenues to meet the grave dangers that confront our country” (p. 1).

Similar statements appeared repeatedly in the *Midyear Economic Report of the President* for 1950, the *Congressional Record* (1950), among a number of Senate reports and documents. For this reason, this policy is classified as “endogenous spending-driven.”

³For details and examples on this classification system refer to Romer and Romer (2009).

- **Public Law 89-800.** Enacted on September of 1966, this policy suspended the 7% investment tax credit and its motivation was to return output to its normal trend. When addressed the Congress for the introduction of this reform, President Johnson recommended:

“the Congress promptly make inoperative,..., those special incentives for plant and equipment investment and commercial construction that currently contribute to overheating the economy” (Special Message to the Congress on Fiscal Policy, 1966, p.1).

Among the reports that presented similar statements were 1967 and 1968 *Economic Report of the President*, the 1967 *Annual Report of the Secretary of the Treasury on the State of the Finances*, and a number of Congressional reports. Thus, this policy change is classified as “endogenous countercyclical.”

- **Revenue Act of 1971.** The 1972 *Economic Report of the President* suggested that policy makers were concerned about promoting economic growth beyond its long-term trend: “The economy was rising...; but the rise was not as fast as was desirable, especially from the standpoint of reducing unemployment” (p. 65). For this reason, the President introduced the Revenue Act of 1971 to promote growth above normal:

“The fiscal package... was primarily motivated by the desired to stimulate at once a more rapid expansion of the economy” (p. 69).

When there is not a consistent and systematic review of the documents that policy makers use to introduce the reform, Romer and Romer (2009) recognizes that this methodology might lead to wrong conclusions when classifying fiscal policy. For instance, the House of Representatives indicated that “this bill is necessary because

the performance of the economy in recent months has been unsatisfactory,”⁴ which suggests that “Congress...might be acting to merely return growth to normal,” thus indicating that this policy could be classified as “endogenous countercyclical” (Romer and Romer, 2009, p. 55). However, the review of additional documents, such as The Ways and Means Committee reports, among others, indicates that this policy can be classified as “exogenous long-run growth.”

- **Fiscal Responsibility Act of 1982.** This reform proposed the reduction of tax benefits from the Investment Tax Credit. President Reagan clearly stated the motivation for this policy in his 1982 Address to the Nation on the Fiscal Year 1983 Federal Budget:

“The most essential thing is to send a message to the money market that we,..., can agree on reducing the deficit” (p. 3)

The U.S. Congress was more energetic than the president to recognize the need to reduce the fiscal deficit when it declared that the reason for this bill was “to raise revenue as part of an effort to narrow the *unacceptably* large budget deficits...” (emphasis are mine).⁵ For those reasons, this policy is classified as “exogenous deficit-driven.”

Based on Romer and Romer (2009, 2010) classification method, I identified twenty exogenous policy changes in the corporate income tax for the period from 1945 to 2007. Figure 4.1 plots the rate of return of corporate capital in the Manufacturing sector and the exogenous policy changes in the CIT. The first panel shows all changes in the corporation tax. These policy changes are separate into seven exogenous policies that increases the corporate income tax (second panel), and thirteen exogenous policies decreasing the CIT (bottom panel).

⁴92^d Congress, 1st Session, House of Representative Report No. 92-533, 9/29/71, p.3.

⁵97th Congress, 2^d Session, Senate Report No. 97-494, Vol. 1, 7/12/82, p. 96.

The exogenous changes in the CIT, in figure 4.1, are recoded into an indicator variable \mathbf{D}_t that identifies the dates in which these shocks occurred. That is, for the exogenous policy changes that increased the CIT in the 1945-2007 period, $\mathbf{D}_t^i = 1$ if $t = [1976, 1982, 1984, 1986, 1987, 1993, 2004]$, and 0 otherwise. For the exogenous decreases, then $\mathbf{D}_t^d = 1$ if $t = [1953, 1954, 1962, 1964, 1967, 1970, 1971, 1978, 1981, 1982, 1983, 1987, 2003]$, and 0 otherwise.

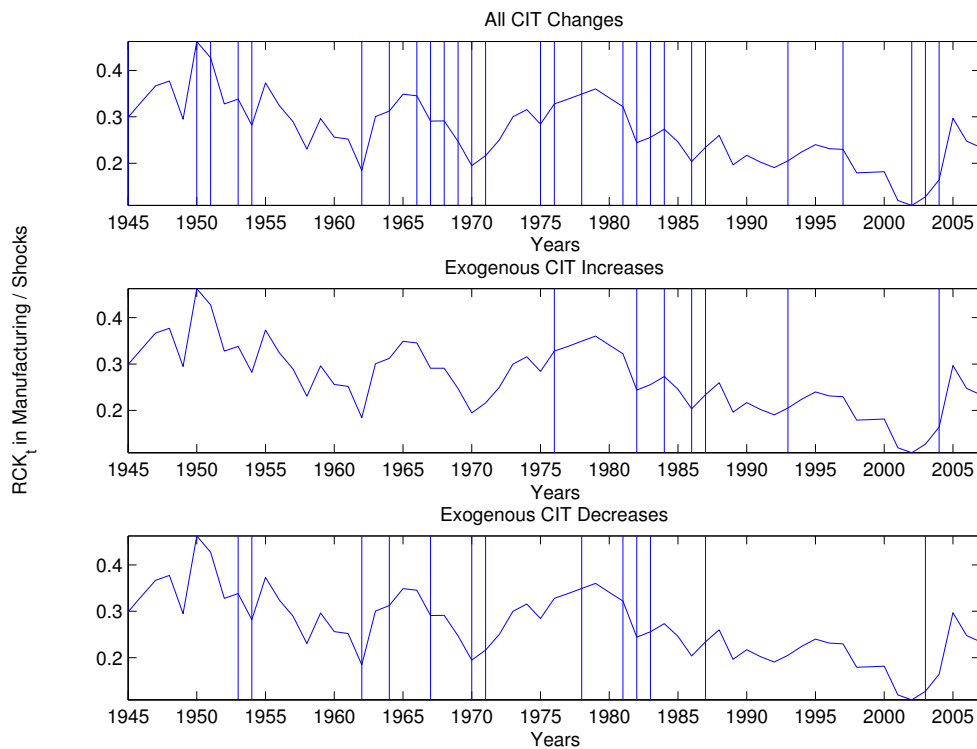


Figure 4.1: Return to corporate capital in Manufacturing and exogenous policy changes in the corporate income tax (CIT), 1945-2007.

Section ?? in the appendix shows all the information compiled about policy changes (endogenous and exogenous) in the corporate income tax, for the period from 1945 to 2007. The major references for this information were Romer and Romer (2009) and the Statistics of Income (SOI) annual reports published by the IRS. The first row describe

the policy information related to the *Revenue Act of 1945*. This policy (or act) was signed in November of 1945 and it consisted on a reduction in the Corporate Income Tax. The policy was classified as endogenous spending-driven because it intended to compensate the decline in government spending that followed the end of WWII by increasing aggregate demand. The fiscal year assigned to this policy was 1945. That is, $D_{t=1945}^d = 0$ for this particular year.⁶

A number of policy changes, such as the *Tax Reform Act of 1962*, were slightly more complex than the one described above because they consisted on both policies that increased and decreased the corporate income tax. This Act, for example, reduces the corporation's income tax payments through the modification of depreciation guidelines but, at the same time, introduces provisions that increased compliance. In this case, the tax policy variable takes the value of $D_{t=1962}^d = 1$ for exogenous tax decreases and $D_{t=1962}^i = 1$ for exogenous increases.

4.3 Return to corporate capital and tax rates

I use information from the Statistics of Income (SOI) annual reports, published by the U.S. Department of the Treasury's Internal Revenue Service (IRS), to estimate the rate of return of corporate capital and a measure for the tax rate. These reports contain information on the balance sheets and income statements at the industry level for the United States. The IRS uses a probability sample as the basis of the data tabulated from corporate returns. The industries are classified under the SIC system for the period from 1945 to 1997 and the NAICS system for the 1998-2007 period, therefore it was necessary to bridge the industry level series using the methodology explained in sub-section 4.1.⁷

The return on corporate capital for industry i at time t is calculated as the ratio of

⁶The fiscal year runs from June 1st to July 31st, of the following year.

⁷For tax year 2007—which includes the accounting periods ending July 2007 through June 2008, the SOI's statistical estimates are based on a stratified sample of approximately 106,000 unaudited reports selected from 5.9 million corporate returns filed (IRS, 2007).

corporate profits (π) to the corporation's capital stock (K):

$$RCK_{it} = \frac{\pi_{it}}{K_{it}}, \text{ for } i = 1, \dots, 8 \text{ and } t = 1945, \dots, 2007; \quad (4.1)$$

where profits are defined as the sum of net income—i.e., the difference between total income and total deductions reported—plus interest paid.⁸ The capital stock is composed of equity capital, which includes both common and preferred stocks, and the interest bearing debt (IBD)—the total amount of bonds, notes, and mortgages payable maturing in the short and long term. The measure of return on corporate capital in equation (4.1) is applied in a number of studies addressing the question of the incidence of the CIT (see Krzyzaniak and Musgrave, 1963; Cragg et al., 1967) as well as in studies from the finance literature that employ accounting-based measures of operating performance (see Barber and Lyon, 1996; Ghosh, 2001).

However, a number of authors use a slightly modified version of equation (4.1) to measure the effect of corporate tax changes on the return to corporate capital. For instance, Krzyzaniak and Musgrave (1963) subtract the IBD component from the denominator—which gives a measure of the return on equity capital, or ROE; Dusansky (1972) substitutes this denominator for total assets, obtaining a measure for the return on assets, or ROA. Gordon (1967) employs a similar version of equation (4.1) but introduces a cash-flow measure of profits, i.e., adding to the numerator other expenses such as depreciation, amortization, and depletion. To test for consistency, I employ the measure of RCK_{it} defined in (4.1) and compare the results with those using the ROA, ROE, and cash-flow measures defined above. I also constructed an additional measure for the return to capital using data from the Bureau of Economic Analysis (BEA) and I did not find any significant difference in the estimated impulse response functions.⁹

⁸Total income (or receipts) includes, but it is not limited to, gross sales, gross receipts from operations, interest received on government obligations, and so on. Total deductions consist of cost of goods sold, cost of operations, depreciation, amortization, among other components.

⁹From the BEA, I take the ratio of profits before taxes (NIPA Table 6-17) to private fixed assets

I also calculate and obtain two alternative measures of corporate tax rates: the average tax rate, ATR_{it} , and the nominal statutory tax rate, $NSTR_t$. The former is calculated as the ratio of total tax liabilities, or simply tax paid, to corporate profits for a particular industry i at time t .¹⁰ The latter refers to the federal tax rate legally imposed on corporations. Both ATR_{it} and $NSTR_t$ are based on information from the SOI reports.¹¹

4.4 Wages and prices

The measure of wages W_{it}^1 is taken from estimates of average weekly earnings of production and nonsupervisory employees, produced by the Bureau of Labor Statistics (BLS)'s Current Employment Survey (CES). This survey offers information on employment, payroll, and hours worked in a monthly basis. Thus, the annual estimates are obtained multiplying by 52 the 12-months monthly averages. Alternatively, I employ information on employees' total compensation and wages and salary accruals at the industry level published by the BEA, W_{it}^2 . Total compensation for employees consist of wages and salaries plus employers' contributions to social security, pension, and health insurance funds.

The data on prices for goods and services correspond to information on consumer P_{it}^c and producer P_{it}^p price indexes, also produced by the BLS. The data are published monthly for a set of industries (e.g., Mining, Manufacturing, Utilities, etc.) and commodities (e.g., oil and chemical products). Thus, to construct the series, I took 12-months seasonally adjusted averages as annual estimates.

A number of studies that analyze the incidence of the CIT on consumers and workers use the measures of prices and wages detailed above (Sebold, 1979; Hassett and Mathur, 2006). However, alternative measures can also be obtained from the corporation's balance

(NIPA Table 3.1ES) as a measure for the return to corporate capital on each major industry. This data also required to bridge the NAICS and SIC series.

