Appendix of 'Capital Maintenance and Depreciation over the Business Cycle'

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April 2013

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A Technical Appendix

A.1 Steady state and determination of θ, ϕ and γ

Using equations (11) and (10) in the paper we get that in the steady state it must hold:

$$\psi\phi U^{\phi} = (1-\alpha)\gamma(1-\psi)\frac{Y}{K}e^{-\gamma\frac{M}{K}}$$

From the capital law of motion it also holds:

$$\frac{I}{K} = \xi\left[\psi U^{\phi} + (1-\psi)\, e^{-\gamma\frac{M}{K}}\right]^{\theta}$$

Equation (12) implies that:

$$\frac{1}{\beta} = \left[r^{*}U + (1-\frac{I}{K}) - \frac{M}{K}\right]$$

Moreover, equation (10) can be rewritten as:

$$\xi\theta\phi\psi\left[\psi U^{\phi} + (1-\psi)\, e^{-\gamma\frac{M}{K}}\right]^{\theta-1} U^{\phi-1} = r^{*}$$

Using the above equations, and imposing $U = 1$ in the steady state, we can derive the following conditions for the values of θ, ψ and ξ:

$$\theta = \frac{r^{*}\gamma + \phi}{\phi\gamma\frac{I}{K}}$$

$$\psi = \frac{r^{*}\gamma e^{-\gamma\frac{M}{K}}}{r^{*}\gamma e^{-\gamma\frac{M}{K}} + \phi}$$

$$\xi = \left(\frac{I}{K}\right)^{1-\theta}\left(\frac{r^{*}}{\theta\psi\phi}\right)^{\theta}$$

A.2 Log-linear conditions

The log-linear first-order conditions are given by the following set of equations (hatted variables denote log-deviations from steady-state values):

$$\theta_n \hat{h}_t + \hat{\eta}_t^h = -\sigma \hat{C}_t + \hat{Y}_t - \hat{h}_t$$

$$\left[\gamma \frac{M}{K} + \frac{\theta - 1}{\theta} \frac{M}{I}\right] (\hat{K}_t - \hat{M}_t) + \frac{\theta - 1}{\theta}(1 - \alpha)\frac{Y}{I}\hat{U}_t - \hat{Z}_t = 0$$

$$\frac{(\theta - 1)}{\theta}\frac{M}{I}(\hat{K}_t - \hat{M}_t) + \left[\phi + \frac{\theta - 1}{\theta}(1 - \alpha)\frac{Y}{I}\right] \hat{U}_t - \hat{Z}_t - \hat{Y}_t + \hat{K}_t = 0$$

$$\begin{aligned} -\sigma \hat{C}_t - \hat{Z}_t - b\hat{K}_t + \hat{\eta}_t^u = -\sigma \hat{C}_{t+1} + \beta b \hat{K}_{t+2} + \beta(1 - \alpha)\frac{Y}{K}\hat{Y}_{t+1} \\ -\beta(1 - \alpha)\frac{Y}{K}\hat{U}_{t+1} - \beta(1 - \delta)\hat{Z}_{t+1} - \left[b(1 + \beta) + \beta(1 - \alpha)\frac{Y}{K}\right] \hat{K}_{t+1} + \hat{\eta}_{t+1}^u \end{aligned}$$

$$\frac{I}{K}\hat{I}_t + \frac{I}{K}\hat{Z}_t = \hat{K}_{t+1} - \left[(1 - \delta) - \frac{M}{K}\right] \hat{K}_t + (1 - \alpha)\frac{Y}{K}\hat{U}_t - \frac{M}{K}\hat{M}_t$$

$$\hat{Y}_t = (1 - \alpha)(\hat{K}_t + \hat{U}_t) + \alpha(\hat{X}_t + \hat{h}_t)$$

$$\hat{Y}_t = \frac{C}{Y}\hat{C}_t + \frac{I}{Y}\hat{I}_t + \frac{M}{Y}\hat{M}_t + \frac{G}{Y}\hat{G}_t$$

The above seven equations describe the path of the seven endogenous variables of the model: output $\hat{Y}_t$, utilization $\hat{U}_t$, capital $\hat{K}_t$, hours $\hat{h}_t$, consumption $\hat{C}_t$, investment $\hat{I}_t$, and maintenance $\hat{M}_t$.

