Exploring The Role of Limited Commitment Constraints in Argentina's "Missing Capital"[*,†]

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Abstract

The paper investigates why capital accumulation in Argentina was weaker in the 1990s and 2000s than suggested by the high productivity growth rates and low international interest rates prevailing then. It is shown that lack of commitment to honor contractual obligations with foreign investors introduces two mechanisms that account for that puzzling capital accumulation dynamics. First, the response of investment to a total factor productivity increase is muted and short-lived, while the response to a decrease is large and persistent. Second, unlike in an economy with commitment, low international interest rates may reduce capital accumulation, because they increase the relevance of future commitment constraints.

A quantitative implementation of a canonical open economy model with limited commitment constraints shows that the two mechanisms are very important to understand the evolution of Argentina's capital stock over time. The model accounts for virtually all the capital missing from Argentina in the period 1980-2019, relative to that which would have been observed in the absence of the limited commitment friction.

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1 Introduction

The relegation of Argentina from among the top ten nations in output per capita at the beginning of the 20th century to around 65th place a hundred years later has fascinated researchers and accordingly inspired innumerable studies. The relative decline is especially apparent during the so-called "lost decade" of the 1980s. Equally relevant for any attempt to account for Argentina's stagnation is the observation that in the subsequent decade, and the mid 2000s, total factor productivity (TFP) grew rapidly, yet the capital stock remained almost flat. Figure 1a documents the levels of the capital stock and of TFP in the period 1980-2019. The weakness of capital accumulation during periods of high productivity growth stands in contrast to the 1980s, when capital stock responded to low productivity growth by adjusting rapidly downwards. As a result, GDP growth was also relatively slow, as shown in Figure 1b.

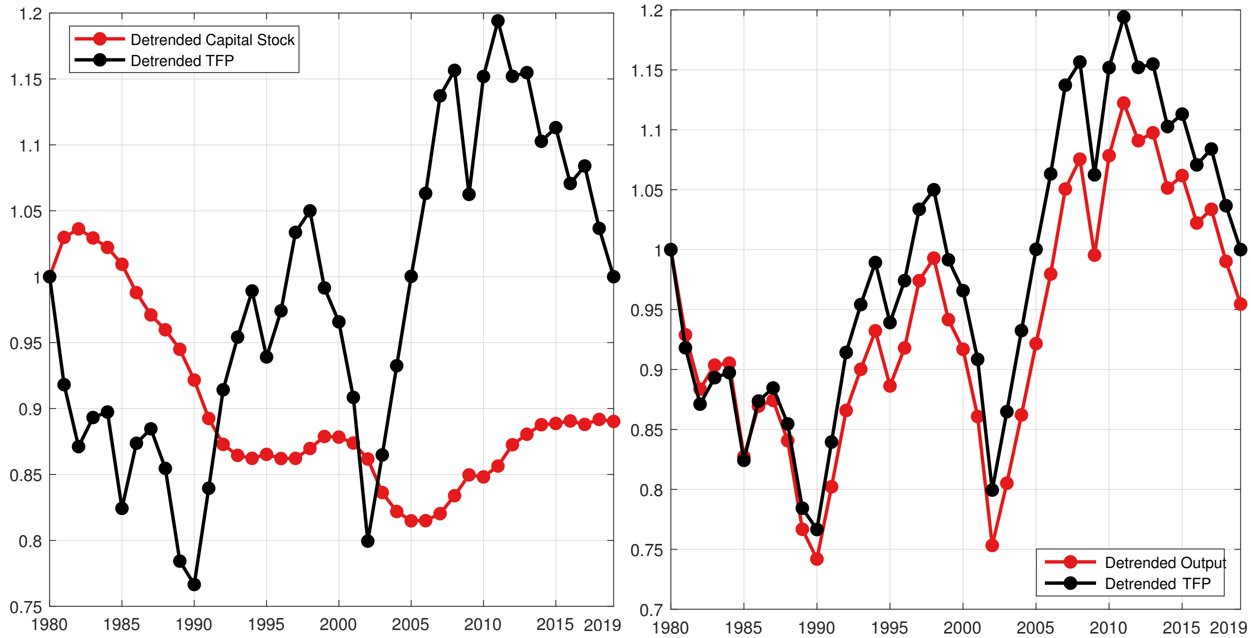
The muted response of the capital stock in the mid 1990s and 2000s is even more puzzling when taking into account that the then prevailing international real interest rates were low. The real international interest rates, shown in Figure 2, were about two percentage points lower in the mid-1990s than in the 1980s on average. Even lower rates failed to boost capital accumulation through the mid-2000s. Capital thus appears to be "missing" from Argentina's economy despite in principle favorable productivity and international interest rates developments.

The goal of this paper is to investigate whether limited enforcement constraints can account for Argentina's "missing capital", including the asymmetric response of capital to high and low productivity, as well as its apparent insensitivity to real international interest rates.

The conjecture that Argentina has faced limited enforcement constraints seems plausible given that it defaulted on its external obligations at the beginning of the 1980 and that its capital stock was at a historical record high then. This may have convinced foreign investors that Argentina is inclined to repudiate foreign debt by strategic "opportunistic" considerations when capital and productivity is relatively high. As shown by Kehoe and Perri (2002) and many others, governments will be particularly inclined to repudiate foreign debt precisely under those conditions.