¹⁰As a result of the Korean War, the U.S. Congress imposed an excess profits tax—i.e., a tax on profits over a certain level, effective from 1 July 1950 to 31 December 1953. The SOI reports separates the excess profits tax from the total tax paid category, but I combined both categories in order to obtain the total tax liability for the 1950-1953 period.

¹¹Table 2.2 shows a comprehensive list of measures applied in this literature.

sheets and income statements. For instance, Arulampalam et al. (2008) and Dye (1998) used the ratio between the cost of employees to the number of employees and the ratio of corporate profits to total sales as measures for the industry (or company) average wages and prices, respectively. These later measures are not considered here.

Table 4.2 illustrates the summary statistics for some of the series collected and constructed from the information in the SOI reports for the All Industries category. For the period 1949 to 2007, average profits for all corporation, which is obtained as the sum of net income plus interest paid—totaled \$743,082 billion. Also, the average rate of return on corporate capital (*RCK*) is 20.6%, significantly larger than the return on assets (5.7%). The mean value for the average tax rate (24.4%) is significantly below than the average tax rate established in the U.S. legislation (*NSTR*=43.3%), suggesting that corporations reduce a large amount of their tax liability using loopholes and provisions, such as amortization, depreciation, and depletions. The minimum value of 34% for the *NSTR* was established during the 1987-1993 period through the *1986 Tax Revenue Act*. The reduction in the statutory corporate tax follows a worldwide trend seing across many developed economies. The series *L – stock* is an alternative measure for the corporate income tax—found in Krzyzaniak and Musgrave (1963), which is obtained as the ratio of tax liabilities to capital stock.¹²

Tables 4.3 and 4.4 show the set of financial indicators and tax measures calculated for each industry for the 1945-2007 period. According to these calculations, the highest average return to corporate capital is obtained in Mining (32.4%), followed by Manufacturing (26.9%), Finance (22.3%), and Trade (21.8%). The smallest average return for the period 1945-2007 is shown in Agriculture (10.8%). However, the Agriculture sector born the highest average tax rate in the 1945-2007, at 59.1%.

Figure 4.2 shows the U.S. nominal statutory tax rate (*NSTR*) for the period 1945-

¹²Dusansky (1972) uses a similar idea to measure the changes in the corporate income tax, but he employs the ratio of tax liabilities to total assets. See appendix table for details.

Table 4.2: Summary Statistics for All Industries Combined

Series	Mean	Std. Dev.	Min	Max
Assets	15,007,830	20,306,262	441,461	81,486,346
Capital Stock	4,124,511	5,266,315	127,707	18,295,354
Profits	743,082	908,573	25,134	3,921,896
Interest Paid	400,579	477,598	2,198	2,085,113
Net Income	342,503	451,032	22,876	1,948,655
Tax Liability	119,494	174,669	8,710	1,248,285
RCK	20.6%	4.6%	9.8%	32.3%
ROA	5.7%	1.1%	2.9%	8.1%
ROE	71.3%	33.1%	31.6%	154.7%
ATR	24.4%	10.9%	10.5%	46.7%
NSTR	43.3%	7.0%	34.0%	52.0%
Lstock	5.1%	2.5%	1.4%	11.5%

Note. Sample period from 1945 to 2007, in billions of US\$.

2007. The figure suggests several changes in the U.S. corporate tax policy. In 1949, the U.S. federal corporate tax rate was 38%. As the government needed resources to finance the Korean War, it increased the *NSTR* to 50.75% in 1951. For over a decade the *NSTR* was maintained at this level until it was reduced to 48% in 1965 and to 34% in 1987. The last corporate tax change recorded in the sample was in 1994, when the U.S. government slightly increased the *NSTR* to 35%.

Table 4.3: Financial Indicators by Industry

Sector	Variable	Mean	Std. Dev.	Min	Max
Agriculture	RCK	10.8%	4.6%	3.7%	25.7%
	ROA	6.2%	2.5%	2.2%	14.4%
	ROE	34.6%	15.4%	7.7%	83.2%
	ATR	25.5%	11.6%	11.5%	59.1%
	L-stock	2.8%	2.0%	0.8%	8.3%
Mining	RCK	32.4%	41.7%	4.7%	208.0%
	ROA	10.1%	10.8%	1.6%	56.8%
	ROE	159.3%	252.6%	17.8%	1010.6%
	ATR	36.9%	14.1%	15.0%	71.3%
	L-stock	13.5%	19.8%	1.3%	95.5%
Construction	RCK	21.4%	7.5%	9.5%	45.2%
	ROA	7.1%	2.3%	3.4%	14.1%
	ROE	139.1%	119.4%	24.8%	586.7%
	ATR	36.9%	14.1%	15.0%	71.3%
	L-stock	5.8%	3.4%	2.2%	15.8%
Manufacturing	RCK	26.9%	7.2%	10.9%	46.3%
	ROA	9.5%	2.8%	3.8%	17.1%
	ROE	115.4%	55.4%	39.5%	221.7%
	ATR	34.6%	11.3%	17.9%	59.1%
	L-stock	9.8%	4.9%	2.5%	23.6%

Note. Sample period from 1945 to 2007.

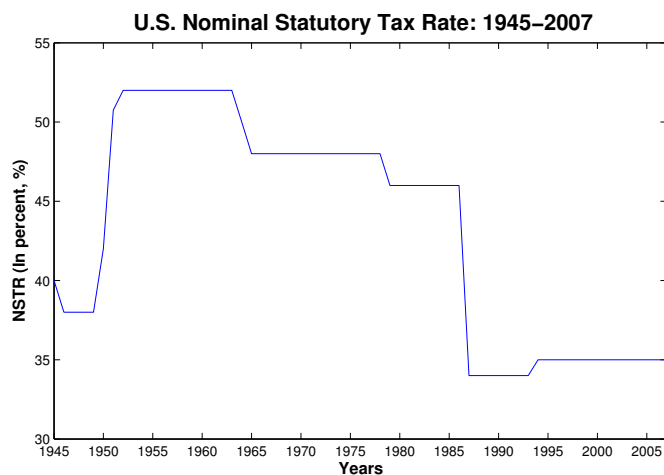


Figure 4.2: Nominal Statutory Tax Rate (NSTR), 1945-2007

Table 4.4: Financial Indicators by Industry (Cont.)

Sector	Variable	Mean	Std. Dev.	Min	Max
Utilities	RCK	10.7%	2.7%	3.0%	16.2%
	ROA	5.8%	1.2%	1.4%	7.4%
	ROE	39.7%	20.2%	13.8%	104.8%
	ATR	27.7%	8.9%	16.1%	48.8%
	L-stock	2.9%	1.0%	0.7%	7.1%
Trade	RCK	21.8%	6.8%	12.1%	46.3%
	ROA	8.3%	2.5%	5.7%	18.3%
	ROE	99.0%	52.1%	31.7%	224.7%
	ATR	28.9%	11.3%	13.9%	57.8%
	L-stock	6.5%	3.6%	2.2%	19.1%
Finance	RCK	22.3%	7.9%	10.1%	47.7%
	ROA	3.7%	1.4%	1.8%	7.6%
	ROE	78.4%	45.9%	28.9%	200.3%
	ATR	10.0%	5.2%	2.2%	20.3%
	L-stock	2.1%	1.0%	0.8%	4.2%
Services	RCK	14.7%	4.4%	6.5%	31.9%
	ROA	7.0%	2.2%	2.4%	16.5%
	ROE	71.3%	33.3%	27.8%	138.6%
	ATR	27.4%	10.5%	11.4%	46.1%
	L-stock	4.0%	2.0%	1.5%	11.4%

Note. Sample period from 1945 to 2007.

CHAPTER V

Estimation and Results

5.1 An exogenous increase in the CIT

Figures 5.1 and 5.2 show the impulse response functions. The columns present the effect of a exogenous increase in the corporate income tax on the rate of return on corporate capital RCK (column 1), the worker's wages (column 2), and the price of goods and services (column 3). Each row or section corresponds to a particular sector, and the scale on the ordinal axis ("x" axis) of each individual chart measures time in years. Following a common practice in this literature (Sims and Zha, 1999; Ramey, 2011), the bootstrap standard error bands shown are 68% bands.

The first row in figure 5.1 shows the effect of a exogenous increase in the corporate income tax on the return, or cost, of corporate capital, wages, and prices, respectively, for the Mining sector. The cost of corporate capital initially increases about 0.1% (or 10 basis points) with the introduction of the tax. Over time, the RCK reaches slowly its pre-tax level in approximately 17 years. The increase in the corporate cost of capital causes a significant drop of approximately 2% (up to 3% withing the first two-years) in the wage rate. After two years of the imposition of the tax, workers' wages slowly increase but never come back to the pre-tax level. In the long-term, the CIT causes a drop of 1% in the wage rate for workers in the Mining sector. Thus, the increase in the cost of corporate

capital is more than offset by a decline in the wage rate, which suggests that corporate owners of Mining companies shift (more than fully) the burden of the CIT to workers. In the third column, we observe a permanent drop in the price of mining products, which could be explained by the firm's gains obtained from a permanent decline in labor cost.

For Transportation & Utilities (corporate, non-tradable), panel 2 in figure 5.1, the effect of an increase in the CIT is exactly what Harberger's model would predict. The CIT raises the cost of corporate capital, increasing the gross rate of return approximately 0.2%, or 20 basis points. The cost of corporate capital takes approximately 7 years to pull back to its pre-tax level. The wage rate initially drops by 0.5% to absorb tax tax-wedge. Although worker's wage rate consistently increases after they absorb the CIT, it never returns to its pre-tax conditions, thus significantly affecting workers in this sector. Prices significantly increase as a result of the large capital intensity of the Transportation & Utilities sector.¹

The response to an exogenous increase in the CIT for the Wholesale & Retail Trade (third row in figure 5.1) and Construction (second row in figure 5.2) are very similar. In both sectors, the CIT causes an increase in the cost of corporate capital—approximately 6% in Wholesale & Retail and 10% in Construction. The wage rate declines to absorb the tax-wedge. Prices in Wholesale & Retail increases by 1.5%, while in Construction raises by only 1% after few years of the imposition of the tax.

As capital moves from the corporate to the non-corporate sectors, the return to capital declines in the Service sector (panel one in figure 5.2). The decline in the rate of return to capital is more than 4% within the first two years; thereafter, the return to capital increases until it reaches its pre-tax level, in about 25 years. Workers in the service sector bear a small burden of this tax as wages decline. Prices unambiguously decline as a result of a lower labor and capital cost, as predicted in Harberger (1995, 2008a,b), benefiting

¹For Transportation & Utilities, the average value added to capital is approximately 51% for the period from 1947 to 2009.

capital owners and workers as consumers in this sector.

The third section in figure 5.2 illustrates the effect of the CIT on the Manufacturing sector. Similar to Mining, the impulse response functions show that the increase in the CIT raises the cost of corporate capital, returning to its pre-tax level after four years. However, wages in the manufacturing sector significantly increase with the tax (an unpredicted result in light of Harbergers model). For a tradable sector with non-homogeneous goods such as Manufacturing, the models of Harberger (2008a,b), Gravelle and Smetters (2006), and Randolph (2006) suggest that the respond to prices will depend on the degree of capital (or labor) intensity with respect to the numeraire sector, e.g. Mining. For Manufacturing, prices increases as a response to the higher cost in both capital and labor.²

Overall, the results above are generally in light of Harberger (1995, 2008a,b)'s predictions. An exogenous increase in the CIT raises the cost of capital in the corporate sectors of Mining, Manufacturing, Transportation & Utilities, Wholesale & Retail Trade, and Construction due to the imposition of the tax-wedge. For the non-corporate sectors, such as Services, the return to corporate capital declines with the tax. Therefore, this analysis suggests that, in the short-term, capital owners bear the burden of the corporate income tax.

For an open economy with perfectly homogeneous and tradable goods, Harberger (1995, 2008a,b) predicts that wages will decline economy-wide to fully absorb the CIT. In other words, the response of wages will depend on the degree of competition and the price elasticities that producers will face in international markets. The estimations above show that wages significantly decline across all non-tradable sectors, i.e., Services, Transportation & Utilities, Construction, and Wholesale & Retail Trade. Also, wages in the Mining sector, which could be assume that produces an homogeneous and tradable good

²The capital share in Manufacturing (36%) is significantly lower than Mining (68%), thus the labor cost will have a larger weight than the capital cost in determining the evolution of prices for manufacturing products. See table 3.1 for details.

