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ABSTRACT

Option Pricing and Foreign Investment under Political Risk*

The Paper analyses foreign investment and asset prices in a context of uncertainty over future government policy. The model endogenizes the process of learning by foreign investors facing a potentially opportunistic government, which chooses strategically the timing of a policy reversal in order to attract more capital. We characterize the evolution of confidence, investment and asset prices over time, as well as perceived policy risk. Quite generally, perceived risk abates as current policy is maintained, leading to a gradual appreciation of asset prices and a gradual decrease in their conditional variance. The approach thus provides a measure of the evolution over time of perceived political risk from market prices. We next compute option prices under the process generated by the model's hazard rate of policy reversal plus an additional market risk component. We show that both the time series and the term structure of conditional volatility in general is downward sloping and its overall level falls steadily over time, although it may exhibit initially a hump shape in the case of very low initial reputation. Another testable implication is that in price series without a policy reversal, implied volatility from option prices will exceed actual volatility. Over time and in the absence of a reversal, this wedge progressively disappears. This may be viewed as the volatility analogue of the 'peso premium' for assets subject to large, infrequent price drops.

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NON-TECHNICAL SUMMARY

International capital flows have vastly expanded until the recent crisis; foreign direct investment volumes and emerging market prices have risen, incorporating the effect of international diversification as a result of financial integration. The rise has taken place at first tentatively and has progressively accelerated until the recent crisis.

The time path of foreign direct investment is quite comparable across countries. The initial flows were small, accelerating over time, reflecting high *ex post* profitability of early experiences and leading into a dramatic climb at a late stage.

This gradual build-up, mirrored in the time pattern of returns on the local capital markets, is consistent with various explanations. A simple argument has to do with logistics: it takes time to train and build capacity. However this simple explanation cannot account for the parallel progressive acceleration in portfolio flows. Alternatively, investment delays may arise because there is value in waiting to invest when some fundamental uncertainty is resolved only over time. This explanation raises the question of what is the source of uncertainty and how this 'learning hypothesis' may be tested against models without a gradual resolution of uncertainty.

Modelling political uncertainty is a novel challenge for financial economists. The recent crisis has shown that integration introduced a new type of risk for investors. Evolving legal, political and economic circumstances have created both opportunities and novel risks for which traditional pricing and risk management models have proven inadequate. This has advanced the notion that policy uncertainty is priced.

In this Paper we investigate the characteristics of political risk in a fundamental fashion, both empirically and theoretically.

Previous work has focused on modelling political risk as a non-systematic jump process with exogenous stochastic characteristics. There are at least two serious objections to this approach. First, the recent experience of emerging market crises happening simultaneously raises the question as to whether emerging market pricing reflect a systematic risk premium. Second, this approach ignores significant advances in the analysis of the political economy of the reform process, which should allow researchers to model more closely the underlying process of uncertainty in order to test its implications to the data.

In this Paper we study the impact of government policy uncertainty on foreign investment and financial asset prices. We analyse the time series of foreign investment and asset prices in a context of uncertainty over future government policy. The model endogenizes the process of learning by foreign investors facing a potentially opportunistic government, which chooses strategically the timing of a policy reversal in order to attract more capital.

The model thus generates endogenous hazard rates of policy reversal. We use the time profile of endogenous political risk to characterize the evolution of confidence, investment and asset prices over time, as well as perceived policy risk, as a *mixed diffusion-jump process*. Quite generally, perceived political risk abates as the announced reform policy is maintained. This results in asset price appreciation and in a gradual decrease in the conditional variance of the price series.

Since the model has implications for the conditional expectations of future volatility, its implications for political risk can be naturally assessed by examining the implied volatility of options written on financial assets exposed to such political risk. The model thus offers a chance to estimate both time series and term structure of volatility on assets exposed to political risk using a structural model. In contrast, existing models with exogenous parameters fix these values by assumption.

In order to test the model's implications on expected volatility we compute option prices under the generated hazard rates for policy reversal and general market risk. We show via simulations that both the time series and the term structure of implied volatilities in general is downward sloping and its overall level falls steadily over time, although it may initially exhibit a hump shape for certain parameter values (essentially, extremely low initial credibility).

An additional implication of the approach is that in time series without a policy reversal, implied volatility from option prices will exceed actual volatility. Over time and in the absence of a reversal, this wedge progressively disappears with improved perceptions about government credibility. This may be viewed as the volatility analogue of the 'peso premium'.

The method thus provides a measure of the evolution over time of perceived political risk from market prices.

A prudent ruler ought not to keep faith when by so doing it would be against his interest, and when the reasons which made him bind himself no longer exist.

Niccolo' Machiavelli, "The Prince"

1 Introduction

In recent years, the emphasis on the financing of development has shifted from debt to equity and from governments to the private sector. A remarkable rise in foreign direct investment has taken place in reforming economies, at first tentatively and then progressively accelerating, until the recent crisis.

The time path of foreign direct investment is quite comparable across countries. The initial flows were small, accelerating over time, reflecting high ex post profitability of early experiences, and leading into a dramatic climb at a late stage. Figure 1 describes the time series of foreign direct investment capital committed to the People's Republic of China between 1983 and 1998.

This gradual buildup, mirrored in the time pattern of returns on the local capital markets, is consistent with various explanations. A simple argument has to do with logistics: it takes time to train and build capacity. However this simple explanation cannot account for the parallel progressive acceleration in portfolio flows. Investment delays may arise because there is value in waiting to invest when some fundamental uncertainty is resolved only over time (see McDonald and Siegel 1986). Another explanation is that learning about local productivity takes place sequentially (e.g., Chamley and Gale 1994; Thimann and Thum 1998). The latter two explanations raise the question of what is the source of uncertainty, and how this "learning hypothesis" may be tested against models without a gradual resolution of uncertainty.[1]

The fastest rising destination of foreign investment has been economies whose governments had announced market-oriented reforms. In our opinion, this trend reflects diffused expectations that these countries are progressively moving towards a market economy, and a more reliable legal and taxation system. However, since sovereign governments may reverse economic reforms, policy and political risk considerations remain paramount for foreign

[1] An example is the approach taken by Thomas and Worrall [1994], who argue that gradual investment is the result of strategic interaction in the face of expropriation risk, assuming complete certainty and coordination among investors.

investors in developing economies, as the recent crisis in Latin America and financial instability in South-East Asia confirmed. We believe that the progressive decline in perceived political risk has played an important role in explaining this pattern.[2]

There is an expanding empirical literature on the effect of political risk on financial prices. Bailey and Chung (1995) document systematic political risk factors being priced through risk premiums in cross-sections of equity returns on the Mexican Bolsa. In various papers analyzing country risk, Erb, Harvey, and Viskanta (EHV) (1996a, 1996b) find evidence of political risk being priced in expected equity returns of developing economies. EHV (1996) find that Institutional Investor's country credit ratings, a proxy for political (and other) risks, can explain cross-sectional variation in equity returns and volatility. Kim and Mei (1994) show that China-related political factors have a significant effect on Hong Kong stock price movements. In a recent paper studying the impact of capital market liberalizations on various emerging markets, Bekaert and Harvey (1998) find a reduction in the cost of capital after liberalization, while volatility is hardly impacted.

Political risk was historically related to the risk of asset seizures, although value may be also captured via other means such as regulatory policy. The early theoretical literature on expropriation since Eaton and Gersovitz (1984) has focused on the risk of debt repudiation. On the real investment side there have been recent contributions by Rodrik (1991) and Laban (1991) on the impact of uncertainty over policy reform. In most of this line of work, the timing of a potential policy shift is exogenous.

This paper tackles explicitly the modelling of political risk, drawing inspiration from the macroeconomic literature on time-inconsistency of monetary and fiscal policy (e.g., Barro and Gordon 1983, Barro 1986, and Fischer 1986). In this literature rational investors recognize that, as a sovereign entity, the government cannot commit not to change its policy. To date there has been little research on its implications for investment and asset pricing.

We model explicitly the dynamics of policy uncertainty and its effect on foreign investment and asset prices. Our approach is closely related to models of uncertainty over government intention (see Backus and Driffill 1985; Cukierman and Meltzer 1986). The closest reference is Barro (1986),

[2]The sources of political risk include time inconsistent taxation and legal systems, capital expropriation and nationalization policies, the imposition of foreign exchange and capital controls, and the institution of tariffs and barriers.

who studies the timing of a surprise strategy by an opportunistic government in charge of monetary policy. We focus here on the case where a government may encourage capital investment by promising a favorable tax framework, but once capital accumulation has taken place, it may prefer to expropriate it.[3]

Our model shows that a reform policy maintained for some time may in fact conceal an opportunistic policymaker "biding its time" prior to changing the rules of the game.[4] As a result, investors will be reassured only gradually about the stability of any market reform. By characterizing the optimal intertemporal strategy of an uncommitted government, the model endogenizes the entire time path of hazard rates. The results are intuitive: as time elapses without a policy shift, government credibility grows, and so does foreign investment. Using the equilibrium dynamics of confidence building, we also derive testable implications on the time path of prices, investment, and potential risk for shares representing equity claims on foreign investment.

