TECHNICAL APPENDIX FOR MEASURING THE BURDEN OF THE CORPORATE INCOME TAX UNDER IMPERFECT COMPETITION

APPENDIX A: THEORY

In this section we first summarize the Davidson and Martin (1985) (DM) model of the incidence of the corporate income tax under imperfect competition and then derive a comparative static result that describes how the degree of imperfect competition affects the incidence of the corporate income tax. The comparative static result presented in the last section suggests that the wage elasticity with respect to the corporate tax is an increasing function of the industry concentration level.

A1. Partial Equilibrium in the Corporate Sector

Suppose that there are *I* industries in the economy. Each industry has a corporate (imperfectly competitive) sector and a non-corporate (competitive) sector. The corporate sector has *N* firms. The corporate group plays a repeated game in which each firm produces constrained quantities of a single good *X* under constant cost. Constrained production maximizes the joint profit in the corporate sector subject to no cheating. If any firm cheats by producing a higher quantity at time *t*, every firm will revert permanently to the Nash output level. Each firm compares the current gain from cheating to the present value of profit loss by permanently producing at a lower output level. The net gains from cheating (*Z*) are

(A1) $$Z = (\pi^{ch} - \pi^{c}) - \frac{1}{r}(\pi^{c} - \pi^{n})$$

where π^{ch} denotes the profit from cheating, π^{c} the profit per firm under constrained production, π^{n} the profit per firm in the static Nash equilibrium, and r the price of capital, i.e. the interest rate.

Let Q_c denote the constrained production quantity per firm. The corporate sector chooses Q_c from the set of sustainable outputs defined as $Q \equiv \{Q_c : Z \leq 0, Q_c \geq 0\}$. The profit of the corporate group is:

(A2) $\pi^c = Q_c[P(X_c, \omega) - c]$

where $P(., \omega)$ is the inverse demand function for good X,[1] c the constant unit cost of production and ω is a vector of shift parameters. The static Nash profit is:

(A3) $\pi^n = \max_{Q_n} Q_n \{P[(N-1)\overline{Q} + Q_{n,\omega}] - c\}$

for which DM assume the existence of a symmetric solution. Lastly, the profit from cheating is:

(A4) $\pi^{ch} = \max_{Q_{ch}} Q_{ch} \{P[(N-1)Q_c + Q_{ch,\omega}] - c.$

Focusing on the special case in which the representative consumer has a utility function of the form: $U(X,Y) = (1-\alpha)\ln Y + \alpha X$, the inverse demand curve for X is:

(A5) $P_x = \dfrac{\alpha M}{X}$,

where M is the total income, and α is the budget share of good X.

Substituting (A5) into profit functions (A3) and (A4), DM solve for π^n and π^{ch}. Further substituting π^n, π^{ch} and π^c into equation (A1) and setting $Z(Q_c) = 0$, DM solve for Q_c as

(A6) $Q_c = \dfrac{\alpha M(N-1)(rN-1)^2}{cN^2(rN+1)^2}$.

The inverse demand curve for X now becomes

(A7) $P_x = \dfrac{N(rN+1)^2}{(N-1)(rN-1)^2} c.$

[1] $P(., \omega)$ is assumed to be single peaked and twice differentiable to guarantee a well-defined maximization problem.

In general, the inverse demand function under cooperation is a function of the basic parameters in the model:

(A8) $P_x = P_x(\omega, c, r).$

In the perfect competition case, r represents the net return to capital and affects the output price by increasing the cost of production c. Under imperfect competition, r enters (A8) as a separate argument. This separate effect captures the impact of the price of capital on the pricing decision of the corporate group. Specifically,

(A9) $$\frac{dP_x}{dr} = \frac{\partial P_x}{\partial c}\left(\frac{\partial c}{\partial r}\right) + \frac{\partial P_x}{\partial r}.$$

The first term in (A9) is positive since an increase in r increases the cost of capital. The second term in (A9) is negative since an increase in r represents a greater inducement to increase output, which leads to a lower price. It captures the additional effect of r on prices under imperfect competition. The overall impact of r on the price depends on the relative magnitude of these two effects.

A2. The Corporate Sector in General Equilibrium

Now consider the corporate sector as part of the standard two-sector general equilibrium model. There are two goods in each industry, X and Y. Perfect competition prevails in the Y sector, while the behavior of firms in the corporate sector (X) is characterized as above. Both sectors employ capital (K) and labor (L) both of which are fully mobile between sectors. All firms are price takers in the capital market.

Following standard notation, q_j is the gross-of-tax output price of good j, c_j the unit cost function for good j, w and r the net returns to labor and capital, respectively, T_j one plus the ad valorem output tax on good *j*, T_{ij} one plus the partial factor tax on input *i* used in the production of good *j*, and *M* the aggregate income.