(e.g., fuel and nonfuel minerals), also decline with the tax.³ However, in Manufacturing wages significantly increase after the imposition of the CIT.

Finally, the effect of the CIT on the price of goods and services will depend on the capital shares of each industry analyzed. The results show that for highly capital intensive sectors, i.e., Transportation & Utilities, Construction, Manufacturing, and Wholesale & Retail Trade, prices increase with the tax. Further, prices decline for sectors with a relative low capital income share: Mining and Services. Therefore, these results validate the original predictions from Harberger (1995, 2008a,b) on the effect of an exogenous increase of the corporate income tax for a multi-sector open economy.⁴

³In 2010, the U.S. exports of mineral raw materials (e.g., gold, soda ash, zinc, concentrates, etc.) totaled \$7.5 billion, while exports of processed minerals (e.g., metals, chemicals, etc.) were \$87 billion (Survey, 2011).

⁴The estimates of the capital income share in Agriculture and Mining are 74% and 43%, respectively. However, these large estimates, compared to other sectors in the economy, are attributed to the land income share, which is also part of the capital income share, in both Agriculture and Mining. For example, Valentinyi and Herrendorf (2008) find that Agriculture has the largest land share in the economy (18%), which is approximately one-third of Agriculture's total income share to capital.

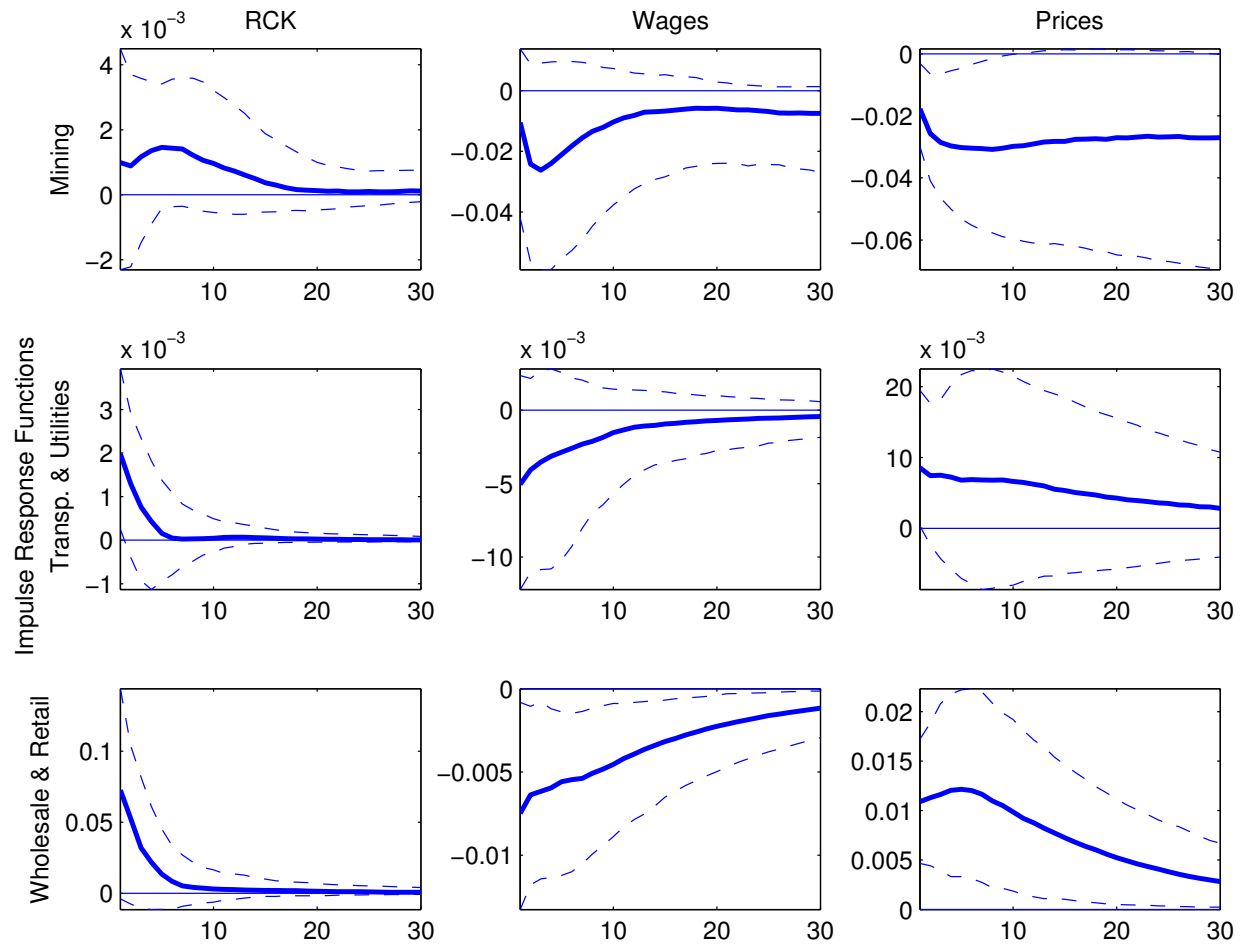


Figure 5.1: Exogenous increase in CIT

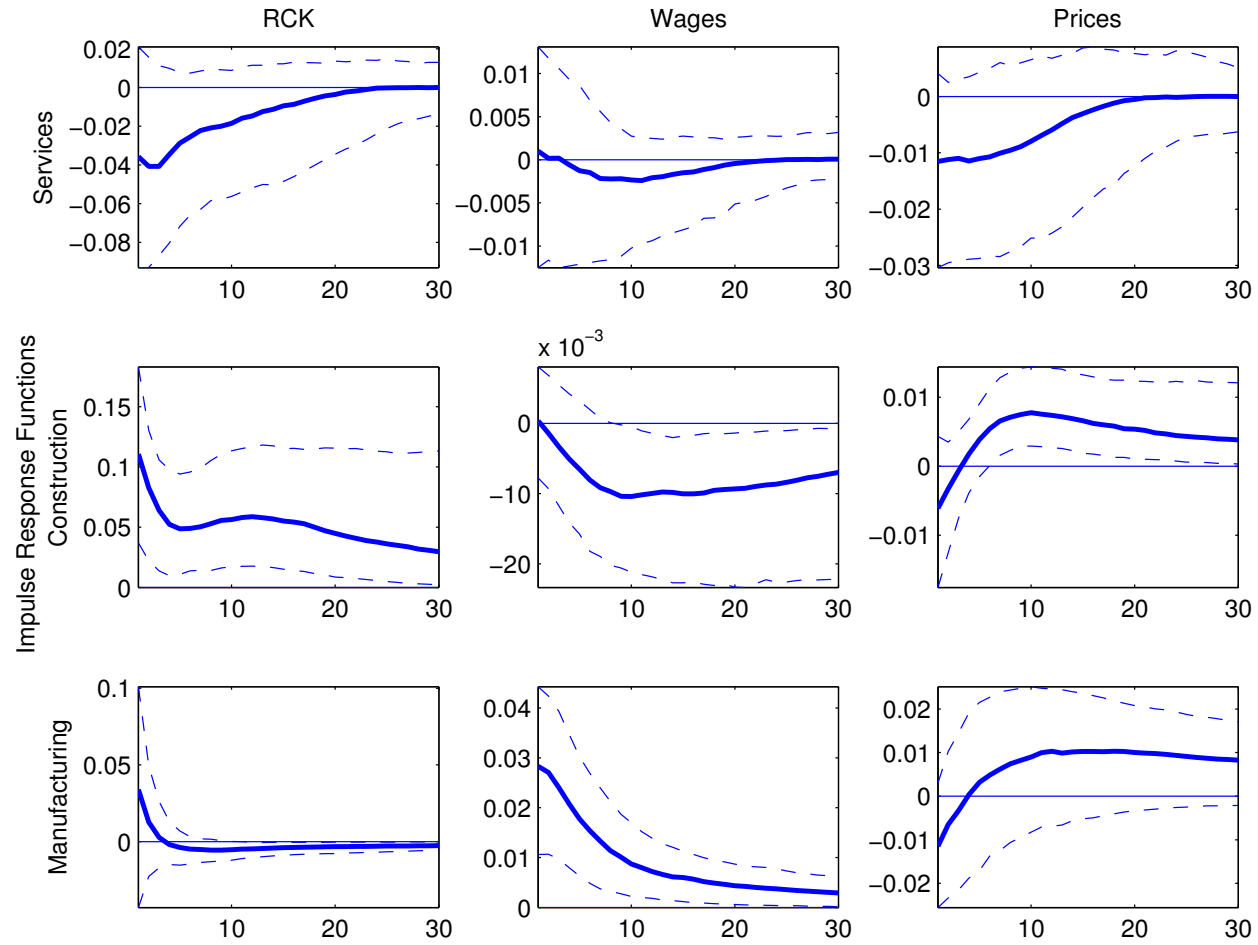


Figure 5.2: Exogenous increase in CIT

5.1.1 A Note on Agriculture and Finance Sectors

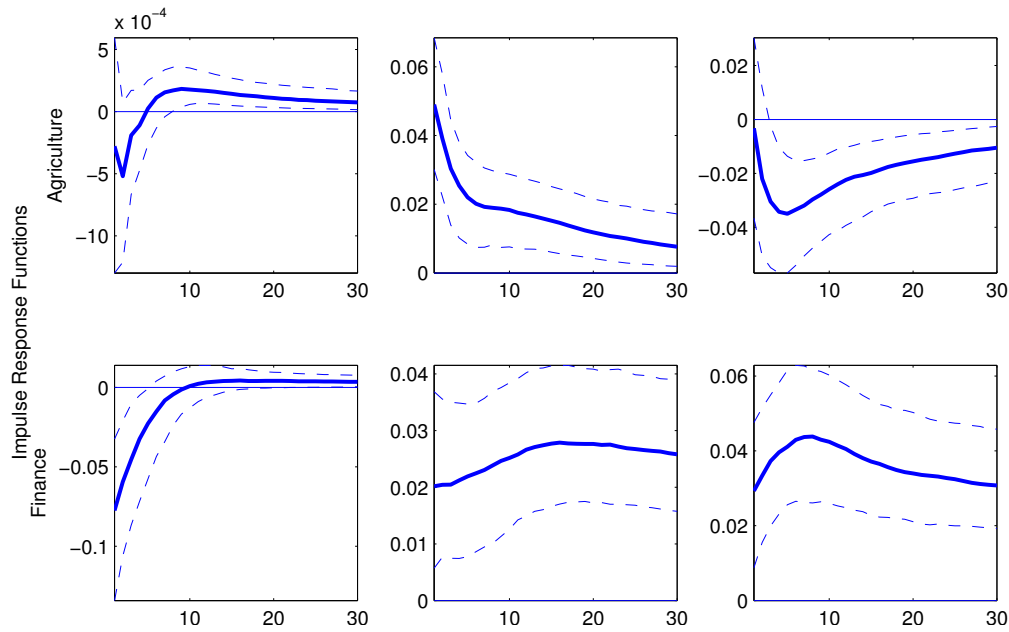


Figure 5.3: Effect of an increase in CIT on Agriculture and Finance sectors

Figure 5.3 shows the impulse response functions for the Agriculture and Finance & Insurance sectors, respectively. As before, the columns represent the return to corporate capital (column 1), the wage rate (column 2), and the prices (column 3) in each sector. In both, the return to capital initially drops. However, while we observe a permanent negative effect in the rate of return to capital in Finance, the return in Agriculture becomes mildly positive after approximately five years. The rebound in Agriculture's rate of return to capital might be explained by the rise in the return to land, which is part of the return to capital and it is not accounted for in my estimations. (The capital income share in Agriculture, including land rent, is 74%. See table 3.1 above). In the open economy model of Harberger (1995, 2008a,b), agricultural prices do not change because products are assumed to be tradable and homogeneous. However, we observe that Agricultural

prices significantly decline with the tax (approximately 4%), which might be explain by the drop in capital cost. For Finance, the rate of return initially drops by 0.08%, and then slowly moves to its pre-tax level in about ten years. In both sectors, wages increase after the CIT.