In our model, lack of news is good news, and asset prices increase if nothing happens. Thus we obtain a so called "peso premium": the time series of prices can exhibit excess returns and positive serial correlation in the absence of policy changes. Since it is difficult to draw precise inferences from realized returns, we focus on the empirical implications in terms of expected future volatility.

While this measure cannot be extracted from a time series on physical investment or asset prices, it can be obtained from the *implied volatility* embedded in option prices on assets exposed to political risk. We thus develop an option pricing model based on the endogenous underlying price process, inclusive of political risk. In order to do that, a set of simulations of the price path of financial assets exposed to political risk is generated using the current model, after adding an independent market uncertainty component.[5]

The option pricing approach allows us to compare the impact of political risk on both the implied stock price volatility and realized volatility. By pricing a range of options and simulating their price evolution over time

[3]This can reflect either pure opportunism (political risk) or ex post opportunism (policy risk).

[4]A theoretical treatment of strategic transmission of information is in Sobel [1985], where an informed agent may incur short term costs to gain credibility and increase its payoff from a surprise move.

[5]Adding a market risk factor is necessary to apply the model to price data, since high frequency events are as significant for daily asset pricing as large events.

we extract the term structure of Black-Scholes implied volatilities for these options. We show that both the time series and the term structure of conditional volatility in the absence of policy changes are downward sloping and their overall level falls steadily over time; only in the case of a very low initial reputation will the time series of implied volatility potentially have an initial hump shape, with perceived price risk soon starting to gradually decline over time.

We also show that the time series of implied volatilities extracted over a period without policy shifts will exceed actual price volatility, reflecting the persistence of a possible policy reversal. In the absence of a reversal, this wedge progressively disappears. This can be interpreted as providing an equivalent measure of the classic "peso premium" in terms of the second moment of the price distribution. This approach can be used to extract information from option prices on the perceived dynamics of political risk.

The next section presents a model of capital investment which endogenizes the probabilistic timing of a possible policy shift, and derives the time profile of foreign investment, its valuation and its risk. In the third section we compute option prices based on a lattice of potential asset prices generated by the theoretical political risk model augmented by a generic market risk factor.[6] We then describe the empirical implications of the model in terms of implied volatility. The final section concludes and offers thoughts for further research.

2 Capital Investment under Policy Uncertainty

At time 0, the government announces a fiscal policy favorable to foreign investors.[7] The government may be either contrary or favorable to a future tax on foreign capital; we refer to the former as committed, denoted by C, and to the latter as opportunistic, or uncommitted, denoted by U. A committed government is averse to taxation, while the other maximizes the expected stream of tax revenues, discounted at a rate δ per period. Investors are uncertain about government preferences and motives, and assign prior beliefs p_0 and $1 - p_0$ to government type, respectively. We will refer to p_t as

[6]While it would be easy to introduce market risk explicitly in the model of Section 2, this would have no impact on the equilibrium strategy as it is capital and not profits which is seized by the government.

[7]The notion of fiscal burden should be taken broadly to include regulatory costs.

the government credibility, or reputation for commitment, at time t. Both the government and foreign investors are risk neutral; alternatively, investors can fully diversify the political risk of a single country in their international portfolios.

The government is unable to credibly reveal its type; we rule out any ex ante revealing signal such as upfront subsidies to foreign investors. Thus investors can ascertain its policy intentions only by observing its actual choices. The game is played over an infinite horizon, $t = 0, 1, ..., \infty$. (This is not crucial to our results). In each period, the government strategy space is $\{0, \tau\}$, i.e., it may choose either to impose a tax rate on invested capital, or not at all.[8]

Capital investment is fully reversible and can be costlessly scaled down within one period; alternatively, the capital stock fully depreciates in one period. The pretax cost of capital, denoted by r, is constant and equals the risk-free rate. The technology is represented by a twice differentiable production function $R(K)$, with $R'(\cdot) > 0, R''(\cdot) < 0$, and $R'(0) = \infty$. The only source of uncertainty is the tax policy of the government. In other words, investors have a choice between a linear, nontaxable technology (lending), and a concave technology subject to taxation risk (capital investment). In each period, first investors decide how much to invest, then the government decides its tax policy, and finally output is realized.

We solve for the Perfect Bayesian Equilibrium (PBE), described for each $t > 0$ by:

1. the government reputation p_t, namely the posterior beliefs of investors about the likelihood of government commitment. As investors are rational, this is computed from their priors, p_{t-1}, according to Bayes' rule using the equilibrium strategy of the two types;

2. the optimal strategy for both types of government. Under the general case of mixed strategies, this will be described by a sequence of randomizing probabilities over $\{0, \tau\}$. The choice of strategy for each type is the probability with which it chooses to tax at time t, which is denoted by μ_t for an opportunistic government and by λ_t for a committed

[8] A capital levy may also be chosen when there is an immediate need for large revenues, when profits are nonverifiable or simply when invested capital is the only asset which can be seized.

type, where

$$t = 1, 2, .., \infty;$$
$$0 \leq \mu_t \leq 1 \quad \text{and} \quad 0 \leq \lambda_t \leq 1.$$

3. an investment rule K_t for the investors, which is a function of the history of the game as well as their own beliefs about the future policy of the government.

2.1 The Optimal Capital Investment Strategy

Investors choose their investment given the risk of an opportunistic change in policy.[9] By assumption, the committed government is strongly averse to capital taxation, so its optimal strategy is trivially a pure strategy: λ_t equals zero for all $t \geq 0$. However, agents recognize that if the government is not committed, it will tax their investment with probability μ_t. Let Θ_t denote the subjective probability at time t of the government announcing a capital levy in the current period. Its value equals:

$$\begin{aligned}\Theta_t &\equiv Pr[\text{tax at } t] = Pr[\text{tax at } t \mid U]Pr[U] + Pr[\text{tax at } t \mid C]Pr[C] \\ &= \mu_t(1 - p_t) + \lambda_t p_t = \mu_t(1 - p_t)\end{aligned}$$

where C and U denote a committed and uncommitted government, respectively.

Since capital fully depreciates in each period, investors choose the capital stock on the basis of its expected one period after-tax return, equating marginal productivity of capital to its expected aftertax cost. Thus an investing firm chooses in each period its optimal investment program K_t so as to:

$$\max_{\{K_t\}} \{\mathrm{E}_t[R(K_t) - (r + \tau I_t)K_t]\} \tag{1}$$

where I_t is an indicator function that takes the value 1 if taxation is imposed at t and 0 otherwise, so that $\mathrm{E}_t[I_t] = \Theta_t$. [10] The first order condition is:

$$R'(K_t) = r + \tau\mu_t(1 - p_t) = r + \tau\Theta_t. \tag{2}$$

[9] Agents here are assumed to be atomistic, and unable to coordinate their actions. If they could collude, the level of investment may be chosen strategically to minimize capital levies by inducing early separation.

[10] Note that $R(K_t)$ is a gross rate of return.

Since $R(K)$ is concave and monotonic, the optimal capital investment is unique:

$$K_t = K(\Theta_t) = R'^{-1}(r + \tau\Theta_t). \tag{3}$$

In particular, under certainty the capital stock equals

$$K(1) \equiv \arg\sup_{\{K_t\}} \mathrm{E}_t[R(K_t) - (r + \tau)K_t] = R'^{-1}(r + \tau)$$

when taxation is certain, and

$$K(0) \equiv \arg\sup_{\{K_t\}} \mathrm{E}_t[R(K_t) - rK_t] = R'^{-1}(r)$$

when the government is known to be committed. K_t will lie between these two extreme values, depending on the beliefs on the current hazard rate Θ_t.

In each period agents observe government policy and update their beliefs. Given their prior p_t, and in the absence of taxation at time t, government reputation at $t+1$ will be given by:[11]

$$\begin{aligned} p_{t+1} &= Pr[\text{committed government} \mid \text{no tax at } t] \\ &= \frac{Pr[\text{no tax at time } t \mid \text{government is committed}]Pr[\text{committed}]}{Pr[\text{no tax at time } t]} \\ &= \frac{p_t}{p_t + (1 - p_t)(1 - \mu_t)} = \frac{p_t}{1 - \Theta_t} \end{aligned} \tag{4}$$

Thus as long as no taxes are levied and $\Theta_t > 0$, government credibility increases over time. Next it can be shown that:

Proposition 1 *After the first date at which it imposes a tax on capital, an opportunistic government switches to a pure strategy of taxation, setting $\mu_t=1$ in each following period.*

Proof: See Appendix. □

This is quite intuitive: once the government is found out to be opportunistic, it has no reason to pretend to be otherwise.