B Data Appendix

B.1 Canada

The first part of the Data Appendix describes briefly first the dataset from the Canadian survey on 'Capital and Repair Expenditures'. Private firms, households and government organizations in Canada were asked in an annual survey over the period 1956-1993 about their capital and repair expenditures on equipment and structures. The survey (conducted after 1993 in an updated form) is a census with a cross-sectional design and a sample size of 27,000 units; the target population is all Canadian businesses and governments from all the provinces and territories in Canada and the response rate is roughly 85%. Prior to the selection of a random sample, establishments are classified into homogeneous groups (i.e. groups with the same NAICS codes, same province/territory etc).

Capital expenditures are gross expenditures on fixed assets, which are assumed to cover spending devoted to 'new' investment, in accordance to the broad definition given earlier. These include expenditures on (i) fixed assets (such as new buildings, engineering, machinery, and equipment) which normally have a life of more than 1 year, (ii) modifications, additions, major renovations, and additions to work in progress (iii) capital costs such as feasibility studies and general (architectural, legal, installation and engineering) fees, (iv) capitalized interest charges on loans with which capital projects are financed, (v) work by own labor force. On the other hand, repair expenditures cover spending devoted to 'maintenance' cost, again in accordance to the broad definition given earlier. These expenditures cover (i) maintenance and repair of nonresidential buildings, other structures, and on vehicles and other machinery, (ii) building maintenance (janitorial services, snow removal, sanding), (iii) equipment maintenance (such as oil changes and lubrication of vehicles and machinery), (iv) repair work by own and outside labor force machinery and

equipment.

The following variables from the Canadian Survey on Capital and Repair Expenditures of Canada Statistics were used for capital and repair expenditures. Backward values for the manufacturing sector up to 1956 were obtained by using the growth rates for capital expenditures (the growth rates for 1992 and 1993 are common for the two surveys) and then by extrapolating the series for repair expenditures through their share in total capital and repair expenditures over 1956 to 1993.

- Capital expenditures in manufacturing, machinery and equipment: variable v754442 [D878253], 1994 to 2005, and variable v62547 [D842202], 1956 to 1993.

- Repair expenditures in manufacturing, machinery and equipment variable v754445 [D878256], 1994 to 2005, and variable v62550 [D843232], 1956 to 1993.

The rest of the Canadian variables used in the paper and their sources are as follows.

- *Manufacturing capital stock in machinery and equipment*: manufacturing sector end-year capital stock, variable v1071437 [D819523], 1955 to 2007 (Canada Statistics, Table 031-0002, current prices).

- *Manufacturing output*: Gross value added in manufacturing (source: OECD, Gross Domestic Product: B1GD), available from 1981 onwards. Backward values were extrapolated by using the industrial production index (source: International Financial Statistics, variable: 15666..CZF...) and the industrial selling price index (source: International Financial Statistics, variable: 15663...ZF...).

- *Manufacturing employment*: index 2000=100 (source: International Financial Statistics, variable 15667EY.ZF...).

- *Hours worked*: Annual average number of hours worked for all jobs; Non-durable manufacturing, index 1992=100 (source: Canada Statistics). The number of hours worked in all jobs is the annual average for all jobs times the annual average hours worked in all jobs. According to the retained definition, hours worked means the

total number of hours that a person spends working, whether paid or not. In general, this includes regular and overtime hours, breaks, travel time, training in the workplace and time lost in brief work stoppages where workers remain at their posts. Time lost due to strikes, lockouts, annual vacation, public holidays, sick leave, maternity leave or leave for personal needs are not included in total hours worked.

- *Consumption*: Annual nominal consumption in million Canadian dollars (source: Penn World Tables). It is obtained by multiplying consumption share of GDP per capita (variable: cc) times GDP per capita (variable: cgdp) and total population (variable: POP).