5.2 An exogenous decrease in the CIT

By intuition, Harberger's model predicts that an exogenous decrease in the CIT will have the opposite effects on the economy when compare to a tax increase. However, there is no reason to expect a symmetric result in the empirical estimations because the tax policy transmission mechanism can be very different for tax increases and tax decreases. In fact, when analyzing the impact of tax changes on the economy, Romer and Romer (2009) find that tax increases have a larger effect than tax decreases on GDP. Similar results are found when estimating the effect of tax policy changes on consumption, investment, among other macroeconomic variables.⁵

Figures 5.4 and 5.5 show the the impact of a decrease in the CIT on the return to corporate capital, the wage rate, and prices, across the same sectors shown above. In general, the decrease in the CIT reduces the cost of capital almost in all sectors. The wage rate also increase in Transportation & Utilities, Wholesale & Retail Trade, Services, and Construction. Further, prices decline across all highly capital intensive industries, including Transportation & Utilities, Mining, Construction, and Manufacturing. In the labor intensive industry of Services, the decrease in the CIT causes an increase in prices, which is attributed to the increase in labor cost, as Harberger's model would predict.

⁵See also the results from Barro and Redlick (2011).

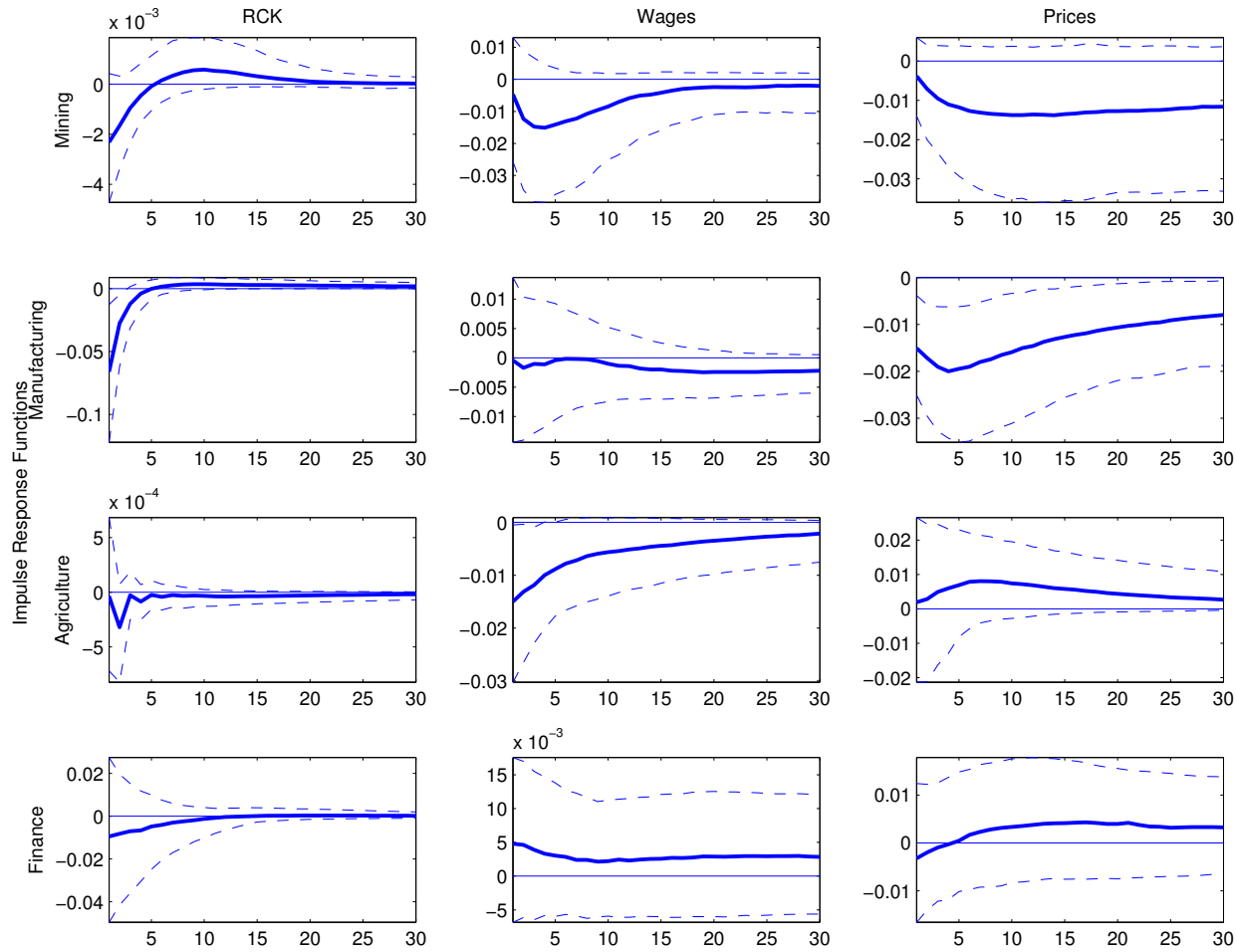


Figure 5.4: Exogenous decrease in CIT

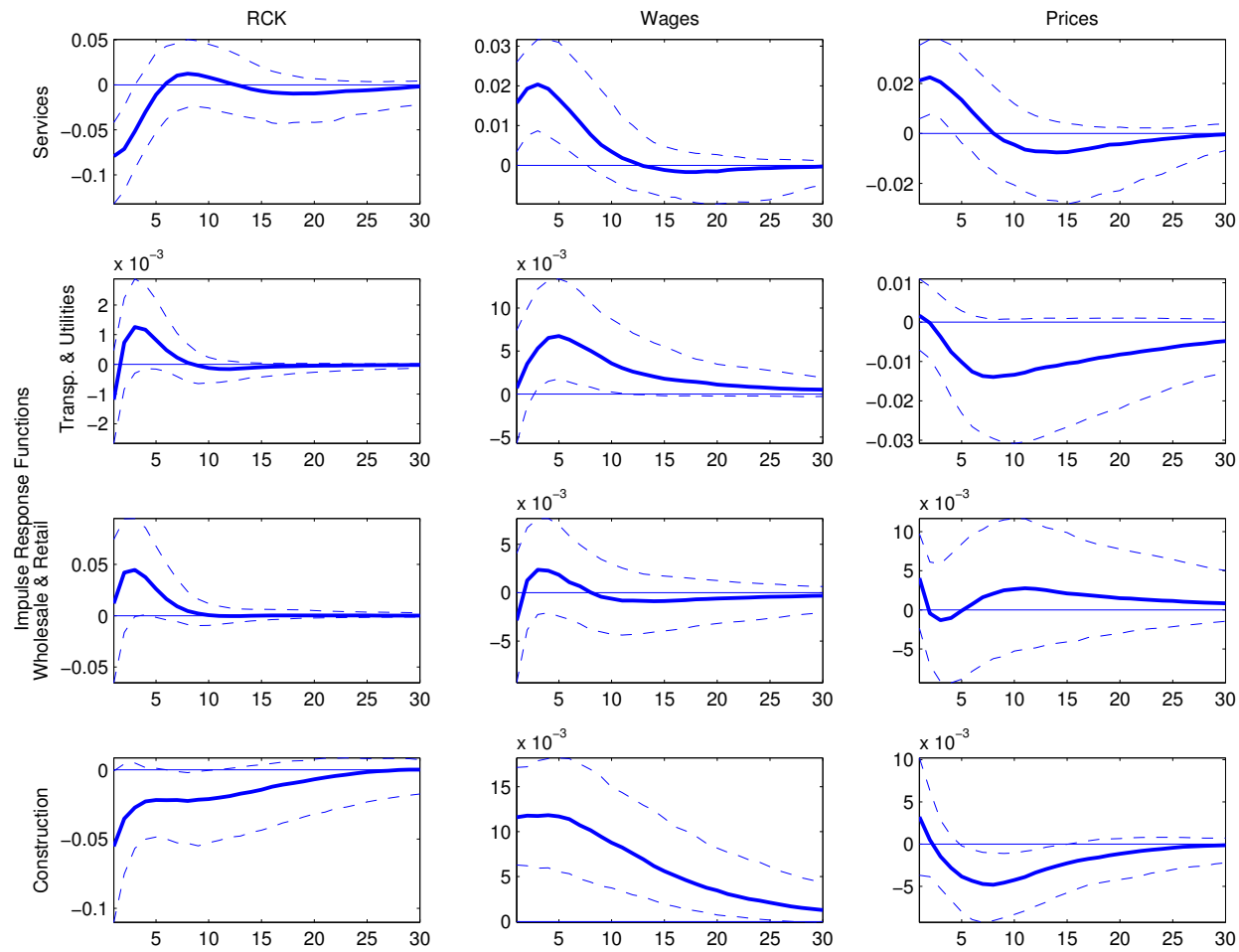


Figure 5.5: Exogenous decrease in CIT

CHAPTER VI

Conclusions

The wellhead producers would say, “You know, we’re going to bear this tax, the whole thing. Whatever percentage rate it is going to be, that is going to be borne by us.” The next day, we would meet with the pipeline people, who would say, “You know, we are going to bear this tax; the whole thing is going to fall on us.” The refiners came in the next week. The refiners said, “We’re going to bear that tax, the whole thing on us.” The retailers, they were going to bear the tax, the whole thing. Labor groups, the same. Consumer groups came in and said, “You know, in the end, the consumer is going to be paying this tax” (p. 75).

Thomas A. Barthold

Discussions on a proposed energy tax between the Joint Committee on Taxation
and representatives of different economic groups.

This paper employs a new and better methodology that allows for improved analysis of how the incidence of the corporate income tax (CIT) is distributed over time among workers, consumers, and capital owners. Using annual information for the period from 1945 to 2007, I analyze the effects of exogenous changes in corporate tax policy on the rate of return to corporate capital, the wage rate, and the prices of goods and services for eight major U.S. industries: (i) Agriculture, (ii) Mining, (iii) Construction, (iv) Manufacturing, (v) Public Utilities and Transportation, (vi) Wholesale & Retail Trade, (vii) Finance &

Insurance, and (viii) Services. The identification of the exogenous changes on the CIT is based on the work of Romer and Romer (2009, 2010), who provide an extensive analysis of the U.S. federal tax legislation using narrative records from presidential speeches and congressional reports, among other documentations.

The results are generally consistent with the predictions of Harberger (1995, 2008a,b) models. An exogenous increase in the CIT raises the cost of capital in the corporate sectors of Mining, Manufacturing, Transportation & Utilities, Wholesale & Retail Trade, and Construction due to the imposition of the tax-wedge. As capital flows from the corporate to the non-corporate sectors (Agriculture and Services), the return to corporate capital declines. Further, the wage rate declines to absorb part of the tax wedge imposed with the CIT. The drop wages is significant across in almost all sectors, i.e., Services, Transportation & Utilities, Construction, and Wholesale & Retail Trade, but not economy-wide. For the Mining sector wages also decline. However, in Manufacturing and Agriculture, both tradable with imperfect homogeneous goods, wages significantly increase with the CIT.

The estimations show that the CIT raises the prices of goods and services for high capital intensive industries (i.e., Manufacturing, Transportation & Utilities, Finance & Insurance, and Wholesale & Retail Trade). For sectors with a relative low capital income share, such as Agriculture, and Services, prices decline with the tax.

For completeness, I also show the impact of a CIT decrease in the economy. In general, the results behave as the predictions from the theoretical model. That is, a drop in the CIT reduces the cost of capital in almost all highly capital intensive industries—e.g., Transportation & Utilities, Construction, Mining, Finance & Insurance and Manufacturing. The wage rate increases in five out-of nine sectors (i.e., Finance & Insurance, Services, Transportation & Utilities, Wholesale & Retail, and Construction). The lower cost of capital has a negative impact on prices across all major capital intensive industries. In Services, which is labor intensive, prices increase with the corporate income tax.