[11] Since by assumption taxation is a dominated strategy for the committed policymaker, when investors, off the equilibrium path, observe the imposition of a tax which is subsequently repealed, the government reputation remains nil.

Proposition 2 *An uncommitted government taxes with probability one as soon as its reputation p_t satisfies*

$$p_t \geq p^* \equiv \inf\{p_t \in [0,1] \mid K(1-p_t) \geq \delta(K(0) - K(1))\}. \tag{5}$$

Proof: See Appendix.

We now show the conditions under which immediate taxation is not optimal for an opportunistic government.

Assumption 1

$K(1-p_0) + K(1)/(1-\delta) \leq \delta K(0) + \delta K(1)/(1-\delta)$.

Assumption 1 will be satisfied when the government's initial reputation is below a certain threshold.

Proposition 3 *Under Assumption 1, a pure strategy of immediate taxation is not optimal, and the optimal strategy for an opportunistic government is to randomize between taxing now and waiting for at least one period.*

Proof: See Appendix. □

As we are interested in the intertemporal dynamics under policy risk, we focus on the case when the opportunistic government chooses to mask its intentions for at least some time.

From Propositions 2 and 3 it is clear that for immediate taxation to be optimal, the initial reputation p_0 must be sufficiently large to make waiting for even a complete credibility gain too costly. Under Assumption 1, choosing to tax with probability equal to one or zero are dominated by a mixed strategy.

Intuitively, when the initial reputation is very low it makes sense for an opportunistic government to pretend with some probability to be committed and postpone the tax for at least one period. In the absence of taxation its credibility increases and the capital stock tomorrow will be higher. The trade-off is that instead of taxing immediately the existing capital, it can wait one period, increasing its credibility and thus gaining a larger tax base tomorrow.

Next we solve for the length of the time interval over which there is policy uncertainty.

We know from Proposition 2 that an opportunistic policymaker switches to a pure taxation strategy (i.e. sets $\mu_T = 1$) once it achieves the critical level of reputation p^*. This means that we must establish the date T at which p_T exactly equals p^*; the period $[0, T]$ is then the equilibrium randomization period. The optimal strategy for the uncommitted government under Assumption 1 is thus a randomized strategy μ_t where $0 < \mu_t < 1$ for $t < T$, and a pure strategy of taxation $\mu_t = 1$ for $t \geq T$.

To compute this equilibrium mixed strategy, we start from the observation that as long as the optimal strategy calls for taxation with positive probability both today and tomorrow, along the equilibrium path the government must be indifferent between taxing today and taxing tomorrow; otherwise it would have an incentive to deviate.

Define V_t as the value function for the opportunistic government when a tax is imposed at t. For the strategy $\{\mu_t\}$ to be optimal, it must be that:

$$V_t \equiv \tau K(\mu_t(1-p_t)) + \tau K(1)\delta/(1-\delta) = \delta V_{t+1}.$$

where

$$\delta V_{t+1} \equiv \delta[\tau K(\mu_{t+1}(1-p_{t+1})) + \tau K(1)\delta/(1-\delta)].$$

After some simplification, the solution requires $\{\mu_t\}$ to satisfy:

$$K(\mu_t(1-p_t)) + \delta K(1) = \delta K(\mu_{t+1}(1-p_{t+1})),$$

$$\Rightarrow K(\Theta_t) + \delta K(1) = \delta K(\Theta_{t+1}). \tag{6}$$

The left-hand side of Condition (6) represents the stock of capital, that is the tax base, if the government chooses to tax both at t and $t+1$. The right-hand side represents the increased stock of capital in the event that taxation is deferred until t+1. The mixing probabilities are chosen so as to make the opportunistic government exactly indifferent between the two policy options. Equation (6) now implicitly defines the equilibrium sequence of reputation levels p_t, $t = 1, 2, .., T$.

It is now possible to verify an earlier claim.

Proposition 4 *Capital accumulation will increase while the hazard rate will decrease over time as long as no taxation is observed.*

Proof: See Appendix. □

Intuitively, it never pays for an opportunistic government to postpone taxation with probability one, as it forsakes tax revenues with no increase in future tax base.

Thus the capital stock in the absence of taxation monotonically increases, as perceived risk (the expected hazard rate of interference) decreases over time. In order for the U government to be indifferent about the timing of expropriation, the capital stock must increase along the equilibrium path, which requires the perceived hazard rate to fall continuously and the reputation to rise at a decreasing rate in the absence of expropriation (see Figure 2). It can also be seen from (6) that its accumulation over time is characterized by increasingly large net additions; since as capital accumulates, a greater future increase is necessary for postponement.[12] However, beyond some point new investment tends to fall as a proportion of the capital stock.

In conclusion, to derive the optimal randomized strategy $\{\mu_t \mid t > 0\}$ it is necessary to establish first the date T when the U government switches to taxation with probability one. At that date, its reputation hits $p_T \equiv p^*$, the critical level of reputation.

If the initial reputation $p_0 > p^*$, then immediate taxation is optimal. The government announces a policy change, gaining some initial credibility p_0. After receiving some foreign investment $K(1-p_0)$, it immediately taxes it.[13]

If $p_0 < p^*$, the initial strategy is a randomized move. The government first establishes its optimal horizon of dissimulation, which is a strictly decreasing function of its reputation.

The initial randomized choice μ_1 is chosen so as to achieve in the next period a reputation p_1 along the equilibrium path of reputation $p_1, ..., p_{T-1}$ defined by Equation (6).

Along the equilibrium path, the present value of expected tax revenues is the same for all taxation dates $t \leq T$. Whatever the timing of taxation, an U government collects

$$\tau K(\Theta_1) + \tau K(1)\delta/(1-\delta) \equiv \tau K(\mu_1(1-p_1)) + \tau K(1)\delta/(1-\delta),$$

which exceeds the payoff from immediate taxation $\tau K(1-p_0)+\tau K(1)\delta/(1-\delta)$ as long as μ_1 is strictly less than one. Intuitively, the logic of a randomized strategy is that the uncommitted government taxes with probability less than one, thus inducing a higher initial capital stock.

Along the equilibrium path, the hazard rate of taxation Θ_t as perceived by investors falls monotonically. In contrast, the conditional probability of

[12] All figures in the paper are obtained by solving the optimal taxation strategy under the production function $R = 2\sqrt{K}$.

[13] It can be easily shown that when $p_0 > p^*$, Assumption 1 is violated.

taxation μ_t under a U government is not a monotonic function of time, but depends crucially on the curvature of the production function; it rises sharply only at the end of the randomization period (see Figure 2). Until this final date there will be a decreasing residual amount of policy uncertainty.

The other general implication is that a committed government, which never taxes, can achieve complete credibility only gradually.

2.2 The Evolution of Financial Prices and their Conditional Volatility

We can now characterize the impact of policy risk on financial prices. The realized equity value of foreign investment is the capitalized value of a stream of its expected after tax profits. Let $\pi(K_t, I_t) \equiv R(K_t) - (r + \tau I_t)K_t$ denote the ex post realized profit when invested capital is K_t, where I_t takes value 1 if taxation is imposed and 0 otherwise. Let $q_t(i)$ denote the probability that an uncommitted government does not tax until $t + i$:

$$q_t(i) \equiv \prod_{j=1}^{i}(1 - \Theta_{t+j}).$$

The expected profit at time $t + i$ will then be:

$$E_t[\pi_{t+i}] \equiv \Theta_{t+i}q_t(i-1)\pi(K_{t+i}, 1) + (1 - \Theta_{t+i})q_t(i-1)\pi(K_{t+i}, 0) + (1 - q_t(i-1))\pi(K(1), 1).$$

The value of an equity claim at t equals the discounted sum of the perpetual stream, $E_t[\pi_{t+i}]$, for i = 1, ...∞.

The intertemporal dynamics of price volatility is driven by the evolution of beliefs. As it is intuitive, in the absence of taxation the value of the asset rises over time, as policy credibility increases (Proposition 2). The price may rise very quickly at first, reflecting a high rate of resolution of uncertainty. Over time, percentage increases in the absence of a policy shift tends to decrease, reflecting the fact that the unconditional hazard rate Θ_t is decreasing at a decreasing rate (Proposition 4). In other words, the rate at which beliefs are updated tends to slow down as time progresses, reflecting the accumulation of information as beliefs converge to complete confidence at T. Ultimately, this produces a concave time path for the stock price in the absence of policy changes.