Aware of the incentive to repudiate foreign debt, foreign investors will not fully exploit high returns to capital that they would take advantage of in the absence of enforcement problems. As a result the capital stock will not increase as much in times of high productivity. On the other hand, when productivity is low, the enforcement friction doesn't matter, because foreign investors have no interest in investing in a country offering a low return to capital, which precisely for that reason falls. The capital stock thus responds asymmetrically to a productivity shock.

We show that the limited enforcement frictions can also account for the unresponsive-



(a) Capital Stock and TFP. Index, 1980=1.

(b) GDP and TFP. Index, 1980=1.

Figure 1: TFP, capital stock and GDP for Argentina, 1980-2019, detrended.

ness of the capital stock to low real international interest rates. Specifically, we show that lower international interest rates can reduce, instead of increase, foreigners' incentives to invest in a small open economy whose rate of return on capital is particularly high after a sequence of high realizations of TFP. The economic intuition behind that mechanism is that the lower interest rates tend to make the limited enforcement constraints more severe, because they tend to shift consumption from the future to the present. As a result, consumption distortions associated with binding limited enforcement constraints are larger for lower international rates. This decreases the capital stock, because lower capital stock partially alleviates the limited enforcement constraints. This "second best" effect can even dominate the direct effect that lower international rates have on the required rate of return. We examine this mechanism in a simple special case that permits a closed-form solution and in a series of numerical examples.

Our quantitative exploration calibrates a deterministic growth model with enforcement frictions to Argentina's data.[1] The key requirement for a successful quantitative exploration are reliable data about Argentina's capital stock. Since Argentina's capital stock is not regularly produced by the country's official statistical agencies, we constructed the capital stock series with the perpetual inventory method, as explained in more detail in section 5.

We find that the calibrated model traces the decline that that country's capital stock experienced during the 1980s with remarkable accuracy because, as predicted by the the-

[1] Kehoe and Perri (2004) and Aguiar and Amador (2011) also use a deterministic perfect foresight environment.

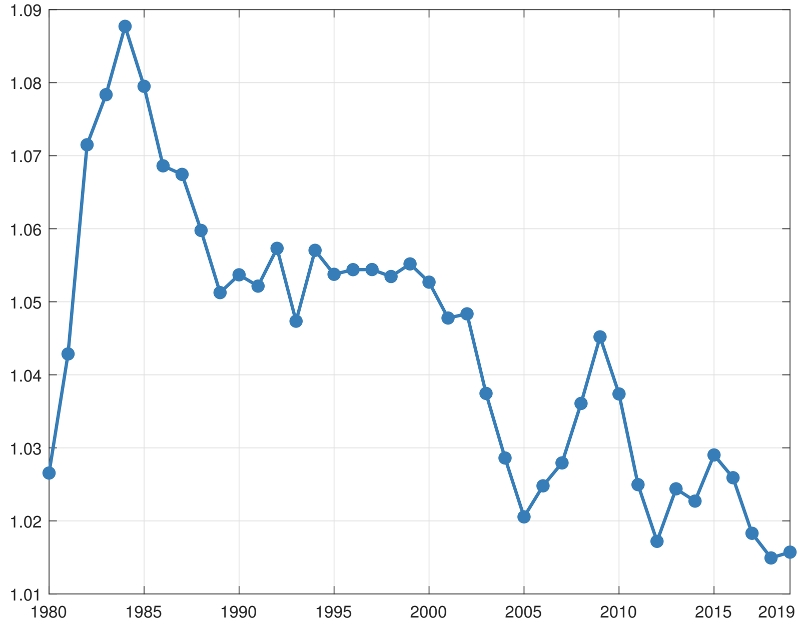


Figure 2: Real International interest rate: Moody's Seasoned Aaa Corporate Bond Yield minus expected inflation. Source: FRED Database Federal Reserve Bank of St. Louis and authors' calculations.

ory, the limited commitment constraints were almost never binding during that decade. At the same time, the limited enforcement frictions were often binding in the subsequent decades, accounting therefore for almost all of the capital stock missing from the Argentine economy, when compared with that which would have been observed in a small open economy not afflicted by such a limited commitment friction. The model is also successful in replicating Argentina's capital stock asymmetric response to positive and negative changes of its total factor productivity and to its seemingly subdued reaction to lower international interest rates. The relatively good quantitative performance of the model is especially noteworthy given that the paper stays away from introducing exogenous costs of default to improve the matching between the model predictions and the data, as most of the existing literature does.

To check the quantitative implications of the limited commitment constraints, the paper performs numerical experiments that assume that those constraints disappear, first starting in 1991 and then in 2003. The capital stock predicted by these exercises turns out to be in 2019 double than that in the model with the constraints. This result implies that, if foreign investors didn't fear confiscation of their capital, real wages in 2019 would have been 35% than under the limited commitment constraints. That same calibration implies that, in steady state, real wages would be a still impressive 30% higher in a small open economy with commitment than without it.

The remaining sections of the paper are structured as follows. Section 2 presents the small open economy environment. Section 3 characterizes the constrained efficient allocation implied by the optimal contract between the small open economy and the risk-neutral foreign lender.[2] Section 4 investigates the mechanisms that generates the asymmetric responses of the capital stock to changes in productivity and its insensitivity to the international real interest rates. Section 5 provides details of the data sources, construction of the capital stock series, calibrates the model economy to Argentina's data and studies the role of both asymmetries. Section 6 elaborates on the benefits to Argentina of getting rid of the limited commitment friction. Section 7 offers concluding remarks.