Finally, these results validate the original predictions from Harberger (1995, 2008a,b)

on the effect of an exogenous increase of the corporate income tax for a multi-sector open economy. Although, this paper does not calculate numerical burdens of the CIT, Harberger (1995) obtains plausible estimations based on the results discussed above. He concludes that U.S. capital bears a small burden of the CIT (about 25% of total CIT receipts), while labor bears approximately 100% of the burden of the U.S. CIT. Further, both capital owners and workers receive a benefit in their role as consumers, but this gain is offset by the benefits obtained by landowners.

APPENDICES

APPENDIX A

Data Appendix: Time Series Plots

A.1 Time Series Plots

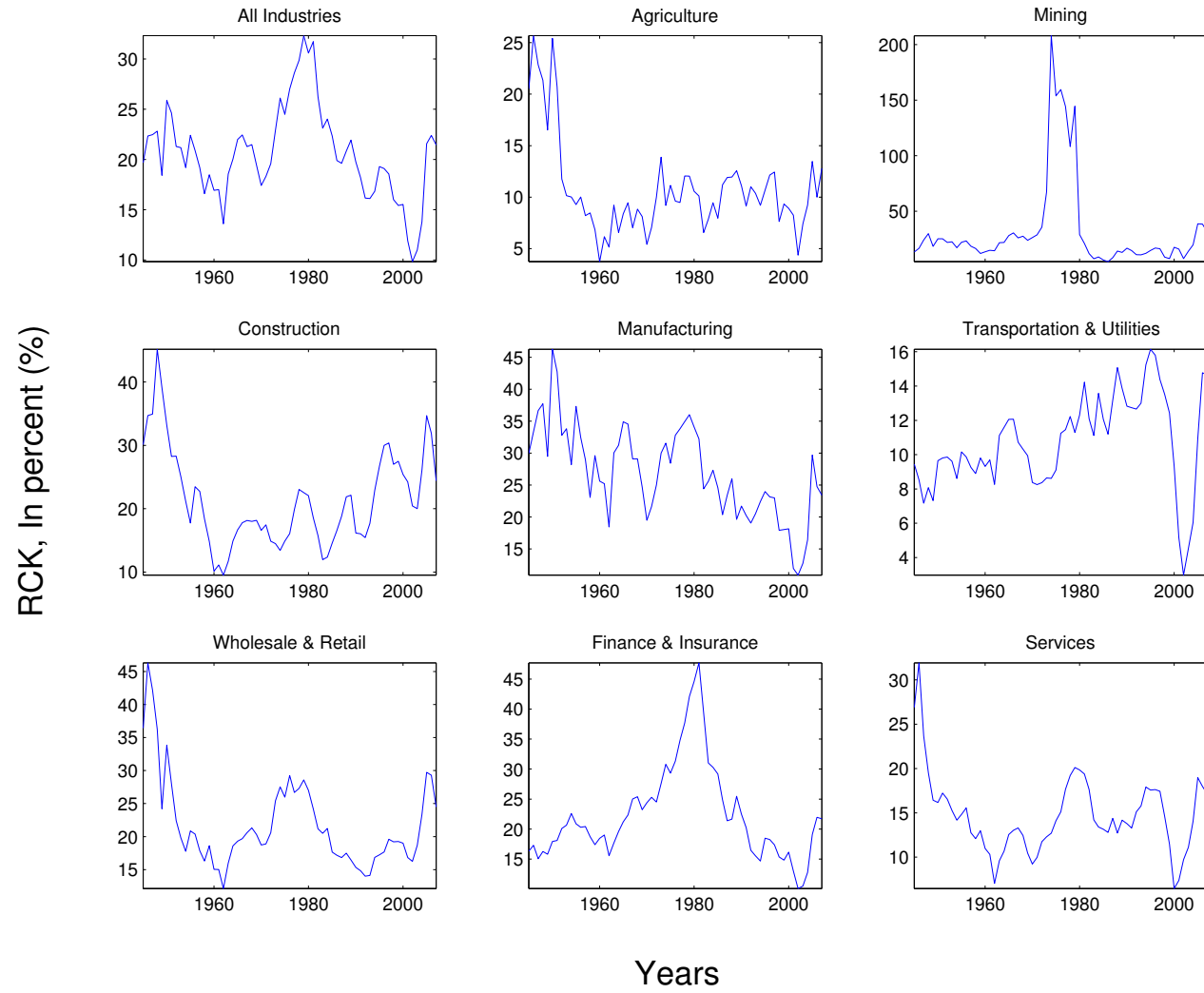


Figure A.1: Return on Corporate Capital, Period 1945-2007. Source: Statistics of Income Report

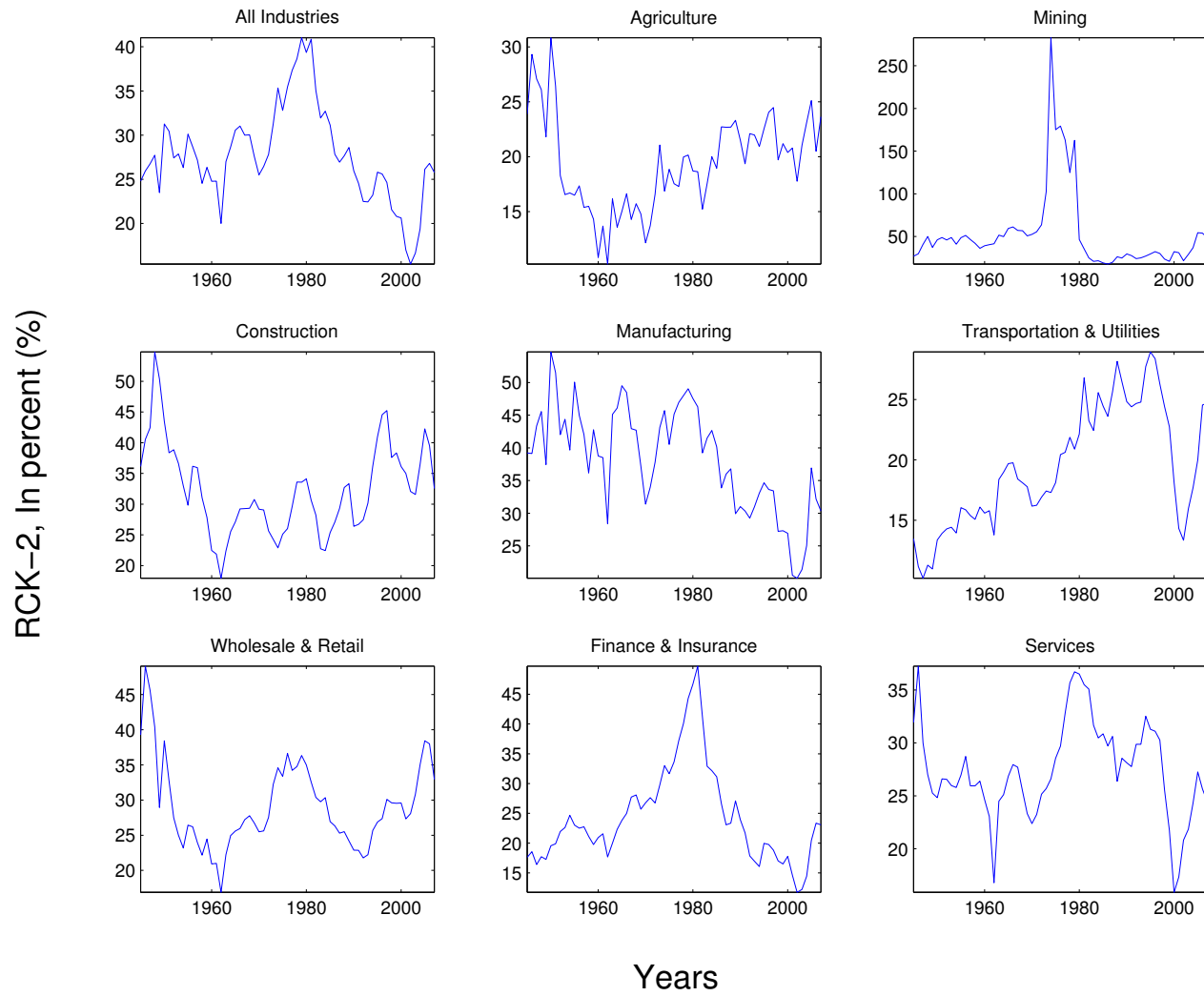


Figure A.2: Return on Corporate Capital - Cash Flow, Period 1945-2007. Source: Statistics of Income Report

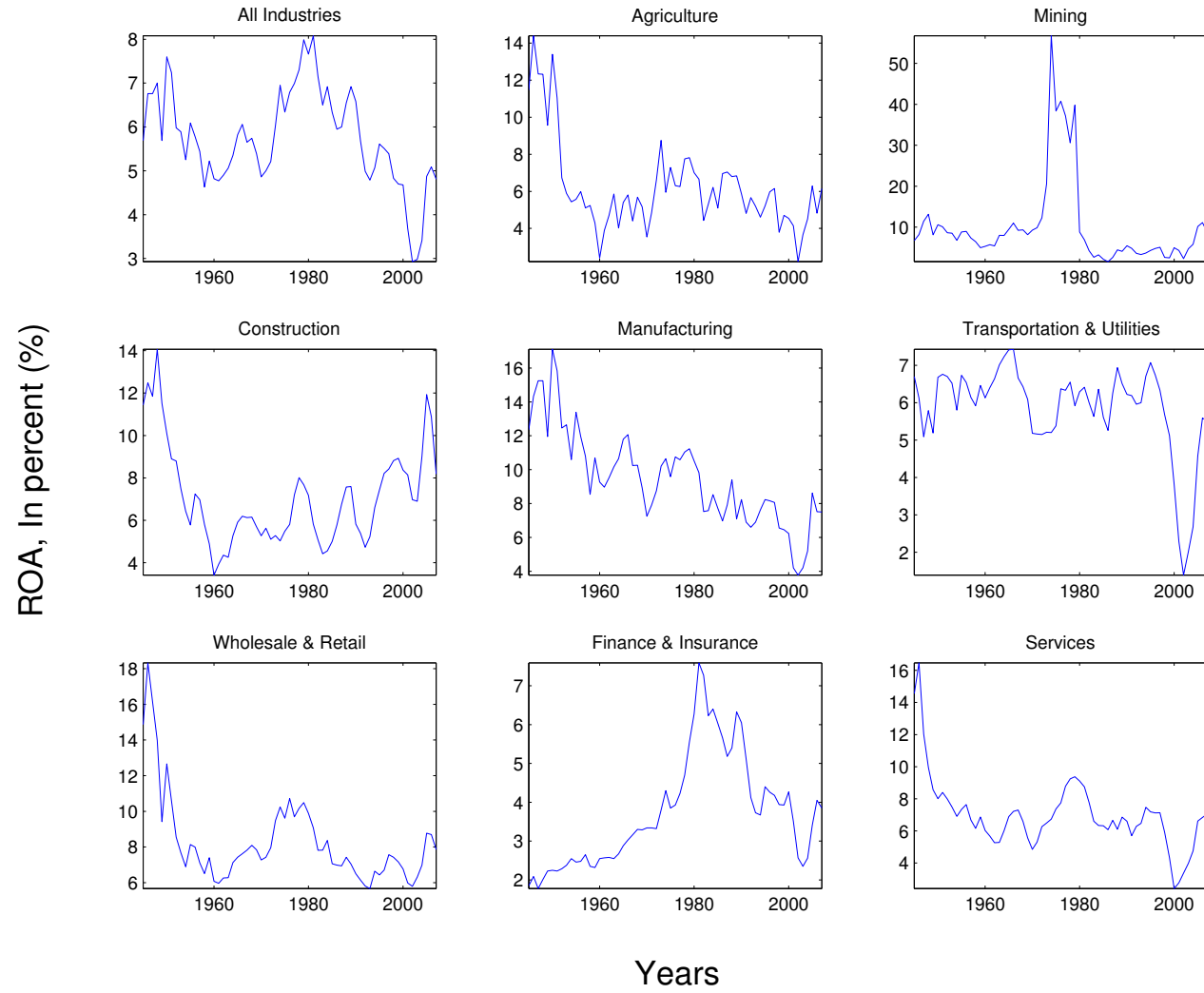


Figure A.3: Return on Assets, Period 1945-2007. Source: Statistics of Income Report