Intuitively, the learning process progressively reduces the uncertainty over expected profits. In general, price volatility will fall monotonically over time in the absence of a shift in policy. One qualification is in order here. Under extreme parameter values, specifically a very low initial reputation and at the very beginning, the increase in price may be quite rapid, which may mean that initially the price risk may possibly increase. The intuition is that in this case the hazard rate Θ_t is relatively high and the pre-tax marginal profitability very high. As a result, the potential percentage price drop in case of taxation may increase at a rate that overwhelms the more gradual decrease in the hazard rate. (The optimal strategy of the opportunistic government does not result in a smooth path because the government would seize the capital, not the financial asset.) But even in this case, quite soon price rises decelerate, and the price path becomes strictly concave. Thus, for any initial condition, the decline in Θ_t ultimately reduces the expected volatility of stock prices due to political risk.[14]

In estimating the expected price volatility, rational investors will not only factor in the potential downside due to sudden policy shifts, but also the related price rise due to increasing policy credibility if no shifts occur.[15] More specifically, in the model, the conditional volatility of asset values is driven by the rate of information release Θ_t. To see this, we calculate the variance of posterior beliefs σ_t (for $p_{t-1} > 0$) conditional on no expropriation:

$$\begin{aligned} \sigma_t^2 &= (1-\Theta_t)(p_t - p_{t-1})^2 + \Theta_t(p_{t-1} - 0)^2 \\ &= (1-\Theta_t)(p_{t-1})^2[\Theta_t/(1-\Theta_t)]^2 + \Theta_t(p_{t-1})^2 \\ &= (p_{t-1})^2\Theta_t/(1-\Theta_t). \end{aligned} \tag{7}$$

When initial reputation p_0 is low, there may be initially a period of decreasing credibility p_t, but the first term $(p_{t-1})^2$ eventually rises with t as credibility slowly converges to one. The second term is falling with t as from Proposition 4:

$$\lim_{\Theta_t \to 0} \Theta_t/(1-\Theta_t) = 0.$$

The conditional volatility of equity prices will closely parallel this pattern.

In conclusion, the dynamics of political risk may have an initial phase in which the **perceived risk may be rising in absolute terms**. This will happen when the initial reputation is low so that its rate of increase is

[14]For $t > T$ government preferences are known with certainty and the variance is zero.

[15]Note that capital inflows may continue to accelerate; even as the probability of taxation falls, decreasing returns to scale require larger additional increases in the capital stock.

rapid. Roughly, when the value of foreign capital increases rapidly from a low basis, the potential **absolute price fall** may initially rise, as a much greater amount of capital is exposed to a still very high political risk. This initial hump is immediately followed by a progressive gradual fall in perceived risk.

The comparative statics are quite intuitive. When initial reputation p_0 is higher, the number of periods over which a randomized policy is played is lower as the critical threshold p_T is reached more quickly. The higher is the expropriation rate τ (relative to the real interest rate), the larger is the impact of an improved initial credibility over the capital stock. The optimal dissembling strategy then has a longer time horizon. Then updating of reputation is slower; the slower increases in prices are counterbalanced by slowly falling residual risk of a policy shift. However, when the tax rate is low, to make postponement worthwhile, a large increase in the future capital stock is necessary; thus, early hazard rates are quite large, updating is more rapid, and the time interval during which a randomized policy is played is shorter. Hence, in countries where uncertainty concerns small tax increases, the resolution of uncertainty is likely to be more rapid.

The U government's discount rate on tax revenues δ has the opposite effect on the dissembling strategy as τ. When δ is large, there is a strong temptation for early taxation. Therefore the conditional probability of revelation Θ, is large in the early periods, and falls fast to induce the rapid capital growth needed to compensate for the heavy discounting of future tax revenues. In countries where policymakers have short term horizons, the rate of learning will be higher, reflecting a faster resolution of uncertainty.

Having solved for the optimal dissembling strategy, we can graph the dynamics of expected price volatility. Figure 3 illustrates the behavior over time of the conditional one-period volatility of reputation σ_t as a function of initial reputation p_0 in the case of an initial hump-shaped time path. The graph is concave, due to the fact that government reputation is increasing at a decreasing rate. Resolution of uncertainty is initially rapid as the hazard rate Θ drops quickly. As learning approaches its saturation point, beliefs are updated at a much slower rate until full confidence in government commitment is established. The lower the initial reputation, the longer is the period during which the resolution of uncertainty takes place.

The volatility of credibility is closely correlated with the volatility of profits. Since the stock price is the capitalization of expected profits, the implied volatility of the stock price is a compounded average of the sequence of one-period volatilities (the time series of implied stock price volatility is therefore much smoother). We show later that the term structure of conditional volatility of the price P_t is usually downward sloping and its overall level falls steadily over time.

The next section uses the current model to generate simulations of the price path of assets exposed to political risk. We generalize the model by also introducing market risk, orthogonal to political risk, in order to produce a general option pricing model. We then solve for option prices over the entire lattice. We focus our attention on stock price series in which no expropriation has taken place (we refer to it as a conditional price series). We compare the implied and conditional volatility paths to describe how the gradual resolution of political risk impacts the pricing of options, and conversely, how option prices may be used to extract information on investor confidence.

3 Option Pricing under Political Risk

This section constructs an option pricing model which incorporates the impact of policy risk on the underlying asset price.

The process generated by the model's political hazard rate plus an additional market risk is modelled as a discrete time process.[16] We maintain the assumption that investors are risk neutral, so that they value claims at their expected value discounted at the risk-free rate. This assumption is necessary as it is not possible to use an arbitrage pricing model: the price process is not binomial but trinomial, so existing assets cannot span its return. Thus we compute, working backwards, the expected payoff to the option at each point in the lattice, and price it back by discounting it at the risk-free rate. Risk neutrality is necessary to compute option prices on our complex price process since a multifactor model does not allow pricing by arbitrage.[17] In this case, the expected return is the risk-free rate. However, along an arbitrary conditional sample price path, stock returns will exceed the expected return as a result of the Bayesian updating. In other words, as long as no expropriation occurs there will be excess returns. This excess return reflects not a risk premium but the capital gains due to the increasing confidence by

[16]Note that the market risk has constant volatility, but the price process includes the political risk process which exhibits the stochastic volatility derived in the model.

[17]Technically, since there is no traded security whose payoff is contingent on the policy reversal, the set of securities does not span all the possible states; in this case it is not possible to construct a riskless hedge and we must employ an equilibrium pricing model.

investors over the risk of expropriation. We discuss later the implications of introducing risk aversion.

More formally, consider the stock of a firm exposed to expropriation risk as described in the previous section. Assume that its value depends on the tax policy of the government as well as an additional *generic* shock, uncorrelated to the tax policy. We refer to the latter as the market uncertainty component of the stock price process. This assumed market uncertainty is standard in the option pricing literature.

From the perspective of an investor, in each period $t < T$, expropriation occurs with probability Θ_t. If expropriation occurs, the price drops to the expropriated stock price S^*, given by:

$$S^* = \frac{\pi(K_t(1), 1)}{r} = \frac{\sqrt{K_t(1)}}{r} = \frac{1}{r(r+\tau)}.$$

S^* is modelled as an absorbing state, meaning that the stock price following expropriation remains at S^* with probability one.[18] If no expropriation occurs at time t, the fundamental value of the asset moves from S_t to $S_{t+1,}\quad t < T$ according to the political risk model. This capital gain reflects the Bayesian updating described in Section 2.2.

As mentioned, in addition to expropriation risk, we also model generic price uncertainty as a discrete time geometric Brownian motion. That is, assume that in each period the fundamental value may move by an equiprobable "up" move $u > 1 + r$ and "down" move d, **uncorrelated** to political risk. Thus, the generic shock factor has an impact on stock returns which variance is constant over time.

In summary, the stock price in each period can take one of three new values:

$$S(t+1; s_{t+1}) = \begin{cases} S(t+1; s_t)\, u & w.p.\, \frac{1}{2}(1-\Theta_t) \\ S(t+1; s_t)\, d & w.p.\, \frac{1}{2}(1-\Theta_t) \\ S^* & w.p.\, \Theta_t \end{cases}$$

where s_t captures the history of the sequence of the u's and d's up to time t and the stock price at time t. Since the process is geometric, the tree is recombining (i.e., an "up" movement followed by a "down" movement leads to the same value as a "down" movement followed by an "up" movement). The

[18]This is not crucial to the analysis and is made purely for computational ease.

price S_t is defined as the stock price generated by the model in Section 2.2. Formally:

$$S_t = \frac{1}{(1+r)}\left[\frac{1}{2}(1-\Theta_t)S(t+1;s_t)\,u + \frac{1}{2}(1-\Theta_t)S(t+1;s_t)\,d + \Theta_t S^*\right].$$

This also demonstrates that the expected stock price return is the risk free rate. A tree diagram depicting the evolution of the stock price process is given in Figure 4.

We consider a range of parameter values for which we compute the optimal randomization period T. We then simulate the stock price pattern in the time interval $[0, T]$. We obtain for all dates t, $(t+2)$ possible states, generating a complete tree (or lattice) of all the possible price paths of the stock price process in discrete time.

