

APPENDIX A

A Brief Review of Abel (1983):

Suppose the firm is risk neutral and maximizes the expected present value of its cash flow subject to the capital accumulation:

$$V(K_t, p_t) = \max_{I_s, L_s} E_t \int_t^{\infty} [p_s L_s^\alpha K_s^{1-\alpha} - wL_s - \mathcal{I}_s^\beta] \exp(-r(s-t)) ds$$

From maximizing we get:

$$I_t = \left(\frac{q_t}{\beta\gamma} \right)^{\frac{1}{\beta-1}}$$

where

$$q_t = \frac{hp_t^{\frac{1}{1-\alpha}}}{r + \delta - \frac{\alpha\sigma^2}{2(1-\alpha)^2}} \quad (1)$$

and

$$h = (1-\alpha)(\alpha/w)^{(\alpha/(1-\alpha))}$$

where r is the discount rate, δ is the rate of depreciation and σ^2 denotes the variance. This equation shows that the optimal rate of investment is an increasing function of q_t ¹ and I_t depends on q_t and is independent of K_t . Since, I_t is increasing function of q_t and depends on it, we can determine the qualitative effect of uncertainty on investment simply by analyzing the effect of uncertainty on q_t . From (1) it is clear that for a given level of the current price of output p_t , an increase in uncertainty, as captured by an increase in σ^2 , will increase I_t , and it is independent of the convexity of marginal adjustment function.

¹ - It is known as “marginal q ”.

A Summary of Solving the Maximization Problem by Pindyck (1991):

We want a rule that maximizes the value of our investment opportunity $F(V)$:

$$F(V) = \max E_t[(V_t - I)e^{-\mu t}]$$

Hence, after some substitutions and simplicity we will have

$$\frac{1}{2}\sigma^2 V^2 F_{VV} + (\mu - \delta)VF_V - \mu F = 0 \quad (2)$$

Now suppose the price of output P follows the stochastic process:

$$dP = \alpha P dt + \sigma P dz$$

And assume that $\alpha < \mu$. If the output is a storable commodity, δ will represent the net marginal convenience yield from storage, that is, the flow of benefits (less storage costs) that the marginal stored unit provides. For simplicity we assume that δ is constant and marginal and average production cost is equal to a constant, C and that the project can be cheaply shut down if P becomes less than C and then can be restarted if prices goes above the C . Another assumption is that the project produce one unit per period, it is infinitely lived and invests sunk cost of I . With these assumptions two problems are to be solved. First, finding the value of the project $V(P)$. Second, with the value of the project in hand, we must value the firm's option to invest in it, and determine the optimal exercise (investment) rule. This will reduce to finding a critical P^* , where the firm invest only if $P \geq P^*$. In a same way that we reached to equation (2) we will have:

$$\frac{1}{2}\sigma^2 P^2 V_{PP} + (r - \delta)PV_P - rV + j(P - C) = 0 \quad (3)$$

That $j=1$ if $P \geq C$ and $j=0$ otherwise. This equation must be solved subject to the following boundary conditions:

- I) $V(0)=0$
- II) $V(C^-)=V(C^+)$

$$\text{III) } V_P(C^-) = V_P(C^+)$$

$$\text{IV) } \lim_{P \rightarrow \infty} V = \frac{P}{\delta} - \frac{C}{r}$$

The condition (IV) says that as P becomes very large the probability that over any finite time period it will fall below cost and production will cease become very small.