- *Capital utilization*: Industrial (total non-farm goods producing industries) capacity utilization rate (source: Canada Statistics, variables v142812, Table 028-0001, percent), averaged from quarterly data available from 1962 onwards. Backward values were extrapolated by fitting a linear regression on total fixed non-residential capital stock for all industries (source: Canada Statistics, variable: D99027311000) divided by Canada Gross National Product (source: International Financial Statistics, variable 15699A.CZF).

- *Industrial selling price index*: Industrial selling price index (source: International Financial Statistics, variable: 15663...ZF...)

- *Population*: Population 15-64 (source: OECD, ALFS Summary Tables).

Maintenance, total investment, capital stock, consumption and output were deflated with the industrial selling price index and divided by total working population 15-64. Hours per worker were obtained by multiplying manufacturing employment and hours worked and dividing by total working population 15-64, as in Smets and Wouters (2007).

B.2 United States

The following variables for U.S. manufacturing data (NAICS classification) were used.

- *Manufacturing output*: Total value added in million US dollars from Becker and Gray (2009), variable vadd, period 1958-2005. The series was extrapolated for years 2006-9 using the growth rate of value added from the U.S. Census Annual Survey of Manufacturers (Table: Statistics for Industry Groups and Industries). The item is derived by subtracting the cost of materials, supplies, containers, fuel, purchased electricity, and contract work from the value of shipments (products manufactured plus receipts for services rendered), adjusted by the addition of value added by merchandizing operations plus the net change in finished goods and work-in-process between the beginning and end of year inventories.

- *Hours worked*: Production worker hours in millions from Becker and Gray (2009), variable prodh, period 1958-2005. The series was extrapolated for periods 2006-9 using the growth rate of production workers hours from the U.S. Census Annual Survey of Manufacturers (Table: Statistics for Industry Groups and Industries). The item covers all hours worked or paid for at the manufacturing plant, including actual overtime hours (not straight-time equivalent hours). It excludes hours paid for vacations, holidays, or sick leave when the employee is not at the establishment.

- *Capital expenditures*: Total capital expenditures in million US dollars from Becker and Gray (2009), variable invest, period 1958-2005. The series was extrapolated for years 2006-9 using the growth rate of total capital expenditures from the U.S. Census Annual Survey of Manufacturers (Table: Statistics for Industry Groups and Industries). The item represents the total new and used capital expenditures reported by establishments in operation and any known plants under construction. These data include expenditures for permanent additions and major alterations to manufacturing and mining establishments, new and used machinery and equipment used for replacement and additions to plant capacity, including work done by contract, as well as by the establishment's own workforce. Capital expenditures for machinery-equipment and buildings & other structures were obtained by using the average shares of these expenditures over the period 2002-2009, reported in the U.S.

Census Annual Survey of Manufacturers (Table: Statistics for Industry Groups and Industries).

- *Capital stocks*: Real capital stocks (total, equipment, structures) in million US dollars from Becker and Gray (2009), variables cap, equip, plant, period 1958-2005. The series were converted in current U.S. dollars using the investment deflator from Becker and Gray (2009), variable piinv and extrapolated for years 2006-9 assuming a constant capital-output ratio and constant shares for equipment and structures.

- *Capital utilization*: Capacity utilization in manufacturing for years 1958-2009 was obtained using the historical series from the Board of Governors of the Federal Reserve System (Table G.17).

- *Consumption*: Annual nominal consumption in million US dollars (source: Penn World Tables). It is obtained by multiplying consumption share of GDP per capita (variable: cc) times GDP per capita (variable: cgdp) and total population (variable: POP).

- *Population*: Population 15-64 (source: OECD, ALFS Summary Tables).

- *Producer Price Index*: Producer Price Index: All Commodities (source: U.S. Department of Labor, Bureau of Labor Statistics).

Capital expenditures, capital stock, consumption and output were deflated with the Producer Price Index and divided by total working population 15-64. Hours per worker were obtained by dividing Hours worked by total working population 15-64, as in Smets and Wouters (2007).