Given this stock price trinomial lattice, options can be easily priced using the risk-neutral valuation assumption. This is similar in spirit to the framework of Cox, Ross, and Rubinstein (1979), which says that the call option's price $c(t,\Gamma)$, where $\Gamma < T$ is the maturity date of the option, is always equal to the discounted value of its expected payoff. More formally,

$$c(t,\Gamma) = \frac{1}{(1+r)}\left[\frac{1}{2}(1-\Theta_t)c(t+1,\Gamma) + \frac{1}{2}(1-\Theta_t)c(t+1,\Gamma) + \Theta_t c^*\right],$$

where the call option's price is obtained by backward substitution, starting with the terminal call option condition: $c(\Gamma,\Gamma) = \max[S_\Gamma - K, 0]$ where K is the strike price. We only price *at-the-money* options.[19] At-the-money options are defined as ones which strike price K is chosen such that for fixed t:

$$K = S_t(1+r)^{\Gamma - t} \tag{8}$$

where S_t is the current stock price, r is the risk-free rate, and $(\Gamma - t)$ denotes the number of periods left to maturity for the Γ-maturity option, where $\Gamma < T$.

[19]We restrict our attention to at-the-money options in order to remove biases caused by Jensen's inequality. Feinstein [1995] and others have shown that various *at-the-money* option pricing formulas are approximately linear in conditional future volatility, thus yielding a good measure of investors' perceived future volatility.

Upon obtaining an initial set of at-the-money option prices at time t for various maturity dates Γ, we extract the *term structure* of implied volatilities using the Black and Scholes formula.[20] By the term structure of implied volatilities we mean the implied volatilities for the different option maturities Γ calculated at a fixed date t. Hence, by varying Γ we can construct a term structure of at-the-money option prices and their corresponding implied volatilities as desired. The latter gives the market's anticipated (i.e., implied) volatility over different time horizons at a given point in time. The implied and conditional volatility series are now compared under the gradual resolution of political uncertainty. In fact, the whole term structure of implied volatilities is compared against the time series of realized volatility. As far as we know, this is the first paper to utilize the implied volatility technique to determine the market's assessment of future volatility under conditions of political risk.

In order to do the above, the sample price series along the conditional stock price lattice (i.e., with no expropriation) is first simulated. For each of these price series the realized volatility of price returns is calculated. Then, an *average* realized volatility measure for date t is constructed by averaging the resulting values across the sample paths. This process is repeated for all dates with condition (8) being satisfied at each point in time, thus generating a time series of the term structure of at-the-money implied volatilities and the corresponding time series of the average realized volatility given no policy reversal. For computational convenience, we restrict our parameter set so that the furthest expiration date does not exceed 50 periods. This gives a manageable stock price trinomial lattice with a maximum of 52 nodes at expiration.

Our results, for a given parameter set, are provided in Figure 5, which illustrates the evolution of the term structure of call option prices over time conditional on no expropriation. As call options grant the owner the right to acquire the stock at a future date at a given price, a rising call price indicates increasing investor confidence in the political commitment of the government. At the same time, the expected volatility is falling, which reduces the rate of increase in the value of the option. The observed pattern of call option prices

[20] Note that the correct option pricing model is not Black and Scholes, since the price process is not the standard geometric Brownian motion but a jump-diffusion type process, albeit in a discrete-time framework. We use the Black and Scholes model here only to compute an implied volatility metric consistent with the standard used by all market participants.

increasing at a decreasing rate is consistent across at-the-money options (see Figure 5).

The next set of figures describes the evolution of implied volatility extracted from the call option prices using the standard Black and Scholes measure. In order to interpret these graphs it is important to recall that under the standard benchmark Black and Scholes assumption, where only generic risk is taken into consideration, the term structure of volatility is flat.[21] In contrast, in our simulation the derived volatility term structure illustrates how option prices reflect the evolution of learning over time of political risk. This can be interpreted as providing an equivalent measure of the classic "peso premium" in terms of the second moment of the price distribution.

The results confirm our comparative statics results. For most parameter values, the decrease in implied volatility is monotonic in time. Figure 6 (a) shows how the term structure of *at-the-money* implied volatilities drops with the passage of time, as a result of the progressive reduction in the perceived expropriation risk faced by investors. Figure 6 (b) documents that the wedge between the Black and Scholes implied volatilities of call options with times to maturity fixed at 3-periods, 5-periods, and 7-periods to maturity, and the average realized volatility is convex and decreasing over time. It can be seen that the overall level of the term structure falls over time, i.e., as time evolves and uncertainty is resolved, the 7-period implied volatility wedge is less than the 5-period one which is in turn less than the 3-period implied volatility wedge. This is due to the fact that given time t information, the 7-period implied volatility is time-averaging future volatility which is expected to diminish more than the 5-period one, and so on, again due to the improved perception about government commitment on the conditional price path.

In the case of an economy with extremely strong initial political risk, namely for low values of the parameter p_0, the term structure of volatilities may briefly rise over the initial maturity range (see Figure 7). This is due to the initial price appreciation (and thus the size of the potential price drop in case of reversal) overwhelming the reduction in the hazard rate. However, the implied volatility term structure almost immediately shifts to a downward profile as no reversal is observed.

[21] In more sophisticated option pricing models where volatility follows a GARCH process, the term structure tends to be U-shaped. In a Constant Elasticity of Variance model (CEV), the term structure may be potentially upward or downward sloping (see Cox and Ross [1976]) but does not generate a hump.

In conclusion, the simulation results confirm that we can interpret the difference between realized volatility and implied volatility as a measure of the changing perception of political risk over time.

4 Conclusion

The paper endogenizes the gradual buildup of policy credibility in an economy moving towards market reforms but facing residual policy risk. We derive the intertemporal price process under such political risk and offer an intuitive interpretation for the gradual expansion of foreign investment and its acceleration over time. It is descriptive of an early stage in foreign direct investment in emerging economies, when reforms are still not fully established and foreign investors act as tentative, cautious pioneers.

Financial economists usually assume that equilibrium prices follow diffusion processes, which implies that new information is released continuously as a flow of a large number of small, uncorrelated events. This is inappropriate in certain contexts such as in emerging markets, when policy shifts have a very large systematic effect on asset values. Because investors' expectations affect their investment decisions, the timing of policy decisions needs to be treated as a strategic variable. The resulting information process is asymmetric: absence of news is good news. This can produce positive serial correlation in prices in the absence of policy changes. In general, price series outside sudden crises will exhibit more sustained trends and larger excess returns than under a continuous and symmetric process of information release (such as a Brownian motion). Our option pricing approach offers several other empirical implications: in particular, the medium term evolution of **implied volatility** is shown, after possibly an initial hump-shape, to be monotonically decreasing. Moreover, the wedge between realized and implied volatility should also fall gradually over time.

Clearly, the assumption of risk neutrality is not particularly appealing. The only alternative would be to provide a pricing model based on investor preferences. On the other hand, the implications of introducing risk aversion can be deduced rather intuitively. Risk aversion would introduce a risk premium in the discounting of payoffs as a function of perceived volatility. In our context, the risk premium would gradually fall as the risk of expropriation falls; this would lead to lower initial prices and a steeper price appreciation over time. Thus our time series results on implied volatility would be strengthened: price volatility would be higher at first (when the conditional price series would have higher capital gains to reflect the required risk premium) and would decline now even faster (since not only the risk of the potential fall, but also the associated risk premium, would gradually fall). Thus such an extension would be consistent with our results and in fact would reinforce its empirical implications.

An interesting observation is that under political risk the time series of prices may resemble the profile of a speculative bubble, even though the true cause of the rapid buildup is simply rational updating of policy credibility. The methodology we have proposed suggests that over time it is possible to discriminate between rational price updating and a deviating bubble: namely, while in the case of rational updating implied volatility should ultimately fall, in the case of a stochastic bubble it should increase over time.

These conclusions have implications for the pricing of derivative products on emerging markets subject to significant policy risk. Such derivative products are essential tools of risk management for international investors and corporations. In principle, the information extracted from option prices may also guide policymakers assess the perception of political risk among market investors.

In future research we plan to investigate empirically the option pricing model and to refine possible instruments for policy analysis. Testing this model would require a time series of implied volatilities from a sample of option prices across several countries facing political risk. The main implications to be assessed are that:

1. implied volatility would exceed historical volatility;
2. the wedge between the two measures should decline over time;
3. the wedge would be correlated with the degree of political risk as proxied by market surveys or other measures commercially available;
4. the term structure of implied volatility and the realized price volatility path would be downward-sloping;
5. the speed of the decline may be correlated with measured improvements in perceived political risk.

While some tests can be carried out using realized volatility, most tests involve implied volatility data, which is not yet available as such option markets are not yet fully developed. However, the rapid evolution in these markets and the increasing need for active risk management suggest that such tests will become feasible in the near future.