The conditions (II) and (III) show that the value of the project, is a continuous and smooth function of P . The solution for equation (3) will yield:

$$V(P) = \begin{cases} A_1 P^{\beta_1} & P < C \\ A_2 P^{\beta_2} + \frac{P}{\delta} - \frac{C}{r} & P \geq C \end{cases}$$

and

$$\beta_{1,2} = \frac{1}{2} - \frac{r - \delta}{\sigma^2} \pm \left[\left(\frac{r - \delta}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2} \right]^{\frac{1}{2}}$$

That $\beta_1, \beta_2, A_1, A_2$ are functions of r, δ, σ and C . When $P < C$ then project is not producing, then, $A_1 P^{\beta_1}$ is the value of the option of the firm to produce in the future, when price increase. When $P \geq C$ the project is producing. If firm continuous to produce in future, the present value of the future flow of profits would be given by $\frac{P}{\delta} - \frac{C}{r}$. Whenever P fall, the firm can stop producing and avoid losses the value of its options to stop producing is $A_2 P^{\beta_2}$. To solve the second problem, similarly the value of the firm's option to invest, $F(P)$ must satisfy the:

$$\frac{1}{2} \sigma^2 P^2 F_{PP} + (r - \delta) P F_P - r F = 0$$

Subject to

$$\text{I) } F(0) = 0$$

$$\text{II) } F(P^*) = V(P^*) - I$$

$$\text{III) } F_P(P^*) = V_P(P^*)$$

The solution is

$$F(P) = \begin{cases} \alpha P^{\beta_1} & P \leq P^* \\ V(P) - I & P > P^* \end{cases}$$

That α , β_1 and β_2 are the functions of r , δ , σ , and P^* that P^* is the solution to

$$\frac{A_2(\beta_1 - \beta_2)}{\beta_1} (P^*)^{\beta_2} + \frac{\beta_1 - 1}{\delta \beta_1} P^* - \frac{C}{r} - I = 0$$

That can be simply solved numerically. The study indicates in a diagram that an increase in σ can lead to an increase in $V(P)$ for any P . The project is a set of call options on future production, so, the greater the volatility of prices, the greater the value of these options. Increase in σ also increases the critical price P^*

because $\frac{\partial P^*}{\partial \sigma} > 0$. The reason is that for any P , the opportunity cost of investing $F(P)$

increases even more the $V(P)$. So, increases uncertainty, reduces investment.

Unit Root Test

The first challenge that must be dealt with is detection of unit root in the data to avoid spurious regression. There are some types of unit root tests in panel level, Maddala and Wu (1999), Levin, Lin and Chu (2002), Im, Pesaran and Shin (2003) (Unlike the two later, Fisher test of Maddala and Wu does not need to complete panel so I utilize this test for detection of unit root in data). This test combines the p-values from N independent unit root tests. Based on the p-values of individual unit root tests, Fisher's test assumes that all series are non-stationary under the null hypothesis against the alternative that at least one series in the panel is stationary. Table-5 shows the results of the test on variables. There is evidence that shows we cannot accept the null hypothesis of non-stationarity in all variables. So, no one of the variables in this panel has unit root. Hence, we can proceed without any concern about spurious regression.

Equations Applied in the Study

Equations used in different panels are presented here. Subscriptions i and t , which are applied to indicate unites and time respectively, are eliminated except where that their elimination are misleading.

1- Changes in policies and macroeconomics outcomes:

$$\ln pri = c + c_i + \beta_1(\ln dcp) + \beta_2(\ln exrdi) + \beta_3(\ln growth) + \beta_4(\ln tot) + \beta_5(\ln t) + \beta_6(\ln inf l) + \varepsilon$$

$$\ln pri = c + c_i + \beta_1(\ln dcp) + \beta_2(\ln exrdi) + \beta_3(\ln growth) + \beta_4(\ln tot) + \beta_5(\ln t) + \beta_6(\ln int) + \varepsilon$$

2- Socio-political institutions and conflicts:

$$\ln pri = c_i + \beta_1(dem) + \beta_2(war) + \beta_3(cwr) + \beta_4(ass) + \beta_5(stkptm) + \beta_6(prgptm) + \beta_7(ritptm) + \beta_8(rev) + \varepsilon$$

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3- Quality of public governance:

$$\ln pri = c + c_i + \beta_1(rgq) + \beta_2(cor) + \beta_3(rol) + \beta_4(\ln prt) + \beta_5(\ln gin) + \varepsilon$$