2 Environment

The economy is deterministic. It consists of a small open economy populated by representative agents and a risk neutral international lender. The representative agent in the country has a working age population of size N_t in period t. The population is exogenous and grows at rate η, $N_t = (1+\eta)^t N_0$. The representative agent consumes $C_t \geq 0$ in period t and evaluates sequences of consumption according to

$$V(\{C_t\}) = \sum_{t=0}^{\infty} \beta^t N_t U\left(\frac{C_t}{N_t}\right), \tag{1}$$

where $0 < \beta < 1$ is the discount factor. We assume that the utility function U exhibits a constant relative risk aversion:

$$U(C) = \frac{C^{1-\sigma}}{1-\sigma},$$

where $\sigma > 0$ is the coefficient of relative risk aversion. The aggregate production function of the country is

$$F(A_t, K_t, N_t) = A_t K_t^{\theta} N_t^{1-\theta}, \tag{2}$$

where $K_t \geq 0$ is the beginning-of-period t capital stock, $A_t > 0$ is total factor productivity in period t, and $\theta \in [0,1]$ is the capital share. The total factor productivity sequence is exogenous. We assume that after some sufficiently distant period T, it grows at rate ζ.

The law of motion for capital is

$$K_{t+1} = (1-\delta)K_t + I_t,$$

where I_t is investment and δ is the depreciation rate. The initial capital stock K_0 is given.

As is standard in open economy models, capital stock adjustments are costly. We

[2] Decentralization of the efficient allocation is discussed in an Appendix available from the authors upon request.

assume that the adjustment costs are given by $\Phi(K_t, K_{t+1})$. The function ϕ is quadratic in the growth rate of the capital stock, and proportional to the current capital stock:

$$\Phi\left(K_t, K_{t+1}\right) = \frac{\kappa}{2}\left(\frac{K_{t+1} - \omega K_t}{\omega K_t}\right)^2 K_t.$$

where the parameter κ measures the strength of the adjustment costs. The function Φ reaches a minimum of zero for capital growth $K_{t+1}/K_t = \omega$. We will later set it so that, along the balanced growth path, the adjustment costs are equal to zero. Given this normalization, the adjustment cost will modify the model dynamics, but will have the same balanced growth path as a model without adjustment costs.

The country can borrow from (or save with) the international lender. The lender is risk neutral and fully commits to the contract. That includes the commitment not to renegotiate in case the borrower deviates from the contract. The lender discounts cash-flows between periods $t-1$ and t by an international interest rate $R_t^* \geq 0$. The sequence of international interest rates $\{R_{t+1}^*\}$ is exogenous. It can be time varying, but is constant after a sufficiently distant period T at a level R^*.

Balanced Growth. The properties of the utility, production, and adjustment cost functions imply that the economy has a balanced growth, where all variables grow at a constant rate. Output, consumption and capital stock grow at rate $(1+\eta)(1+\gamma)$, where $1+\gamma = (1+\zeta)^{\frac{1}{1-\theta}}$ is the growth of per capita values. We detrend the variables by setting

$$a_t = \frac{A_t}{(1+\zeta)^t}, \quad k_t = \frac{Kt}{(1+\eta)^t(1+\gamma)^t}, \quad c_t = \frac{C_t}{(1+\eta)^t(1+\gamma)^t}, \quad i_t = \frac{I_t}{(1+\eta)^t(1+\gamma)^t}.$$

Since A grows at rate ζ after period T, the normalized TFP sequence $\{a_t\}$ is bounded and is equal to some constant a after period T. After the normalization, the representative agent's utility function is now written as

$$v(\{c_t\}) = \sum_{t=0}^{\infty} \hat{\beta}^t U(c_t), \tag{3}$$

where the discount factor is modified by $\hat{\beta} = \beta(1+\eta)(1+\gamma)^{1-\sigma}$. The law of motion for capital is now

$$(1+\eta)(1+\gamma)k_{t+1} = (1-\delta)k_t + i_t.$$

We also set the adjustment cost parameter $\omega = (1+\gamma)(1+\eta)$ to make sure that, along the balanced growth path, where k_t is constant, the adjustment costs are zero. For clarity of the presentation, we will use a general notation for the the adjustment cost function $\phi(k_t, k_{t+1}) = \frac{\kappa}{2}(k_{t+1} - k_t)^2/k_t$, as well as for the production function $f(a_t, k_t) = a_t k_t^\theta$

wherever possible.

We make two assumptions about the long-run international interest rates:

Assumption 1.

$$(1+\eta)(1+\gamma) < R^* \leq \frac{(1+\gamma)^\sigma}{\beta}. \tag{4}$$

The first inequality implies that the present value of any bounded sequence of resources is finite. This assumption is our equivalent of what is called "high implied interest rates" in the general equilibrium versions of the limited commitment models (Kehoe and Perri (2004)), and is imposed in order to ensure that the efficient allocations can be decentralized as a competitive equilibrium. The second assumption means that the borrower is weakly more impatient than the lender.[3] It can be justified for example by political economy frictions in the domestic country, as in Aguiar et al. (2009) or Aguiar and Amador (2011), something that is likely to be relevant for a country like Argentina.

3 Constrained Efficient Allocations

We first consider the constrained efficient allocations for this economy. At time zero, the country and the lender sign a contract that specifies sequences of transfers from the borrower to the lender, $\{tr_t\}$, consumption $\{c_t\}$ and capital stock $\{k_{t+1}\}$. The transfers can be positive or negative. The resource constraint for the economy is

$$c_t + (1+\eta)(1+\gamma)k_{t+1} = f(a_t, k_t) + (1-\delta)k_t - \phi(k_t, k_{t+1}) - tr_t. \tag{5}$$

We require that the lender gets a present value of transfers of at least b_0. Define the implied discount factor between period 0 and t to be $Q_t^* = \prod_{j=1}^{t} 1/R_j^*$, with $Q_0^* = 1$. Then the requirement is

$$\textstyle\sum_{t=0}^{\infty} Q_t^*(1+\eta)^t(1+\gamma)^t tr_t \geq b_0. \tag{6}$$

The present value of transfers b_0 is a parameter of the contract. As usual, by varying the value of b_0, we can trace out the whole Pareto frontier for the problem.