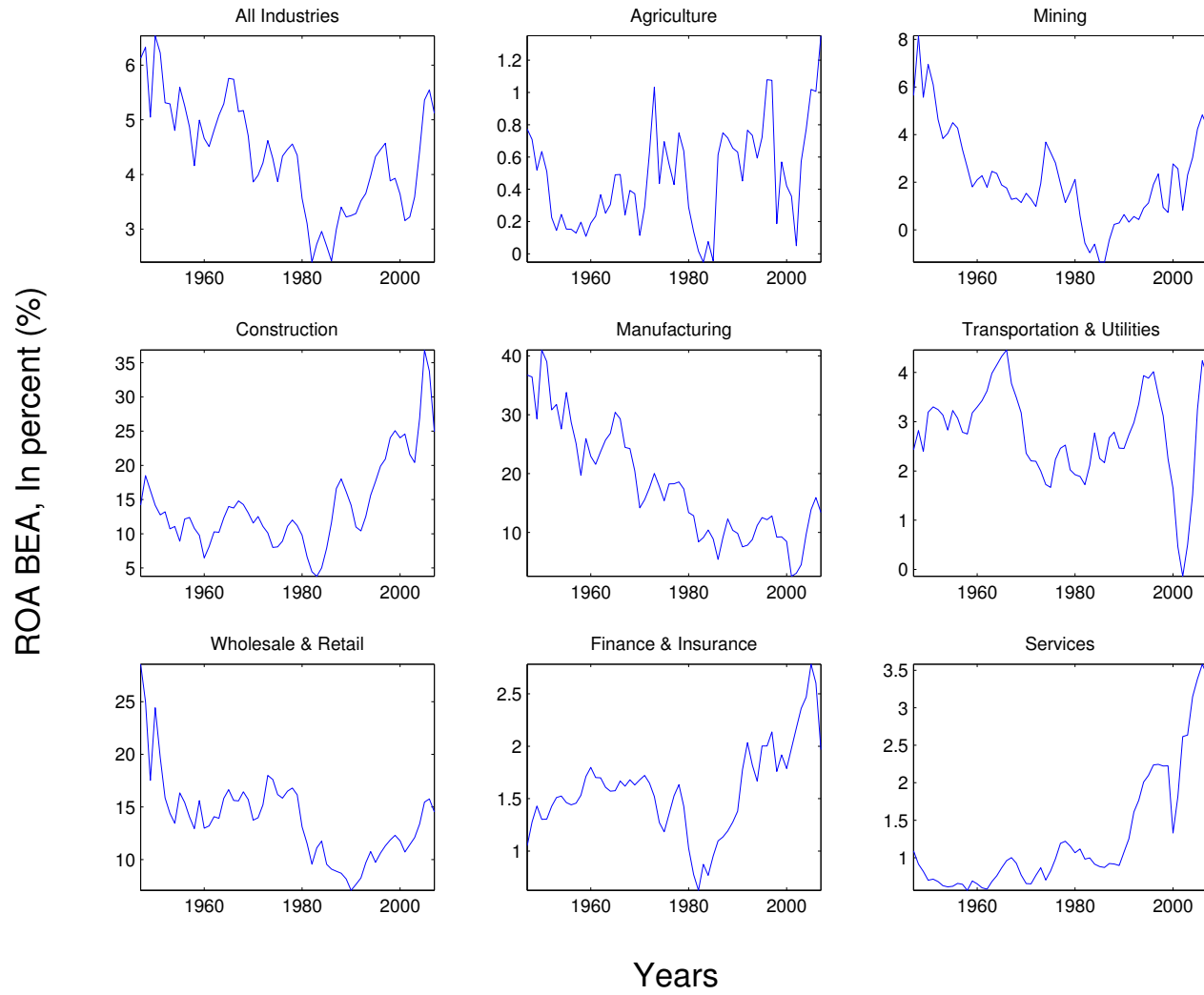


Figure A.4: Return on Assets, Period 1947-2007. Source: Bureau of Economic Analysis

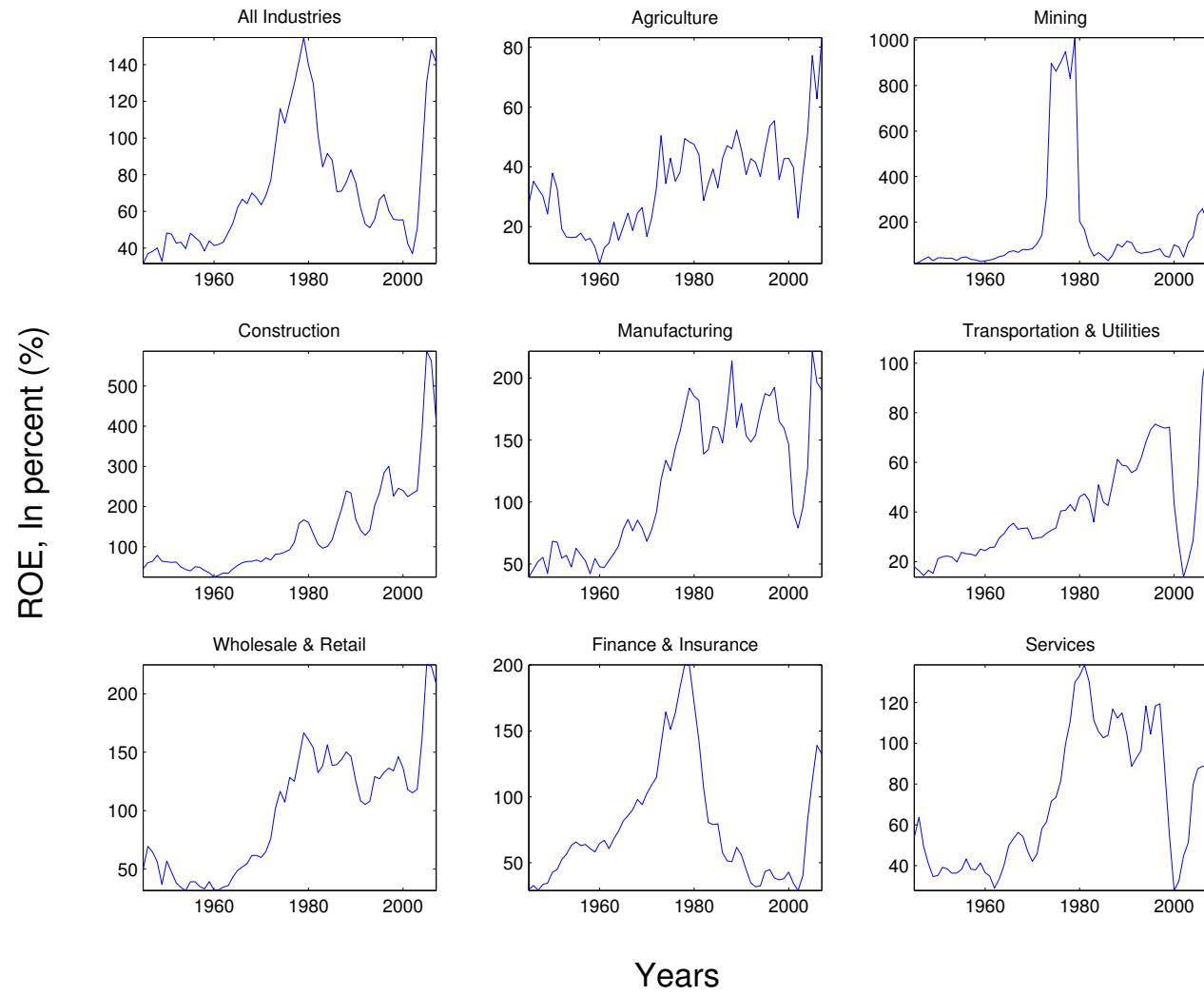


Figure A.5: Return on Equity, Period 1945-2007. Source: Statistics of Income Report

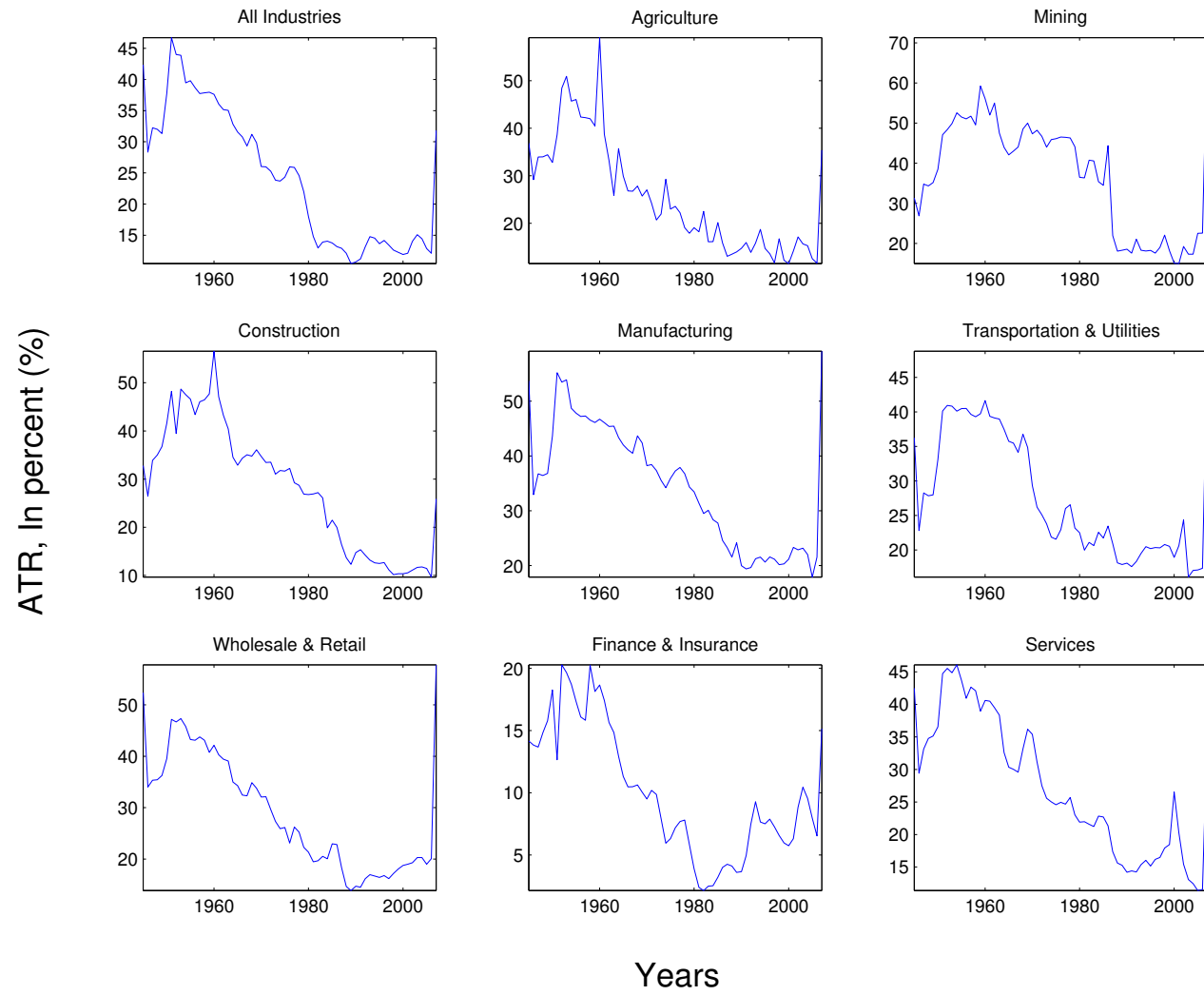


Figure A.6: Average Tax Rate, Period 1945-2007. Source: Statistics of Income Report