Assuming $Z(Q_c) > 0$, the gross price in the corporate sector is given by

(A10) $q_x = q_x(q_y, M, c_x T_x, r)$.

Assuming perfect competition in the *Y* sector, the price of *Y* equals the marginal cost of production:

(A11) $q_y = c_y(wT_{Ly}, rT_{Ky})T_y$.

Aggregate demands for the two products are

(A12) $X = X(q_x, q_y, M)$,

(A13) $Y = Y(q_x, q_y, M)$,

and all income is spent in equilibrium

(A14) $M = q_x X + q_y Y$.

DM also assume fixed supplies of labor (L_0) and capital (K_0) and full employment:

(A15) $c_{Lx}X + c_{Ly}Y = L_0$,

(A16) $c_{Kx}X + c_{Ky}Y = K_0$,

where c_{ij} are the partial derivatives of the *j*th unit cost function with respect to the *i*th factor and represent the *i*th input requirement per unit of output of the *j*th good.

For simplicity, DM choose *w* as the numeraire and drop (A12) from the system, leaving six equations in six unknowns. Substituting the behavior of the corporate sector characterized by (A8) into (A10) yields

(A17) $q_x = \dfrac{N(rN+1)^2}{(N-1)(rN-1)^2} c_x T_x$.

Finally, differentiating (A11) and (A17) we get

(A18) $\hat{q}_x - \hat{q}_y = -(\theta^* + \Psi)\hat{r} + (\hat{T}_x + \hat{T}_y) + \theta_{Kx}\hat{T}_{Kx} - \theta_{Ky}\hat{T}_{Ky}$,

where the circumflex denotes proportional change, $\theta^* = \theta_{Lx} - \theta_{Kx}$ measures the value of factor intensity, and $\theta_{Lj} \equiv wc_{Lj}T_j / c_j$ measures labor's share in industry *j*. The second term $\Psi \equiv 4rN/[(rN)^2\text{-}1]$ captures the effect of change in *r* on the ability of the corporate sector to enforce its output restriction.

Differentiating and differencing the demand (A12)-(A13) and full-employment conditions (A15)-(A16) yields

(A19) $\hat{X} - \hat{Y} = -(\hat{q}_x - \hat{q}_y)$

(A20) $\lambda^*(\hat{X} - \hat{Y}) = -(a_x\sigma_x + a_y\sigma_y)\hat{r} - a_x\sigma_x\hat{T}_x - a_y\sigma_y\hat{T}_y$),

where $\sigma_j > 0$ the elasticity of substitution between *K* and *L* in the production of the *j*th good with respect to a change in relative rental prices, $\lambda^* \equiv \lambda_{Lx} - \lambda_{Kx}$ where $\lambda_{ij} \equiv c_{ij} / i_0$ measures the share of factor *i* in industry *j*, and $a_j \equiv \theta_{Kj}\lambda_{Lj} + \theta_{Lj}\lambda_{Kj} > 0$.

Equations (A18)-(A20) constitute a three-equation general equilibrium model with three unknowns: $\hat{X} - \hat{Y}$, $\hat{q}_x - \hat{q}_y$, and *r*. We now consider the incidence of a capital tax T_{Kx} in the corporate sector.

A tax on capital in the corporate sector T_{Kx} decreases the net return of capital *r*. Note that *r* has two effects on the oligopolistic sector: it allocates the fixed supply of capital between industries and measures time preference. In the latter role, the level of *r* determines the present value of profit loss due to cheating. A fall in *r* reduces the inducement to cheat, and allows the cartel to sustain a lower output and higher price.

In particular, by setting $\hat{T}_x = \hat{T}_y = \hat{T}_{Ky} = 0$ in (A18)-(A20) and solving for the elasticities of relative outputs, prices, and factor returns, the impact of a corporate income tax is characterized by the following system of equations:

(A21) $\hat{r}D^* = (\theta_{Kx}\lambda^* - a_x\sigma_x)\hat{T}_{Kx}$

(A22) $(\hat{X} - \hat{Y})D^* = -(\theta_{Ky}a_x\sigma_x + \theta_{Kx}a_y\sigma_y + a_x\sigma_x\Psi)\hat{T}_{Kx}$

(A23) $(\hat{q}_x - \hat{q}_y)D^* = (\theta_{Ky}a_x\sigma_x + \theta_{Kx}a_y\sigma_y + a_x\sigma_x\Psi)\hat{T}_{Kx}$,

where $D^* \equiv a_x\sigma_x + a_y\sigma_y + \lambda^*(\theta^* + \Psi)$ and is positive for stability.[2] As in the standard model of tax incidence, the corporate tax T_{Kx} induces an output effect $\theta_{Kx}\lambda^*$ and a factor substitution effect $a_x\sigma_x$ in the right-hand side of (A21). Recall that $\lambda^* \equiv \lambda_{Lx} - \lambda_{Kx}$ measures the relative factor intensity in the corporate sector. If the corporate sector is labor intensive, i.e. $\lambda^* > 0$, the output effect will increase *r/w*. On the other hand, the factor substitution effect will unambiguously decrease *r/w*. The effect of imperfect competition, Ψ, affects D^* in the same direction as the sign of the measure of physical factor intensity, λ^*. If the corporate sector is labor intensive, imperfect competition leads to a larger D^* and consequently a smaller elasticity.