The country faces a commitment problem. At any time, it can renege on the contract, and refuse to repay its debt. If that happens, the contract is terminated, and the country moves to autarky. Autarky is permanent, and the country will never again have a chance to sign a new contract, although it can accumulate capital on its own. The lender, on

[3] As one can deduce from the assumption, we call both parties equally patient in the growth economy if the modified discount factor of the lender $(1+\eta)(1+\gamma)/R_t$ equals to the modified discount factor of the borrower, $\beta(1+\eta)(1+\gamma)^{1-\sigma}$.

the other hand, has no commitment problems and always fulfills its contract obligations. The value of autarky in period t is given by

$$v_t^{\text{aut}}(k_t) = \max_{\{c_{t+j}, k_{t+1+j}\}} \sum_{j=0}^{\infty} \hat{\beta}^j U\left(c_{t+j}\right).$$

subject to the nonnegativity constraints $c_t \geq 0$, $k_{t+1} \geq 0$, and the closed economy resource constraints

$$c_{t+j} = f(a_{t+j}, k_{t+j}) + (1-\delta)k_{t+j} - \phi\left(k_{t+j}, k_{t+j+1}\right) - (1+\eta)(1+\gamma)k_{t+j+1}.$$

Without loss of generality, the contract requires that, in any period, the value of the contract cannot be smaller than the value of being in autarky:

$$\sum_{j=0}^{\infty} \hat{\beta}^j U(c_{t+j}) \geq v_t^{\text{aut}}(k_t), \quad \forall t \geq 0. \tag{7}$$

Definition 1. Given exogenous sequences $\{a_t, R_t^*\}$, lender's profits b_0 and initial capital k_0, the *optimal contract* consists of feasible sequences $\{c_t, k_{t+1}, tr_t\}$ that maximize the country's lifetime utility (1) subject to the resource constraint (5), promise keeping constraint for the lender (6) and the limited commitment constraint (7).

We define the relative discount factor of the lender, relative to the borrower to be

$$p_t = \frac{Q_t^*(1+\gamma)^{\sigma t}}{\beta^t}.$$

Assumption 1 implies that p_t is ultimately increasing over time, reflecting the fact that, as time goes on, the difference between lender's and borrower's discounts grows. Let $\lambda > 0$ be the Lagrange multiplier on the promise keeping constraint and $\beta^t \mu_t \geq 0$ be the Lagrange multiplier on the limited commitment constraint in period t. The first-order condition with respect to consumption is

$$U'(c_t)\left(1 + \sum_{s=0}^{t} \mu_s\right) = \lambda p_t. \tag{8}$$

The optimal consumption sequence has standard properties of economies with limited commitment. An increase in consumption in period t not only increases the agents' utility directly, but also relaxes all limited commitment constraints up to period t. It is, however, costly for the lender, and tightens the promise keeping constraint (6), with period-t cost λp_t. Evaluating the first-order condition (8) at two consecutive periods yields the following intertemporal condition that must hold in the optimum:

$$U'(c_t) = \frac{\beta R^*_{t+1}}{(1+\gamma)^\sigma} \frac{1+\sum_{s=0}^{t+1}\mu_s}{1+\sum_{s=0}^{t}\mu_s} U'(c_{t+1}). \tag{9}$$

If the limited commitment constraint (7) does not bind, the marginal utility of consumption increases at rate $(1+\gamma)^\sigma/(\beta R^*_{t+1}) - 1$, and consumption correspondingly decreases. If the limited commitment constraint binds, $\mu_t > 0$ and consumption permanently increases, in order to prevent the country from reneging on the contract.

The optimal capital stock is characterized by two conditions. The first one is the first-order condition in capital,

$$R^*_{t+1}(1+\phi_{2,t}) = f_{k,t+1} + 1 - \delta - \phi_{1,t+1} - \frac{\mu_{t+1}}{\lambda p_{t+1}} \frac{dv^{\text{aut}}_{t+1}(k_{t+1})}{dk_{t+1}}, \tag{10}$$

where the derivatives of the adjustment cost function are

$$\begin{aligned}
\phi_{1,t} &= \phi_1(k_t, k_{t+1}) = -\kappa \frac{k_{t+1}-k_t}{k_t} - \frac{\kappa}{2}\left(\frac{k_{t+1}-k_t}{k_t}\right)^2, \\
\phi_{2,t} &= \phi_2(k_t, k_{t+1}) = \frac{\kappa}{(1+\eta)(1+\gamma)} \frac{k_{t+1}-k_t}{k_t}.
\end{aligned}$$