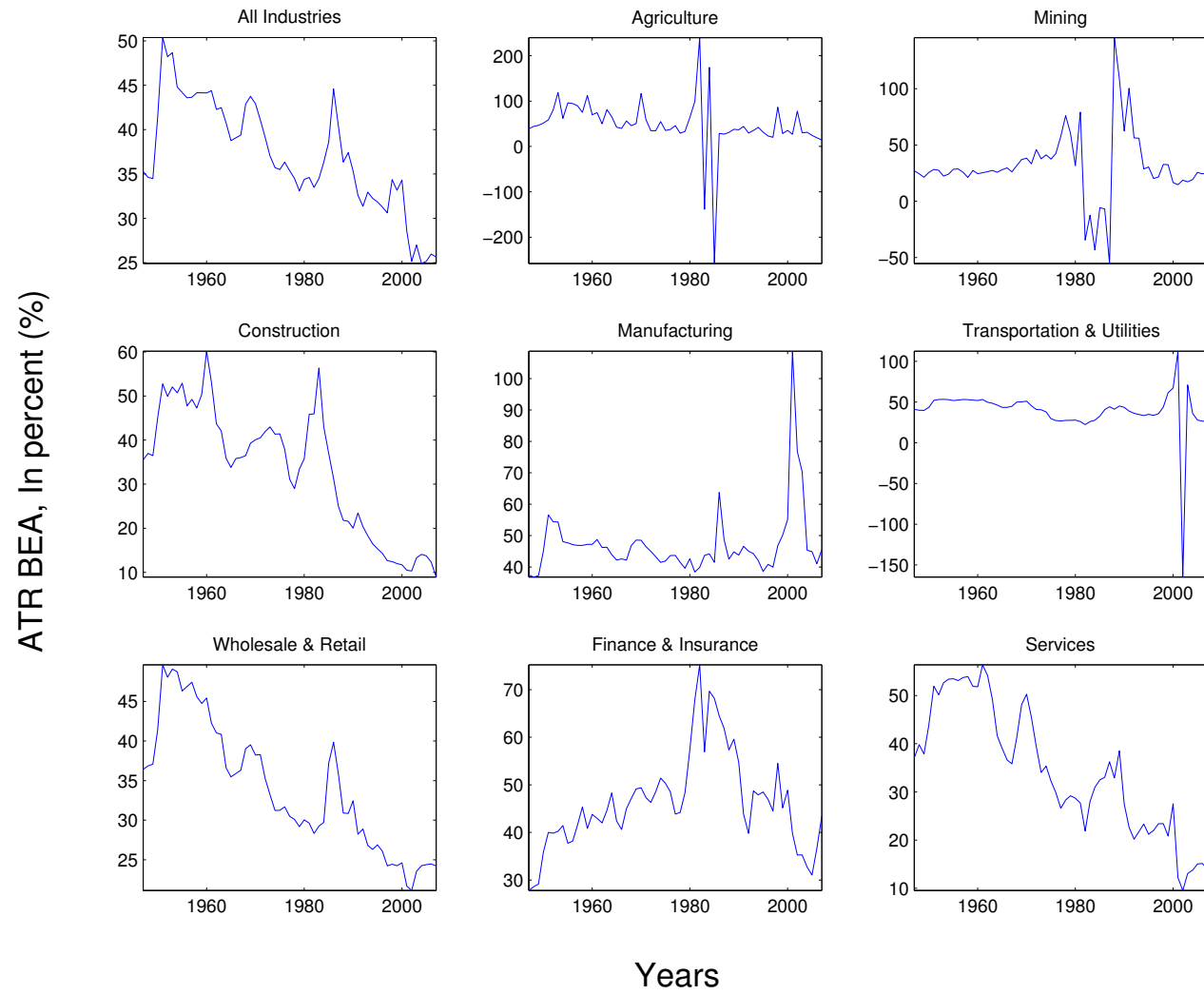


Figure A.7: Average Tax Rate, Period 1945-2007. Source: Bureau of Economic Analysis

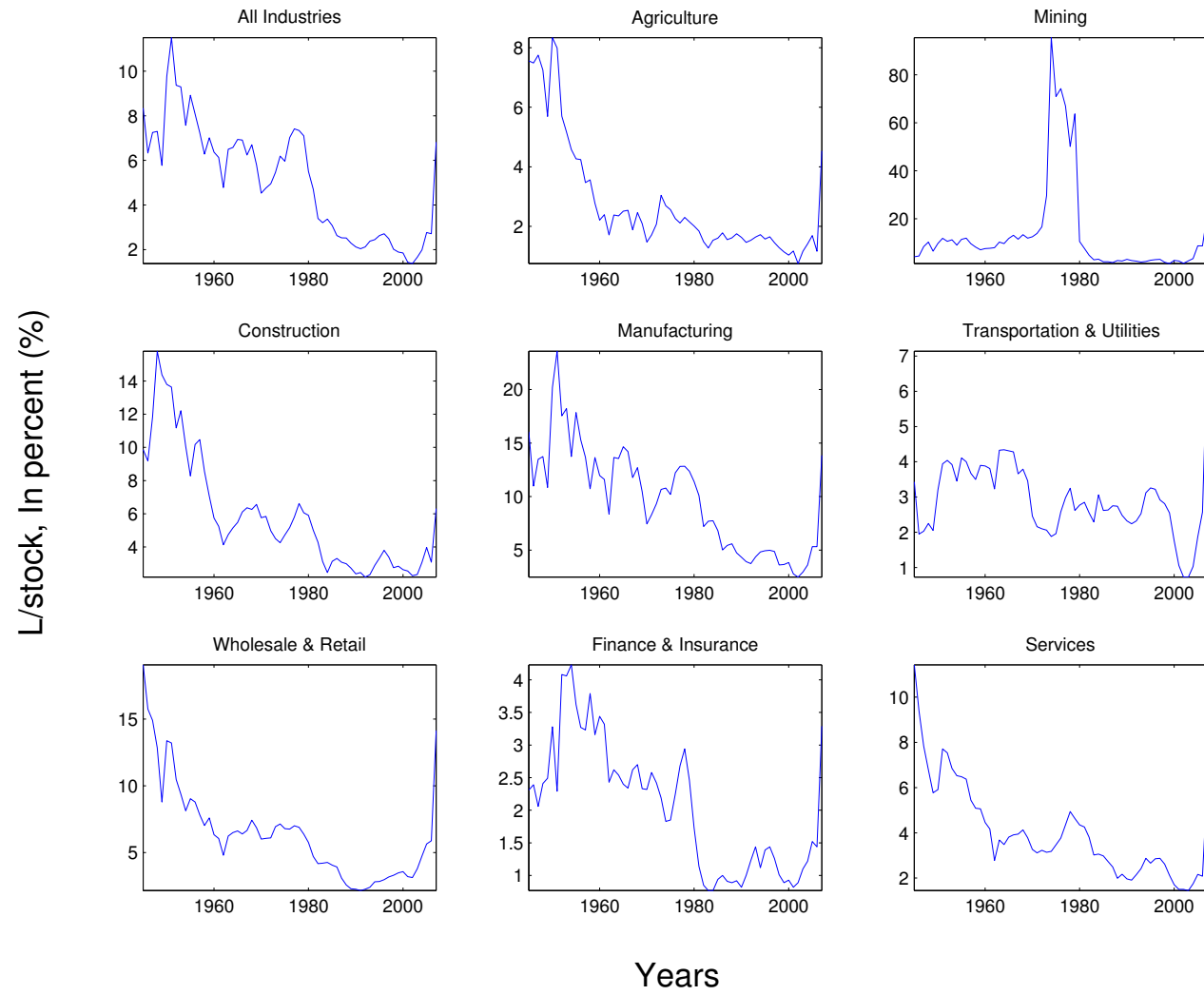


Figure A.8: Liability to Capital Stock Ratio, Period 1945-2007. Source: Statistics of Income Report

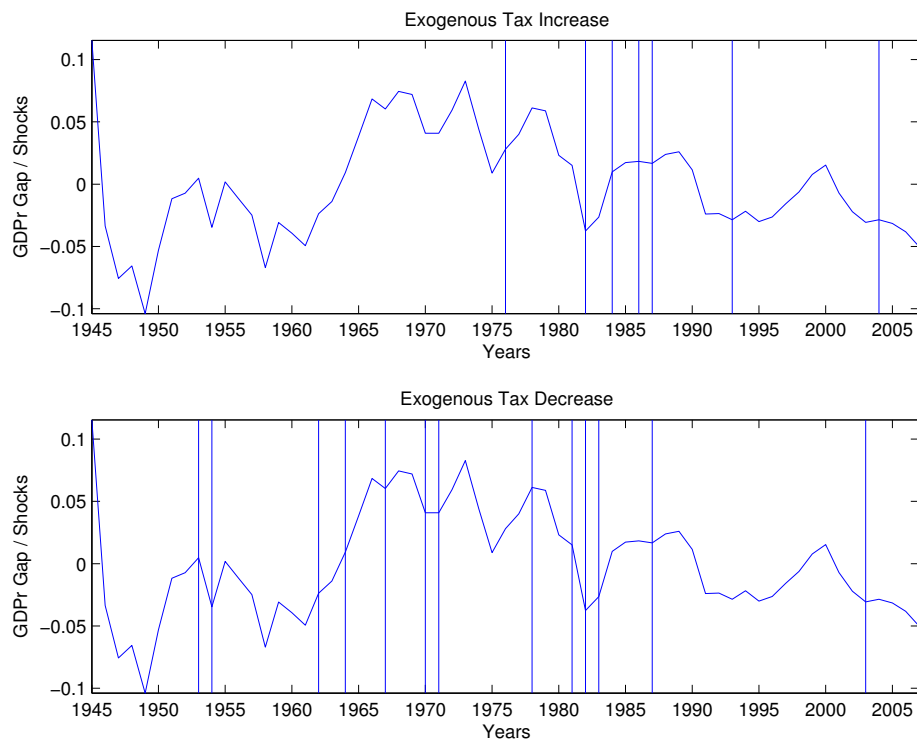


Figure A.9: Real GDP and Exogenous Corporate Tax Changes, Period 1945-2007

APPENDIX B

A Primer in Time Series Regression and Vector Autoression Models

B.1 Introduction to Time Series Econometrics

This section provides key concepts in time series analysis that are useful to understand the Vector Autorregresive model applied in section ???. The following concepts and definitions are neither comprehensive nor a substitute for any graduate time series econometric textbook, and they follow closely the expositions in Wooldridge (2003), Tsay (2005), and Hamilton (1994). For proofs and details, I will refer the readers to these authors.

Section B.1.1 of this appendix introduces the assumptions and properties of the OLS estimator in small samples for time series regressions. Then, in B.1.2, I introduce the concepts of strong and weak stationarity, which are useful to derive the large sample properties of the OLS estimator. Section B.1.3 discusses some examples of weakly dependent processes, including the autorregresive (AR) and moving average (MA) model. Also, this section presents how is calculated the impulse response function (IRF) shown in our estimations. The appendix ends discussing a simple example of a vector autorregresive model and deriving its properties.

B.1.1 Finite Sample Properties of OLS

The finite, or small, sample properties of the OLS estimator can be stated as follows:

- **A.1. Linear in Parameters.** The stochastic process, or time series process, $\{(x_{t1}, x_{t2}, \dots, x_{tk}, y_t) : t = 1, 2, \dots, T\}$ follows a model linear in parameters, e.g.:

$$y_t = \phi_0 + \phi_1 x_{t1} + \dots + \phi_k x_{tk} + a_t \quad (\text{B.1})$$

where $\{a_t\}$ is a sequence of random shocks and T is the number of time periods.

- **A.2. Strict Exogeneity.** The regressors in (B.1), for all time periods, are strictly exogenous: $E(a_t|\mathbf{X}) = 0 \forall t = 1, \dots, T$.

- **A.3. No Perfect Collinearity.**

Theorem: Under **A.1**, **A.2**, and **A.3** it follows that $E(\hat{\phi}_j|\mathbf{X}) = E(\hat{\phi}_j) = \phi_j \forall j = 0, 1, \dots, k$. That is, $\hat{\phi}_j$ is an unbiased estimator of ϕ_j .

- **A.4. Homokedasticity.** The variance of a_t is constant for all time periods: $Var(a_t|\mathbf{X}) = Var(a_t) = \sigma^2 \forall t = 1, \dots, T$.

- **A.5. No Serial Correlation.** $E(a_t a_s|\mathbf{X}) = 0, \forall t \neq s$. Notice, if A.5 does not hold, then $\{a_t\}$ are serially correlated. Also, we are not making any assumptions about the correlations in \mathbf{X} .