A3. Comparative Statics with Imperfect Competition

We are particularly interested in how the tax effect on wages varies with industry concentration. To explore this question we derive the first-order condition of factor prices with respect to the number of firms in the corporate sector. Writing out equation (A21) explicitly, we have

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[2] See Davidson and Martin (1985) for a detailed discussion of the stability properties.

(A24) $\dfrac{\hat{r}}{w} = \dfrac{(\theta_{Kx}\lambda^* - a_x\sigma_x)}{a_x\sigma_x + a_y\sigma_y + \lambda^*(\theta^* + \Psi)}\hat{T}_{Kx}$.

Since percentage deviations from equilibrium equal the natural log-deviations up to first order, we have

(A25) $\ln w - \ln r = \dfrac{-(\theta_{Kx}\lambda^* - a_x\sigma_x)}{a_x\sigma_x + a_y\sigma_y + \lambda^*(\theta^* + \Psi)}\ln T_{Kx} + c,$

where $c = \ln w^* - \ln r^* - \ln T_{Kx}^*$, the difference in pre-perturbation equilibrium values. [3] Rearranging we get

(A26) $\ln w = \dfrac{-(\theta_{Kx}\lambda^* - a_x\sigma_x)}{a_x\sigma_x + a_y\sigma_y + \lambda^*(\theta^* + \Psi)}\ln T_{Kx} + \ln r + c.$

Denote η_{wT} the elasticity of wage with respect to the corporate income tax. It depends on the basic parameters as follows:

(A27) $\eta_{wT} \equiv \dfrac{\partial \ln w}{\partial \ln T_{Kx}} = \dfrac{-(\theta_{Kx}\lambda^* - a_x\sigma_x)}{a_x\sigma_x + a_y\sigma_y + \lambda^*(\theta^* + \Psi)}$.

Based on (A27), we derive two key observations. First, η_{wT} is negative if $\theta_{Kx}\lambda^* - a_x\sigma_x > 0$, for which a necessary condition is that the corporate sector in the U.S. is labor intensive. Second, η_{wT} depends on the degree of industry competitiveness. Specifically,

(A28) $\dfrac{\partial \eta_{wT}}{\partial N} = \dfrac{(\theta_{Kx}\lambda^* - a_x\sigma_x)\lambda^*}{[a_x\sigma_x + a_y\sigma_y + \lambda^*(\theta^* + \Psi)]^2}\dfrac{\partial \Psi}{\partial N}$.

As we know that

(A29) $\dfrac{\partial \Psi}{\partial N} = \dfrac{4r[(rN)^2 - 1] - 4rN[2(rN) \times r]}{[(rN)^2 - 1]^2} = \dfrac{-4r - 4r^3N^2}{[(rN)^2 - 1]^2} < 0,$

[3] T_{Kx}^* =0 before the introduction of capital tax in the X sector.

the elasticity of wage with respect to corporate tax rate decreases with the number of firms in the corporate sector if the corporate sector is capital intensive, or alternatively, if the corporate sector is labor intensive and the output effect dominates the factor substitution effect. For a given positive difference between the output and substitution effect, a small number of firms implies a large share of joint profit for each firm, and alternatively, a smaller gain from cheating. In this case, the tax-induced change in the return to capital would imply a large profit loss from diverting to a higher output level in present value. Consequently, the additional effect of corporate tax due to imperfect competition works in the same direction as the output effect, and has the strongest impact on wages in the least competitive industries.[4]

APPENDIX B:

DERIVATION OF A CONSISTENT INDUSTRY CLASSIFICATION

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[4] As a special case, $\frac{\partial \Psi}{\partial N} \rightarrow 0$ as $N \rightarrow \infty$. The wage elasticity converges to the standard prediction in a two-sector GE model.

We collect data from three major sources: the Bureau of Economic Analysis (BEA) Capital Flows for the calculation of effective tax rates, the Economic Census for the calculation of concentration ratio, and the IPUMS-CPS for individual-level information. Each data source uses a different industry classification system. The BEA's industry groups are based on the Standard Industrial Classification (SIC) system. The Census uses SICs for market concentration data, and the IPUMS-CPS uses the Census Industrial Classification (CIC) system. Each classification also changes over time. The SIC system was entirely replaced by NAICS in year 1997. To overcome the problems due to inconsistency among classification systems, we develop a unified industry classification for the period of analysis.