Equation (10) shows that an increase in the capital stock in period t has an additional negative effect in that it raises the value of autarky in the next period, and so tightens the limited commitment constraint. This decreases the optimal capital stock, and current investment.[4] The adjustment costs have three effects on the optimal level of capital costs. The first two are standard: along the transition path where the capital stock is growing, the future marginal benefit of investment is increased by $-\phi_1 > 0$, because a higher investment today will decrease the adjustment cost incurred tomorrow. The future marginal benefit is discounted by $1/R^*_{t+1}$. On the other hand, the marginal cost of investment today increases by $\phi_2 > 0$, because the current adjustment cost increases. Depending on the size of both effects, the investment will decrease or increase. In a limited commitment economy, there is an additional third effect on the value of capital in autarky. By differentiation of the value function in autarky, we obtain

$$\frac{dv^{\text{aut}}_t(k_t)}{dk_t} = U'\left(g^{\text{aut}}_t(k_t)\right)\left(f_{k,t} + 1 - \delta - \phi^{\text{aut}}_{1,t}\right),$$

where $g^{\text{aut}}_t(k_t)$ is the optimal consumption policy in autarky, and ϕ^{aut} are the resulting

[4] In a two-country model of Kehoe and Perri (2004), there is an additional effect that works in the opposite direction: binding limited commitment constraints increase future consumption and, given limited resources, encourage current investment. This effect is absent in our model, where the lender has unlimited resources.

adjustment costs. Note that $\phi_{1,t}^{\text{aut}}$ will in general be different from $\phi_{1,t}$, because capital stock in autarky follows a different path than along the contract.

The second optimality condition for capital is the transversality condition

$$\lim_{t \to \infty} \left[\frac{(1+\gamma)(1+\eta)}{R^*} \right]^t k_{t+1} = 0. \tag{11}$$

The first-order conditions in consumption and capital stock (8) and (10), the complementary slackness conditions, the transversality conditon (11), and the constraints (5), (6) and (7) completely characterize the optimal allocations.

The Euler Equation. Combining the equations above to eliminate the rate of return R_{t+1}^* yields the following expression for the Euler equation:

$$\frac{U'(c_t)}{\beta(1+\gamma)^{-\sigma} U'(c_{t+1})} (1+\phi_{2,t}) = (1-\Delta_{t+1}) \left(f_{k,t+1} + 1 - \delta - \phi_{1,t+1} \right), \tag{12}$$

where the intertemporal wedge Δ_{t+1} is given by

$$\Delta_{t+1} = \frac{\mu_{t+1}}{1 + \sum_{s=0}^{t} \mu_s} \left(\frac{U'\left(c_{t+1}^{\text{aut}}\right)}{U'(c_{t+1})} \frac{f_{k,t+1} + 1 - \delta - \phi_{1,t+1}^{\text{aut}}}{f_{k,t+1} + 1 - \delta - \phi_{1,t+1}} - 1 \right)$$

If the limited commitment constraint does not bind tomorrow, then $\Delta = 0$ and the Euler equation reduces to its standard frictionless form. If the limited commitment constraint binds tomorrow, then the wedge Δ will in general be nonzero. There are, however, two opposing forces on the intertemporal wedge, and so the wedge can be positive or negative. A positive force behind the intertemporal wedge is due to the fact that higher capital stock makes the value of autarky more attractive. This makes a higher capital stock less valuable. A negative force behind the intertemporal wedge comes from fact that the binding limited commitment constraint increases consumption tomorrow and increases the left-hand side of (12), which is the inverse of the marginal rate of intertemporal substitution.

If the adjustment costs are zero, then the bracketed term in the expression for the intertemporal wedge reduces to $U'\left(c_{t+1}^{\text{aut}}\right)/U'(c_{t+1}) - 1$, and its sign depends only on the relative consumption in autarky and in the contract. If consumption in the autarky falls below consumption in the contract, then the value of capital in autarky is relatively high, the first effect dominates, and the intertemporal wedge is positive. Otherwise, the intertemporal wedge is negative.

3.1 Steady State

What happens when the economy converges to the steady state? We will now show that the result depends critically on whether the borrower is strictly more impatient than lender or not in the long run. If both are equally patient, then the economy converges to a first-best limit, while if the borrower is strictly more impatient, it converges to the steady state of a closed economy.

Proposition 2. *Suppose that the adjustment costs are zero. If $\beta R^* = (1+\gamma)^\sigma$ then k_t converges to the first best steady state level of capital. If $\beta R^* < (1+\gamma)^\sigma$ then k_t and c_t converge to their closed economy steady state levels.*

Proof. First note that the dynamics of consumption and capital in autarky is the same as in a closed economy. The steady state level of capital in autarky k_{ss}^{aut} satisfies k_{ss}^{aut} satisfies

$$f_k(k_{ss}^{\text{aut}}) + 1 - \delta = (1+\gamma)^\sigma / \beta. \tag{13}$$

Consumption in autarky is after period T given by the optimal policy function $g^{\text{aut}}(k)$ which solves a standard dynamic programming problem of optimal growth and is strictly increasing. In particular, consumption immediately after defaulting in steady state is $c_1^{\text{aut}} = g^{\text{aut}}(k_{ss})$, while consumption in the steady state of the autarky is $c_{ss}^{\text{aut}} = g^{\text{aut}}(k_{ss}^{\text{aut}})$. In between, $c_\tau^{\text{aut}} = (g^{\text{aut}})^\tau(k_{ss})$, where τ denotes the number of periods spent in autarky. The consumption sequence in autarky $\{c_\tau^{\text{aut}}\}$ is between c_1^{aut} and its limit c_{ss}^{aut}, to which it monotonically converges.