Appendix

Proof of Proposition 1

By definition, a committed government never taxes capital. Once taxation is imposed in period t, investors conclude that the government cannot be committed: then the reputation is lost, and p_{t+i} will be zero for all $i > 0$. Therefore, if the discredited government were to withdraw the tax, it would forego revenues without inducing additional investment. As a result, after taxation the capital stock falls to its minimum value $K(1)$, where it remains. □

Proof of Proposition 2

By contradiction. Suppose that the opportunistic government choose to tax in the first period with probability one, i.e., it sets $\mu_1 = 1$. Proposition 1 states that its subsequent optimal strategy is to tax every period, so its payoff is:

$$\tau[K(1-p_0) + K(1)\delta/(1-\delta)].$$

Under Assumption 1, this is not an equilibrium. The opportunistic government could deviate from the strategy, not taxing at 1; then investors would infer that it is certainly committed, and would invest $K(0)$ in the next period. Surprise taxation at $t = 2$ then gives it a better payoff.

Suppose now that the opportunistic government chooses not to tax with probability one, i.e., $\mu_t = 0$ at 1; then neither government is expected to tax at all, and there is no update in reputation, so $p_{t+1} = p_t$. Since no taxes are expected, the investment decision by the agents solves:

$$R'(K_t) = r$$

which gives the maximum capital investment $K_t = K(0)$. It is easy to see that this is not an equilibrium. By deviating and raising tax revenues today, the opportunistic government can achieve a payoff of

$$\begin{aligned} \tau[K(0) + \delta K(1) + \delta^2 K(1) + ...] &= \tau K(0) + \sum_{t=1}^{\infty} \delta^t \tau K(1) \\ &= \tau K(0) + \tau K(1)\delta/(1-\delta) \end{aligned}$$

where we made use of Proposition 1. If instead it does not tax at t, its maximum payoff is:

$$\begin{aligned} & \max\left\{\tau[\delta K(0) + \delta K(1)/(1-\delta)],\ [\delta^2 K(0) + \delta^2 K(1)/(1-\delta)], ...\right\} \\ = \ & \tau\delta K(0) + \tau\delta K(1)/(1-\delta) \end{aligned}$$

which is less than the previous payoff, both because there is one less period on which taxes are collected and because $\delta \in (0, 1)$. Therefore, in equilibrium an opportunistic government is better off taxing with strictly positive probability in each period. □

Proof of Proposition 3

Assume that no taxation occurs at T; then investors will infer that the policymaker is indeed committed, and will invest the maximum amount $K(0)$ at time $T + 1$. Therefore, for $\mu_T = 1$ to be optimal, it must be the case that the protax government does not deviate by not taxing at T and waiting until $T + 1$.

At time T, investors will choose K_T according to:

$$\begin{aligned} R'(K_T) &= r + \tau(1 - p_T) \\ \Rightarrow K_T &= R'^{-1}(r + \tau[1 - p_T]) \equiv K(1 - p_T) \end{aligned}$$

After the announcement of the tax the capital stock falls to $K(1)$, and remains at that level, since from Proposition 1, $\Theta_{T+i} = 1$ for all $i > 0$. To ensure that no deviation occurs, the gain from immediate taxation must outweigh the capture of the difference between $K(0)$ and $K(1)$ tomorrow. This will occur precisely if:

$$\tau K(1 - p_T) + \tau K(1)/(1 - \delta) \geq \tau \delta K(0) + \tau \delta K(1)/(1 - \delta).$$

It is easily seen that this inequality is satisfied precisely when p_t is at least as large as p^*. □

Proof of Proposition 4

Assume no taxation is imposed at t. In equilibrium, Equation (6) must hold; this implies that over time the capital stock evolves according to:

$$K(\Theta_t) + \delta K(1) = \delta K(\Theta_{t+1}) \tag{9}$$

Because the second term on the left-hand side is positive, the right-hand side must be larger that the first term on the left:

$$K(\Theta_t) < \delta K(\Theta_{t+1}) \Rightarrow K(\Theta_t)/\delta < K(\Theta_{t+1})$$

Since $K(\Theta_t)$ solves $R'(K_t) = r + \tau\Theta_t$, where $R' > 0$ and $R'' < 0$, $K_{t+1} > K_t$ for all t only as long as $\Theta_{t+1} < \Theta_t$. Moreover, $\delta \in (0, 1)$. Therefore, equilibrium beliefs on the likelihood of taxation must be such that $\Theta_t > \Theta_{t+1}$for all $t \in (0, T)$. On the other hand, after taxation is imposed, $\Theta_{t+i} = 1$ and K_{t+i} falls to $K(1)$, the minimum capital stock, for all $i > 0$. □

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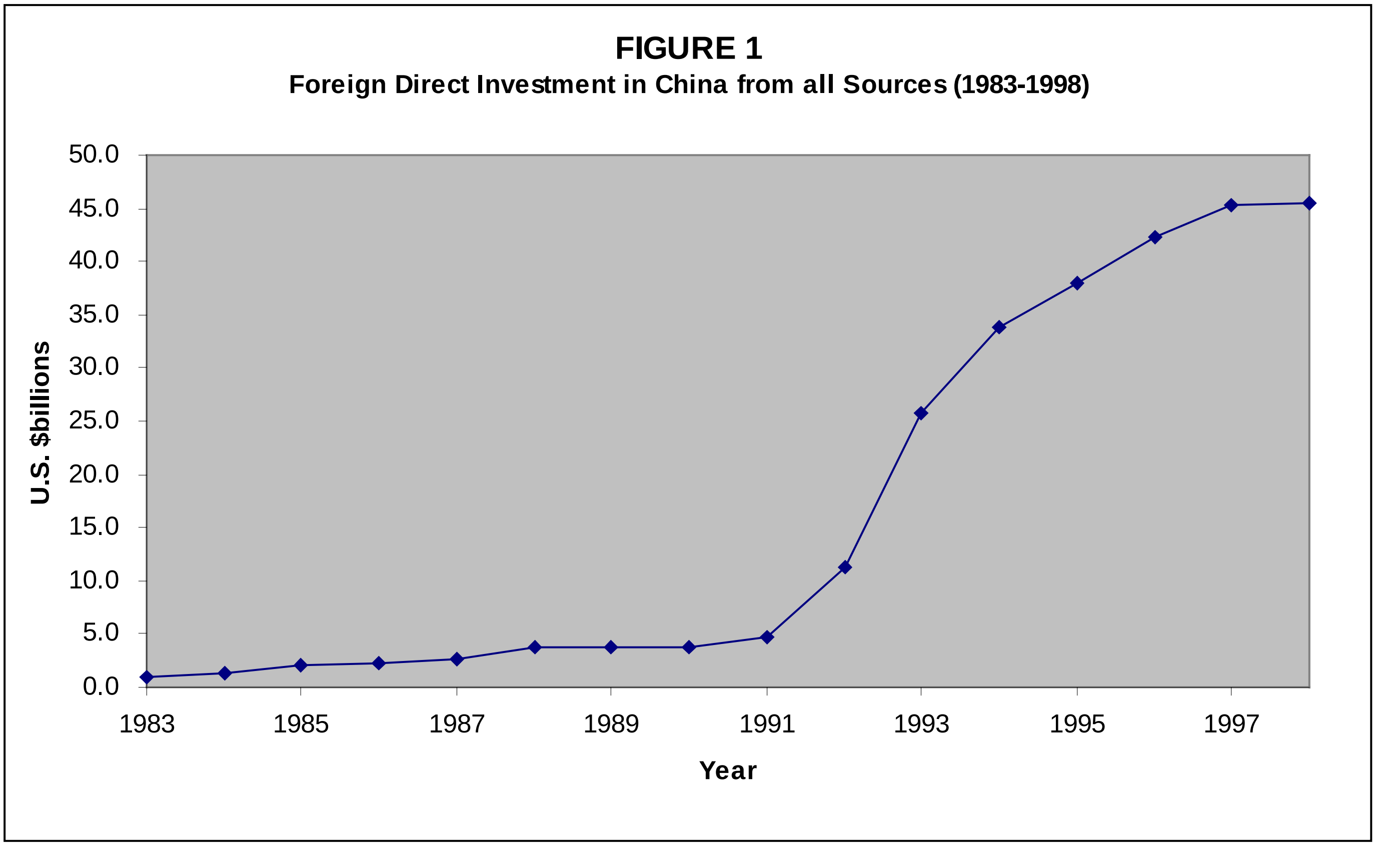

FIGURE 1 : Foreign Direct Investment in China from all Sources (1983-1998) In U.S. $billions: 1983 - $0.9b; 1984 - $1.4b; 1985 - $2.0b; 1986 - $2.2b; 1987 - $2.6b; 1988 - $3.7b; 1989 - $3.8b; 1990 - $3.8b; 1991 - $4.7b; 1992 - $11.3b; 1993 - $25.8b; 1994 - $33.8b; 1995 - $38.0b; 1996 - $42.4b; 1997 - $45.3b; 1998 - $45.6b. Source: China in the World Economy, Nicholas R. Lardy, 1994, Institute for International Economics and UNCTAD, Division of Transnational Corporations and Investments (Wall Street Journal, June 5, 1996, page A2), and China Ministry of Foreign Trade & Economic Cooperation.