Gauss-Markov Theorem: Under **A.1** through **A.5**, the OLS estimators $\hat{\phi}_j, \forall j = 1, \dots, k$, are BLUE conditional on \mathbf{X} .

B.1.2 Stationarity, Weakly Dependent Process, and Large Sample Properties of OLS

On some occasions, the assumptions for the small sample properties of the OLS estimators are violated—e.g., the strict exogeneity assumption might be violated when lagged

values of the dependent variable are introduced in the model. Therefore, it is important to rely on the large sample properties of OLS estimators. This section introduces the concepts of stationary and covariance stationary processes as well as weakly dependent time series, which are required to apply the large sample properties of the OLS estimator.

Stationary Process. The stochastic process $\{x_t : t = 1, \dots, T\}$ is stationary (or strictly stationary) if the joint distribution of $(x_{t_1}, x_{t_2}, \dots, x_{t_k})$ is invariant when it is shift t periods ahead to $(x_{t_1+t}, x_{t_2+t}, \dots, x_{t_k+t}) \forall t$, where k is an arbitrary positive integer and (t_1, \dots, t_k) is a set of k positive integers. When the opposite occurs, the stochastic process $\{x_t\}$ is referred to as *nonstationary process*.

Covariance Stationary Process. The stochastic process $\{x_t : t = 1, \dots, T\}$ is covariance stationary (or weakly stationary) if $E(x_t^2) < \infty$ and the following three conditions hold: (i) $E(x_t) = \mu$, (ii) $E(x_t - \mu)^2 = \sigma^2$, and (iii) $E[(x_t - \mu)(x_{t-l} - \mu)] = \gamma_l$, for any $t, l \geq 1$. In other words, the process $\{x_t\}$ is covariance stationary if the mean and variance of x_t are both time invariant and γ_l depends only on l . In what follows, the term *stationary process* refers to covariance (weakly) stationary process.

Weakly Dependent Process. A covariance stationary process $\{x_t\}$ is weakly dependent if $\rho_l = \frac{E[(x_t - \mu)(x_{t-l} - \mu)]}{\sqrt{E(x_t - \mu)^2 E(x_{t-l} - \mu)^2}} \rightarrow 0$ as $l \rightarrow \infty$. That is, the correlation between x_t and x_{t-l} approach to zero *quickly enough* as l increases unboundedly. When the previous hold, the stationary process is known to be asymptotically uncorrelated. Two examples of weakly dependent processes are the autorregressive model and the moving average model. Details about these models will be provide in section B.1.3.

Large Sample Properties of OLS. Assuming the time series process $\{(x_{t1}, x_{t2}, \dots, x_{tk}, y_t) : t = 1, 2, \dots, T\}$ is stationaty and weakly dependent, the assumptions and properties of the OLS estimators are described as follows:

- **A.1[†]. Linear in Parameters.** Under this assumption the model can be represented as in **A.1** above.

- **A.2[†]. Contemporaneous Exogeneity.** The regressors in (B.1), at t , are contemporaneously exogenous: $E(a_t|\mathbf{x}_t) = 0$ for $\mathbf{x}_t = (x_{t1}, \dots, x_{tk})$.

- **A.3[†]. No Perfect Collinearity.**

Theorem: Under **A.1[†]**, **A.2[†]**, and **A.3[†]** it follows that $\text{plim}(\hat{\phi}_j) = \phi_j \forall j = 0, 1, \dots, k$.

- **A.4[†]. Contemporaneous Homokedasticity.** $\text{Var}(a_t|\mathbf{x}_t) = \sigma^2$.

- **A.5[†]. No Serial Correlation.** $E(a_t a_s | \mathbf{x}_t \mathbf{x}_s) = 0, \forall t \neq s$.

Theorem: Under **A.1[†]** through **A.5[†]**, the OLS estimators are asymptotically normally distributed. Also, the standard hypothesis test: t -stat, F -stat, and LM -stat, are asymptotically valid.

B.1.3 Weakly Dependent Processes: The Autorregressive and Moving Average Models

Subsection B.1.2 identifies the autorregressive and moving average models as examples of weakly dependent processes. This section discusses the properties of both models and develops few examples. The importance of the autorregressive and moving average models is that they represent the basis for more advance time series models, including the Vector Autorregressive Model.

B.1.3.1 Autorregressive Models

The autorregressive model (AR) is motivated when lagged values x_{t-l} ($l > 0$) of the stochastic process $\{x_t : t = 1, \dots, T\}$ can be useful explaining x_t . For instance:

$$x_t = \phi_0 + \phi_1 x_{t-1} + a_t \quad t = 1, \dots, T \tag{B.2}$$

where $\{a_t\}$ is a sequence of independent and identically distributed (i.i.d.) random variables that follow a distribution with mean zero and constant variance, or simply $\sim d(0, \sigma_a^2)$.

The stochastic process $\{a_t\}$ is also known in the literature as white noise. The model in B.2 is known in the time series literature as autorregressive process of order one, or AR(1) model. Under the assumption that $\{x_t\}$ is stationary, it is possible to derive some of the properties of this model as follows:¹

$$E(x_t) = \mu = \frac{\phi_0}{1 - \phi_1} \quad \text{and} \quad Var(x_t) = \frac{\sigma_a^2}{1 - \phi_1^2} \quad (\text{B.3})$$

Since stationarity requires that both the mean and variance of x_t to be finite, i.e., $\phi_1 \neq 1$, and $Var(x_t) > 0$, thus $|\phi_1| < 1$ is a necessary and sufficient condition for B.2 to be stationary. This model can also be generalized to the AR(p) model:

$$x_t = \phi_0 + \sum_{j=1}^p \phi_j x_{t-j} + a_t \quad (\text{B.4})$$

where p is an integer such that $p > 0$, the sequence $\{a_t\}$ is i.i.d., and the first two moments—e.g., mean and variance, can be obtained as we showed above.

B.1.3.2 Moving Average Models

If we assume that $\{x_t : t = 1, \dots, T\}$ is explained by a sequence of random shocks, we can entertain the following moving average (MA) process:

$$x_t = c_0 + a_t - \theta_1 a_{t-1} \quad \text{or} \quad x_t = c_0 + (1 - \theta_1 B)a_t \quad t = 1, \dots, T \quad (\text{B.5})$$

where c_0 is a constant term, $\{a_t\}$ is defined as before, and B is referred to as the “back-shift” operator, i.e., $Ba_t = a_{t-1}$. Similar to the model in B.2, θ_1 is a parameter such that $|\theta_1| < 1$. When this requirement holds, the MA model is said to be invertible. If $|\theta_1| = 1$, then the MA model is noninvertible. The model in B.5 is known as moving average of

¹As mentioned, the term stationarity refers to as weakly stationary process. The stationarity assumption implies: $E(x_t) = \mu$, $Var(x_t) = \gamma_0$, and $Cov(x_t, x_{t-l}) = \gamma_l$, where μ and γ_0 are constant and γ_j is a function of j , or time invariant.

order one, or MA(1) model, and it assumes that x_t is a weighted average of the white noise processes a_t and a_{t-1} . A more general model, MA(q), is represented by:

$$x_t = c_0 + (1 - \theta_1 B - \dots - \theta_q B^q) a_t, \quad \text{with } q > 0 \quad (\text{B.6})$$

Since the sequence $\{a_t\}$ is i.i.d., uncorrelated, and it follows a distribution with mean and variance equals to $(0, \sigma_a^2)$, respectively, the first two moment of the MA(q) above can be easily derived as:

$$E(x_t) = c_0 \quad \text{and} \quad \text{Var}(x_t) = (1 + \theta_1^2 + \dots + \theta_q^2) \sigma_a^2 \quad (\text{B.7})$$

B.1.3.3 ARMA Models

It is possible to combine the models presented in subsections B.1.3.1 and B.1.3.2 into a more general class of models known as autorregressive moving-average, or ARMA(p, q) models. The ARMA(p, q) model assumes that the stochastic process $\{x_t\}$ does not only depend on its lagged values but also on a linear combination of the white noise process a_t . For instance, $\{x_t : t = 1, \dots, T\}$ follows an ARMA(1,1) model if:

$$x_t - \phi_1 x_{t-1} = \phi_0 + a_t - \theta_1 a_{t-1} \quad \text{or} \quad (1 - \phi_1 B) x_t = \phi_0 + (1 - \theta_1 B) a_t \quad (\text{B.8})$$

where it is required that $\phi_1 \neq \theta_1$. Notice, when $q = 0$ the model in B.8 is reduced to the simple AR(1) model case. Alternatively, if $p = 0$, then equation B.8 is equivalent to the MA(1) shown in B.5. The general form of the ARMA(p, q) model can be written as:

$$x_t = \phi_0 + \sum_{j=1}^p \phi_j x_{t-j} + a_t - \sum_{j=1}^q \theta_j a_{t-j} \quad (\text{B.9})$$

or, using the back-shift operator, B , the expression can be simplified as

$$(1 - \phi_1 B - \dots - \phi_p B^p)x_t = \phi_0 + (1 - \theta_1 B - \dots - \theta_q B^q)a_t \quad (\text{B.10})$$

Impulse Response Function. The impulse-response function (IRF) measures the impact of an exogenous shock on the series. To estimate this function, we can represent the ARMA(p, q) model in B.10 as a MA process:

$$x_t = \mu + a_t + \psi_1 a_{t-1} + \psi_2 a_{t-2} + \dots = \mu + \psi(B)a_t \quad (\text{B.11})$$

where μ is the mean value of x_t . Here, the coefficients $\{\psi_j\}$ are known as the IRF of the ARMA model and they measure the impact of the lagged shock a_{t-j} , for $j > 0$, on the current value of x_t . The stationarity assumption implies that $\psi_j \rightarrow 0$, as $j \rightarrow \infty$. This means that the effect of a_{t-j} on x_t decays over time.²

²To obtain the MA representation in B.11, I use the long division of the polynomials $\phi(B) = 1 - \sum_{j=1}^p \phi_j B^j$ and $\theta(B) = 1 - \sum_{j=1}^q \theta_j B^j$, so that

$$\frac{\theta(B)}{\phi(B)} = 1 + \psi_1 B + \psi_2 B^2 + \dots \equiv \psi(B)$$

and the mean of $\{x_t\}$ is obtained as $\mu = E(x_t) = \frac{\phi_0}{1 - \phi_1 - \dots - \phi_p}$. Please, see Tsay (2005, p. 62-63) for details.

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APPENDIX C

Biography of the Author

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Harold is originally from Santo Domingo, Dominican Republic (D.R.). After graduating with a B.A. in Economics at the Technological Institute of Santo Domingo (INTEC), he pursued a Master Degree in Finance at Carlos III University, Madrid, Spain (2002).

Afterwards, Harold returned to the D.R. to work as an economist at the Research Department at the Central Bank of Dominican Republic (2002-2005), while concurrently accepting a position as Assistant Professor of Economics at his alma mater, INTEC. He taught courses in Introductory Economics, Macroeconomics, and Public Finance. During his time at the Central Bank, the Dominican economy experienced one of its major financial crises (2002-2004), which resulted in the establishment of a stand-by agreement with the International Monetary Fund (IMF). Throughout the financial crisis, Harold worked for the team in charge of pursuing the stabilization policies and negotiating the terms of the IMF agreement.

Harold came to Andrew Young School of Policy Studies (AYSPS), Georgia State University, for his Master Degree in Economics (2005) and joined the Ph.D. program in 2007. While pursuing his doctorate, he worked as an intern at the Research Department of the

Federal Reserve Bank of Atlanta (2006-2008), and also as a Research Assistant at the International Studies Program of the AYSPS. He has won two Ph.D. awards at the AYSPS for his outstanding achievements in economics: the Atlanta Economics Club Award and the George Malanos Scholarship in Economics. He was chosen twice as VP for the Graduate Student Association of Economics and he volunteered in different organizations in Atlanta area, such as Operation Hope and Renovacion Conyugal. Currently, Harold is Deputy Director of Research at the Central Bank of Dominican Republic, where his duties involve the research, writing, and publishing of reports on the international economy. His professional research interests are public finance, corporate taxation, international finance, macroeconomics, econometrics, and time series analysis. Today, Harold lives in Santo Domingo.

Last updated: April 19, 2012