To simplify notation, let $\theta = (1+\gamma)^\sigma/(\beta R^*) \geq 1$. In the steady state, consumption and capital are constant at c_{ss} and k_{ss} and the first-order conditions (9) and (10) converge to

$$\theta = \lim_{t\to\infty} \frac{1 + \sum_{s=0}^{t+1} \mu_s}{1 + \sum_{s=0}^{t} \mu_s} \tag{14}$$

$$R^* = [f_k(k_{ss}) + 1 - \delta]\left[1 - \rho \frac{U'\left(g^{\text{aut}}(k_{ss})\right)}{\lambda}\right], \tag{15}$$

where ρ is the steady state value of the ratio μ_{t+1}/p_{t+1}.

Consider first the case when $\theta = 1$. Then equation (14) implies that μ_{t+1} must converge to zero. Hence $\rho = 0$ and the marginal product of capital satisfies $f_k(k_{ss}) + 1 - \delta = R^*$, which is its first-best level.

Consider now the case when $\theta > 1$. Write $\mu_t = \rho\theta^t$. Solving for θ from (14) and by using (8) yields

$$\rho = \frac{\theta - 1}{\theta} \frac{\lambda}{U'(c_{ss})} > 0.$$

That is, the limited commitment constraint must bind in the steady state. As a result, the steady state transfer to the lender tr_{ss} cannot be strictly negative. If it was, the continuation present value of lender's profits is strictly negative and the lender is better off by mimicking autarky in steady state, which delivers zero profits and leaves the lifetime utility of the borrower unchanged. The steady state transfer to the lender tr_{ss} cannot be strictly positive either. If it was, moving to autarky increases the borrower's resources in every future period and must yield strictly higher lifetime utility than the optimal contract, violating the limited commitment constraint (7). Hence, tr_{ss} must be zero. The optimal steady state consumption is given by the resource constraint (5),

$$c_{ss} = f(a, k_{ss}) - (\delta + \eta + \gamma + \eta\gamma)k_{ss}. \tag{16}$$

It is obvious that the steady state level of capital must be below its golden rule level, otherwise one can increase the borrower's consumption and utility by reducing the capital stock and saving resources.

We will now show that $k_{ss} = k_{ss}^{\text{aut}}$. Suppose, by contradiction, that $k_{ss} > k_{ss}^{\text{aut}}$. Then

$$c_{ss} = f(a, k_{ss}) - (\delta + \eta + \gamma + \eta\gamma)k_{ss} > f(a, k_{ss}^{\text{aut}}) - (\delta + \eta + \gamma + \eta\gamma)k_{ss}^{\text{aut}} = c_{ss}^{\text{aut}},$$

where the first equality follows from (16), the inequality form the fact that k_{ss} is below its golden rule level and the proposition that is to be contradicted, and the last equality follows from the steady state of the closed economy. Substitute now ρ out of equation (15) and rewrite is as

$$\frac{(1+\gamma)^{\sigma}}{\beta} = [f_k(k_{ss}) + 1 - \delta] \left[\theta + (1-\theta)\frac{U'\left(g^{\text{aut}}(k_{ss})\right)}{U'(c_{ss})}\right]. \tag{17}$$

For (17) to hold simultaneously with (13), it must be that

$$c_{ss} > g^{\text{aut}}(k_{ss}) = c_1^{\text{aut}}.$$

Since the consumption sequence in autarky monotonically converges from c_1^{aut} to c_{ss}^{aut}, it must satisfy $c_{ss} > c_{\tau}^{\text{aut}}$ for all $\tau \geq 0$. But then the limited commitment constraint (7) must be slack, a contradiction. An analogous argument rules out $k_{ss} < k_{ss}^{\text{aut}}$ by showing that, the limited commitment constraint must then be violated.[5] Hence, it must be that $k_{ss} = k_{ss}^{\text{aut}}$. It then follows from the resource constraint that $c_{ss} = c_{ss}^{\text{aut}}$.

□

Proposition 2 shows that, as long as the borrowers are relatively more impatient than lenders, the first-best and the second-best economy have different implications in

[5] The assumption of zero adjustment costs is useful in this step, because the adjustment costs reduce the value of autarky, but not the value of the contract, where the capital stock is constant.

the long run. While the capital stock in the first-best economy remains at its first-best level, capital stock in the second-best economy converges to the closed economy level. Moreover, borrowing constraints prevent consumption from falling, and so consumption settles at a closed economy level in the long run as well. As a result, the steady state will be independent of the international risk free rate R^*. Lower international interest rates may have a transitory effect on the capital stock, but will have no effect of on capital stock in the long run. Proposition 2 also implies optimal capital and consumption sequences are both bounded, and so is the transfer sequence.

Proposition 2 is also useful for calibration of the model. If the target steady state capital-output ratio is smaller than the one implied by the first best economy, given by $\theta/(R^* + \delta - 1)$, then the borrowers must be more impatient than the lender, and the steady state of the economy can be calibrated as if the economy was closed, independently of the risk free rate risk free rate R^*.

3.2 Decentralizing the Efficient Allocations

The Pareto efficient allocations can be decentralized as a self-enforcing equilibrium where individuals in the country borrow and lend directly from abroad using one period bonds, the government appropriately chooses capital income tax rates (to satisfy the Euler equation (9) and so induce the optimal capital stock), collects debt payments from the agents to pass them to foreigners, and makes default decisions on the collected debt (so as to make sure that the limited commitment constraint (7) holds). The self-enforcing equilibrium is itself an outcome of a sustainable equilibrium, in the language of Chari and Kehoe (1990) and Kehoe and Perri (2004), where the government chooses its policies optimally for any given history of past policies, consumers take policies as given, and the government chooses policies consistent with autarky for off-equilibrium histories. While the decentralization is obviously necessary to justify our focus on the constrained efficient allocations, it is relatively standard, and is relegated to an Appendix available upon request.