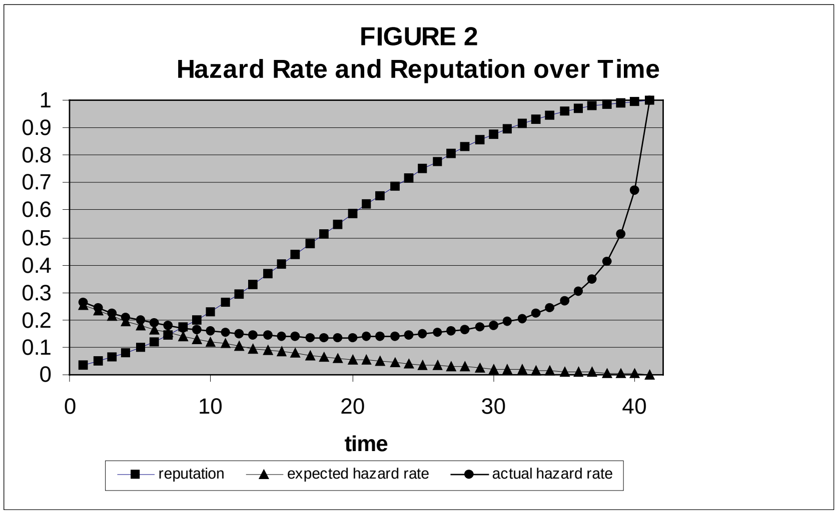

FIGURE 2 : Hazard Rates and Reputation over time under a production function of the type R = 2 √K

This figure plots the resulting time path of government reputation (or commitment) p_t, the expected hazard rate Θ_t, and the actual hazard rate μ_t, under a production function of the type R=2 √K, where r (cost of capital) = 0.01; τ (tax rate) = 0.4; δ (discount rate for tax revenues) = 0.9; p_0 (initial reputation) = 0.02. The optimal expropriation date T, given an opportunistic government, happens in 42 periods.

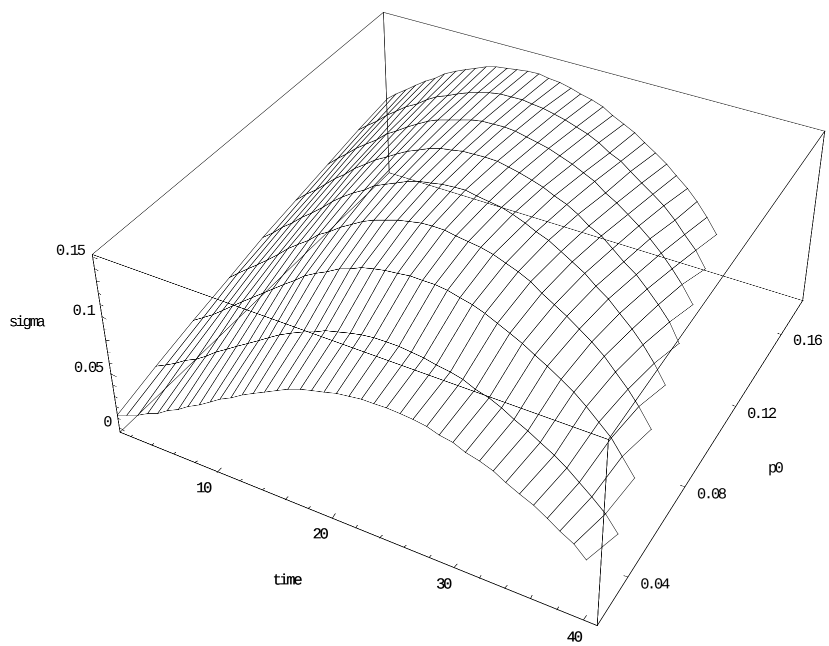

FIGURE 3 : Plot of Conditional Volatility of Reputation p_t with respect to Initial Reputation p_0 and Time

The conditional volatility σ of government reputation p_t for various levels of initial government commitment p_0, ranging from 0.02 to 0.18, under a production function of the type R=2√K, where r (cost of capital) = 0.01; τ (tax rate) = 0.4; δ (discount rate for tax revenues) = 0.9. The opportunistic government will expropriate optimally at various times T for different values of p_0.

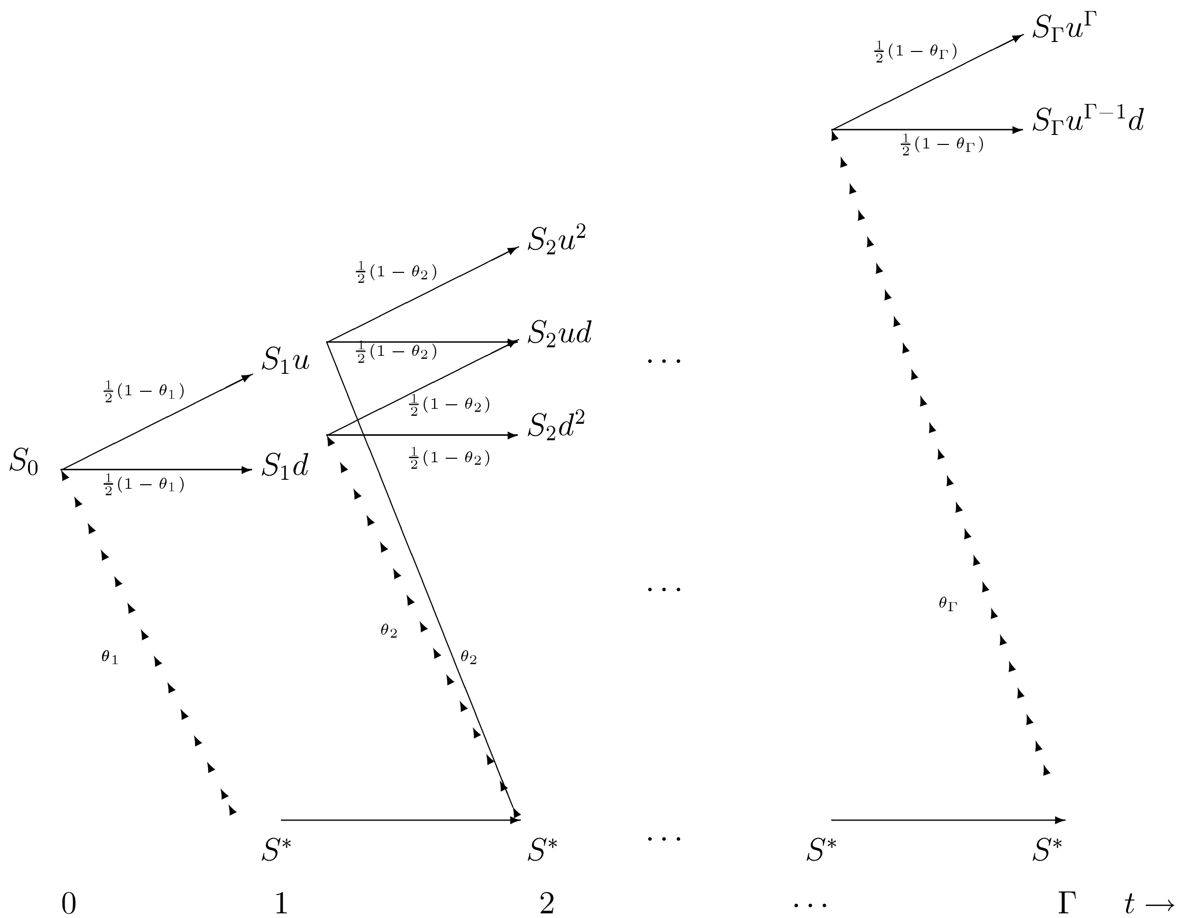

FIGURE 4 : Tree Diagram Describing Stock Price Evolution Over Time

Figure 4 depicts the evolution of the risk-neutralized stock price tree:

$$S_t = \frac{1}{(1+r)} \left[\frac{1}{2}(1-\Theta_t) S(t+1; s_t)\, u + \frac{1}{2}(1-\Theta_t) S(t+1; s_t)\, d + \Theta_t S^* \right].$$

In each period the fundamental value may move driven by an equiprobable market risk factor given by an "up" move $u > 1 + r$ and "down" move d, while for $t \leq \Gamma < T$, expropriation occurs with probability Θ_t, where Θ_t is the hazard rate of expropriation. It is assumed that the market uncertainty factor is uncorrelated to expropriation risk. Γ is the option maturity date while T is the expropriation date.