B1. The Unified Industry Classification

The first step in creating a unified industry series is to create the baseline industry categories. This baseline classification is constrained by the most aggregated classification system in the data sources, the industry groups in the 1992 BEA capital flow table. Following the industry classification of the 1992 national input-output accounts, the 1992 BEA capital flow table groups industries into 64 categories based on the 1987 SICs. Most grouping are based on the 2-digit SICs, while some are based on the 3-digit level.

We further refine this baseline classification due to cross-time matching constraint. Using a concordance between the 72 and 87 SICs, we wanted to assign the 80 industries in 1982 into the 64 groups as in the 1992 BEA data. However, while most industries are grouped at a more detailed 72 SIC level, a few are grouped at a more aggregated than their 82 counterparts.[5] These

[5] For example, information is only available for transportation and warehousing in 1972, while in 1982 detailed information are available for each of the subcategories including railroad transportation (40,474), local and interurban passenger transportation (41), trucking and warehousing (42), water transportation (44), transportation by air (45), pipeline, except natural gas (46), transportation services (472,473,478).

few exceptions require us to further aggregate industries to 41 categories based on the 2-digit 1987 SICs.[6]

B2. Match with SICs and NAICS

The second step is to match 72 SICs and 97 NAICs to the unified classification. For the first match, the 1987 Standard Industrial Classification manual provides a 4-digit code crosswalk between the 1972 and 1977 SICs and between the 1977 and 1987 SICs. Based on this correspondence, all the changes from 1972 to 1987 SIC industries are within the 41 categories. There are no crossover changes. The 72 SICs are directly mapped 87 SICs and the unified industry classes. For the match between 97 NAICS and 87 SICs, we use a crosswalk provided by the Census which links each 4-digit NAICS to their corresponding 4-digit 87 SICs. Although a 4-digit 1987 SIC can be assigned to multiple NAICS, this problem is minimized at 2-digit level, i.e. grouping NAICS by their 2-digit SICs. This is another advantage of our 2-digit SIC based classification system.

B3. Match with CICs

For this match, we rely on the census' classified index of industries and occupations, which provides a crosswalk between the title of each industry and its 3-digit SICs. We assign each CIC a unified industry number by further aggregating the 3-digit SICs at 2-digit level. The 1970 CICs are based on 1967 SICs and the 1990 CICs are based on 1987 SICs. We check group comparability across time using a crosswalk provided by the 1972 and the 1987 SIC manual. All the changes from 1967 to 1987 SIC industries are within the 41 categories. There are no crossover changes.

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[6] With the exception that the Transportation Equipment class is based on the 3-digit SICs.

Table A1
A Unified Industry Classification System

UIC	Industry Description	Related 87SIC
1	Agricultural Production	01,02
2	Agricultural Services, Forestry, and Fishing, Hunting and Trapping	07,08,09
3	Metal Mining	10
4	Coal Mining	12
5	Oil and Gas Extraction	13
6	Mining and Quarrying of Nonmetallic Minerals, Except Fuels	14
7	Construction	15,16,17
8	Food and Kindred Products	20
9	Tobacco Products	21
10	Textile Mill Products	22
11	Apparel and Other Finished Products	23
12	Lumber and Wood Products, Except Furniture	24
13	Furniture and Fixtures	25
14	Paper and Allied Products	26
15	Printing, Publishing, and Allied Industries	27
16	Chemicals and Allied Products	28
17	Petroleum Refining and Related Industries	29
18	Rubber and Miscellaneous Plastics Products	30
19	Leather and Leather Products	31
20	Stone, Clay, Glass, and Concrete Products	32
21	Primary Metal Industries	33
22	Fabricated Metal Products, Except Machinery and Transportation Equipment	34
23	Industrial and Commercial Machinery and Computer Equipment	35
24	Electronic and Other Electrical Equipment and Components, Except Computer	36
25	Motor Vehicles and Motor Vehicle Equipment	371
26	Transportation Equipment, Except Motor Vehicles	372-6,379
27	Measuring, Analyzing and Controlling Instruments	38
28	Miscellaneous Manufacturing Industries	39
29	Transportation	40-7
30	Communications	48
31	Electric, Gas, and Sanitary Services	49
32	Wholesale Trade and Retail Trade	50,51,52-7,59
33	Eating and Drinking Places	58
34	Finance and Insurance	60-4,67
35	Real Estate	65
36	Lodging, Personal, and Miscellaneous Repair Services	70,72,76
37	Business, Legal, Engineering, Accounting, Research, Management, and Related Services	73,81,87,89
38	Automotive Repair, Services, and Parking	75
39	Motion Pictures	78
40	Amusement and Recreation Services	79
41	Health, Educational and Social Services, Museums, Galleries and Zoos, Membership Organizations	80,82-84,86