4 Inspecting the mechanism

To understand the workings of the model, and the forces that determine capital accumulation as well as the dynamics of consumption, we will now consider several simple numerical examples. Unless stated otherwise, all examples assume that the utility is logarithmic, capital share θ is one third, there is full depreciation ($\delta = 1$), there is no population and TFP growth, and the discount factor β equals 0.96. We fist assume that there are no adjustment costs and that $\beta R^*_t = 1$ in all periods.[6] We focus on two aspects: how capital stock responds to a positive versus negative productivity shock, and how it responds to a change in the interest rate.

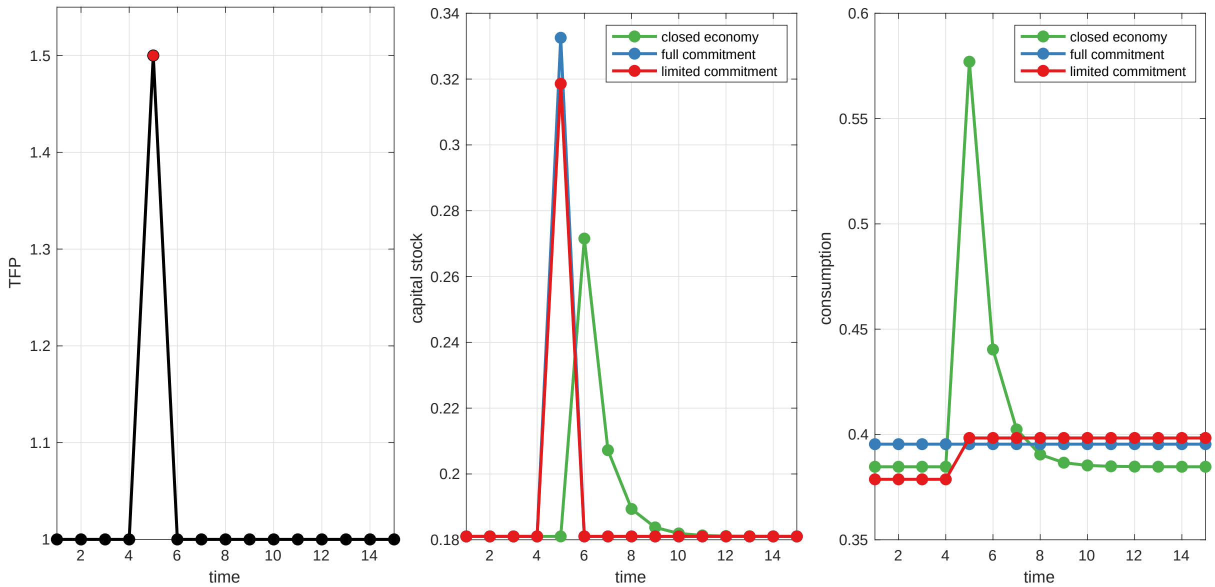
4.1 Response to a productivity shock.

Consider an anticipated one-time increase in the total factor productivity a. The total factor productivity increases in period 5 and then reverts back to its original level, as in Panel 3a. Panel 3b shows how the capital stock responds in a closed economy, in an economy with commitment, and in an economy with limited commitment. In the first-best and the second-best economy, capital and consumption decisions are separated, because the economy can borrow and save. In both economies, capital stock is at its steady state level in all periods except in period 5. In both the first-best and the second-best economy, capital stock increases when the marginal product of capital is high. The increase in capital stock thus happens one period earlier than in a closed economy, because the mechanism behind the increase in capital stock is different: In a closed economy, the desire to smooth consumption prevents the agents to increase capital stock in period 5, because that would require high investment in period 4, and a drop in consumption. Instead, investment only happens in period 5 when the economy has more resources, and the effect on capital stock is purely transitory.

In the second best economy, the desire to invest in capital stock is reduced by the limited commitment constraint considerations. As panel 3a shows, the limited commitment constraint binds in period 5. That is, the first-best level of capital stock would prompt the agents to default and move to autarky. This reduces the capital stock in period 5. The level of consumption, shown in panel 3c is, however, pushed upward. This stands in contrast to the closed economy, where consumption decreases after the shock.