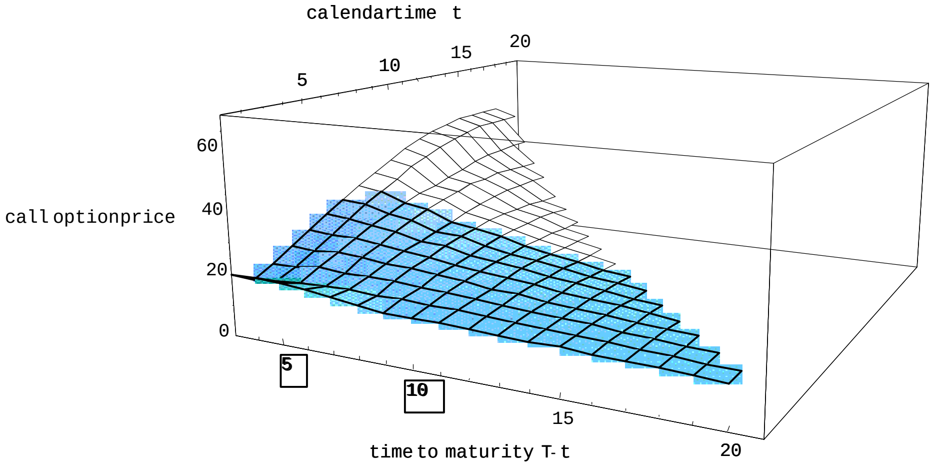

FIGURE 5 : Term Structure of At-the-money Call Option Prices over Time

Figure 5 illustrates the evolution of the term structure of call option prices over time conditional on no expropriation, based on the stock price model under political risk.
The strike price K is chosen such that $K = S_t(1+r)^{(\Gamma-t)}$, where S_t is the current stock price, r is the risk-free rate, and (Γ-t) denotes the number of periods left to maturity for the Γ-maturity option.
The model parameters are given by r (cost of capital) = 0.04; ô (tax rate) = 0.4; ä (discount rate for tax revenues) = 0.9; p_0 (initial reputation) = 0.02.
NB: Under these parameters, the initial reputation is very low, so expected volatility initially rises. Under most parameter values, expected volatility falls from the beginning.

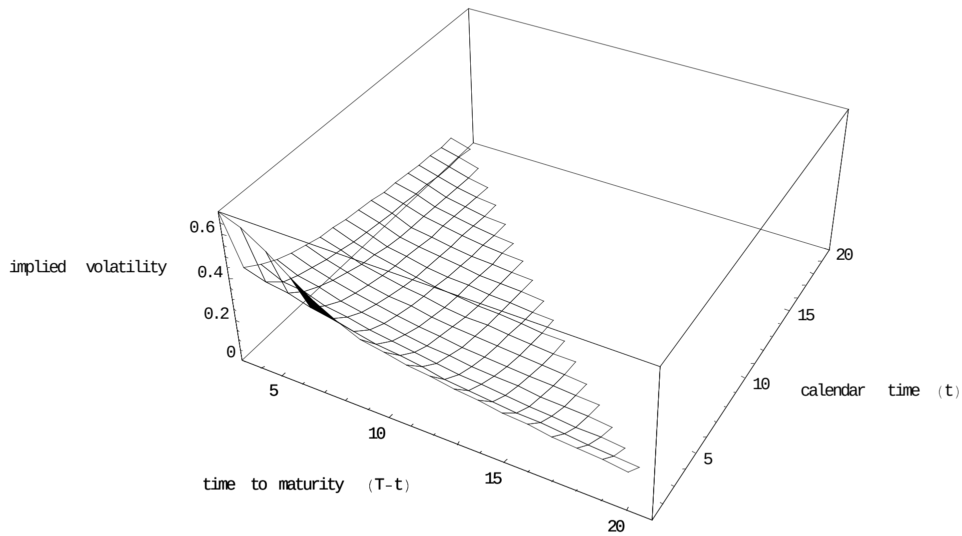

FIGURE 6 (a) : Plot of the Term Structure of At-the-money Implied Volatilities over Time

Figure 6 (a) illustrates the evolution of the term structure of Black-Scholes implied volatilities over time conditional on no expropriation and given the endogenous stock price model with political risk. The strike price K is chosen such that $K = S_t(1+r)^{(\Gamma-t)}$, where S_t is the current stock price, r is the risk-free rate, and (Γ-t) denotes the number of periods left to maturity for the Γ-maturity option. The model parameters are given by r (cost of capital) = 0.04; τ (tax rate) = 0.4; δ (discount rate for tax revenues) = 0.9; p_0 (initial reputation) = 0.02.

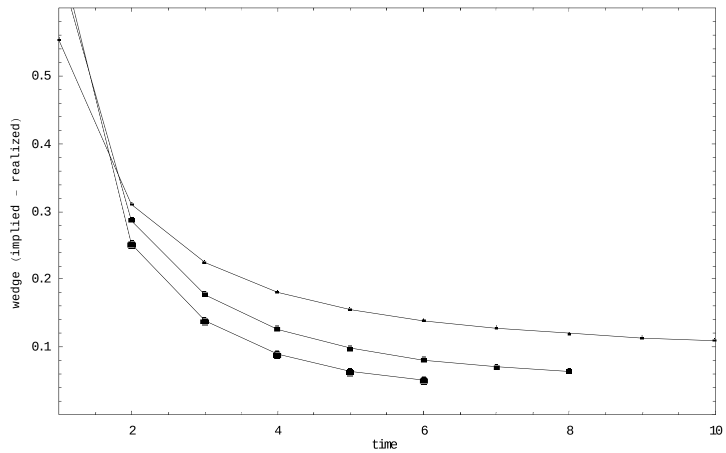

FIGURE 6 (b) : Plot of the 3-, 5-, and 7-period (Implied Volatility - Realized Volatility) over Time

Figure 6 (b) documents the time evolution of the wedge between the Black and Scholes implied volatilities of call options with times to maturity fixed at 3-periods, 5-periods, and 7-periods to maturity and average realized volatility. The strike price K is chosen such that $K = S_t(1+r)^{(\Gamma-t)}$, where S_t is the current stock price, r is the risk-free rate, and $(\Gamma$-t) denotes the number of periods left to maturity for the Γ-maturity option. . The model parameters are given by r (cost of capital) = 0.01; τ (tax rate) = 0.2; δ (discount rate for tax revenues) = 0.7; p_0 (initial reputation) = 0.02.

Key:

- **3-period [Implied-Realized] Volatility**
- **5-period [Implied-Realized] Volatility**
- **7-period [Implied-Realized] Volatility**

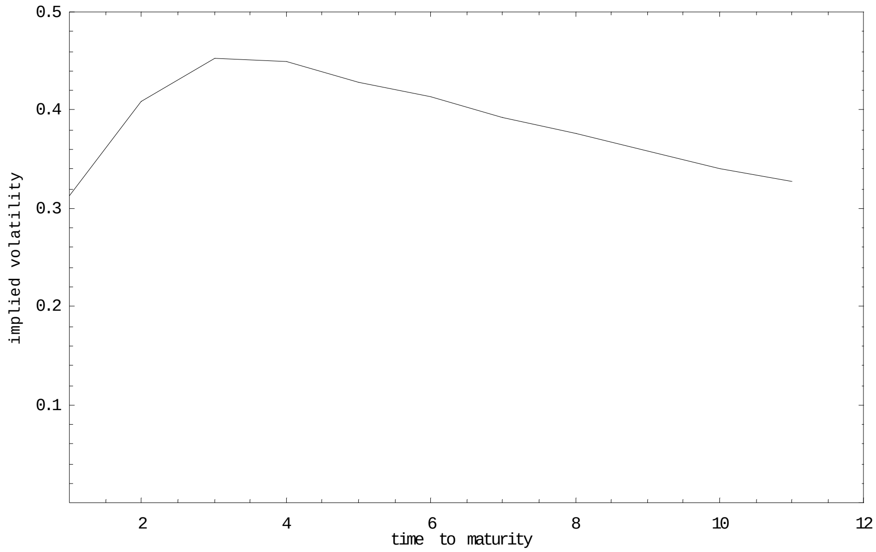

FIGURE 7 : Plot of the Initial Term Structure for Low Initial Reputation

Figure 7 plots the initial Black and Scholes implied volatilities of call options with different times to maturity. The strike price K is chosen such that $K = S_0(1+r)^{\Gamma}$, where S_0 is the initial stock price, r is the risk-free rate, and Γ denotes the number of periods left to maturity for the Γ-maturity option. The model parameters are given by r (cost of capital) = 0.01; τ (tax rate) = 0.2; δ (discount rate for tax revenues) = 0.7; p_0 (initial reputation) = 0.02.