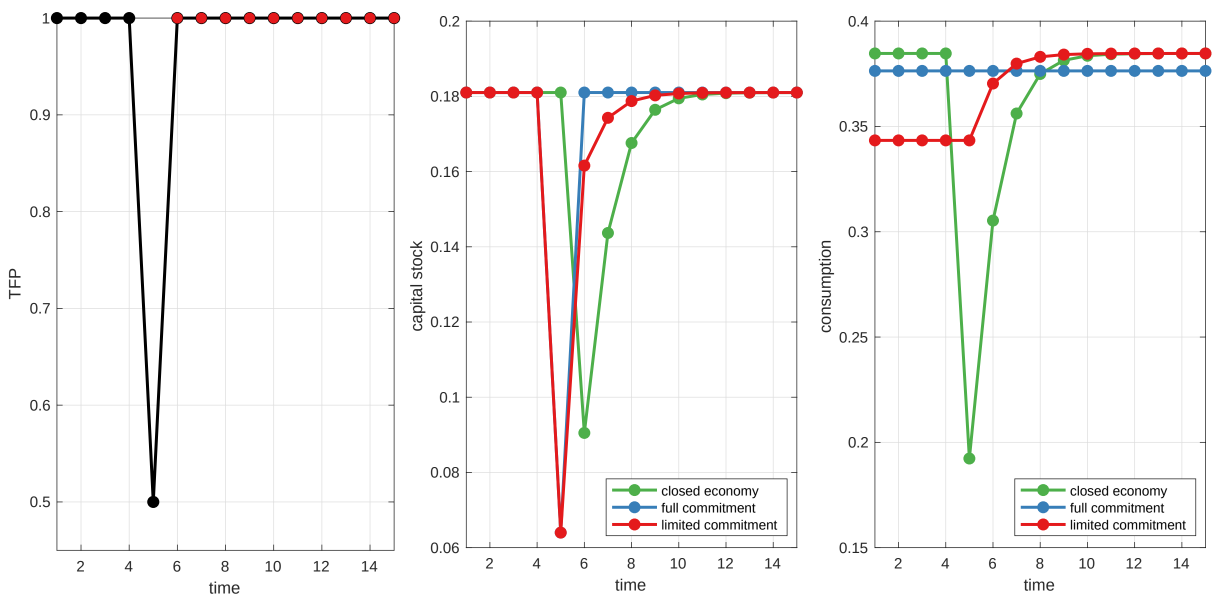
Figure 4 shows a response to a one-time decrease in the productivity shock in period 5. The response of the second-best economy is now different in two aspects. First, since the limited commitment constraint does not bind at the time of the negative productivity shock, capital stock decreases by the same amount as in the first-best economy. Second, the limiting commitment constraint now binds in all the periods following the decrease in productivity. To see why, note that the agents consume more than their production in period 5. Thus, they need to transfer resources back to the lender after period 5. There are no future shocks, and so no benefit from future insurance. If the capital stock immediately reverted back to the first-best level, they would prefer to default. To prevent them from defaulting, the value of autarky needs to be decreased by decreasing

[6] We solve the model by solving the corresponding first-order conditions (8) and (10). We iterate on the set of binding limited commitment constraints by dropping the ones that are slack and by adding those that are violated, until convergence. We then iterate on the Lagrange multiplier λ until the model yields the required initial debt d_0.



(a) Total Factor Productivity **(b)** Capital Stock **(c)** Consumption

Figure 3: Response to a temporary positive TFP shock without adjustment costs. Red dots in panel (a) denote periods when the limited commitment constraint binds.



(a) Total Factor Productivity **(b)** Capital Stock **(c)** Consumption

Figure 4: Response to a temporary negative TFP shock without adjustment costs. Red dots in Figure 1 denote periods when the limited commitment constraint binds.

the capital stock. The recovery of the capital stock is now sluggish compared to the first-best economy, although the decline in period 5 is identical.

Overall, figures 3 and 4 show that the limited commitment constraints introduced an asymmetry to the capital accumulation process. The response to a positive shock is muted, and the reversal to the steady state level is rapid, while a response to a negative shock is large, and the reversal to the steady state level is slow.

When the adjustment costs are introduced, the dynamics of the capital stocks differs in certain aspects: the build-up of the capital stock is gradual in all three economies, and starts before the productivity shock happens. Similarly, the return to the steady state level of the capital stock is slower. But the asymmetric response of the capital stock in the second best economy to a positive and negative productivity shock is still there, and the mechanism is identical to the one explained above.

4.2 The role of international interest rates.

Previous examples were simulated under the assumption that $\beta R_t^* = 1$, and so the required rate of return on capital investment exactly offsets the discount rate. What happens if the investors require a lower rate of return?

An example solved. To understand how the international interest rates interact with capital accumulation, we first consider an example where $\sigma = 0$ and so the period utility is linear. As in Aguiar and Amador (2011), a case with linear utility has a simple closed form dynamics. To simplify the problem further, we continue assuming that there are no adjustment costs, and that $\gamma = \eta = 0$. For simplicity, we consider a case when the nonnegativity constraint on consumption is not binding.

The first-order condition for consumption (8) now simplifies to $\mu_0 = \lambda - 1$, and

$$\frac{\mu_t}{p_t} = (1 - \beta R_t^*)\lambda, \quad t \geq 1.$$

The Lagrange multiplier μ_t is always strictly strictly positive if the lender is more patient and $\beta R_t^* < 1$, and is zero only if both parties are equally patient. Moreover, μ_t always moves in the opposite direction than the international interest rate. That is, the limited commitment problems become more severe if the world interest rate decreases (in a sense that the normalized Lagrange multiplier μ_t / p_t increases). This has important consequences for the dynamics of investment and capital stock. The first-order condition (10) now becomes

$$R_{t+1}^* = (f_{k,t+1} + 1 - \delta)\left(1 - \frac{\mu_{t+1}}{\lambda p_{t+1}}\right) = (f_{k,t+1} + 1 - \delta)\left[1 - (1 - \beta R_{t+1}^*)\right] \tag{18}$$

The first term in the last bracket represents a direct effect of the international interest rates on the marginal product of capital: lower international interest rates decrease the required marginal product of capital, and increase the capital stock. This is a standard "first-best" result. The second term in the last bracket represents the effect of the limited commitment constraints on the capital stock. Rearranging the expression (18) yields

$$f_{k,t+1} = \delta - 1 + \frac{1}{\beta}.$$

The international interest rate R^*_{t+1} has cancelled out, and the marginal product of capital equals $\delta - 1 + 1/\beta$, a steady state closed economy level. In this case, the positive direct effect of lower international interest rates is *exactly* offset by a negative effect of the limited commitment constraints. The second best capital stock is independent of the international interest rate, not only in the steady state, but in every period except period zero.

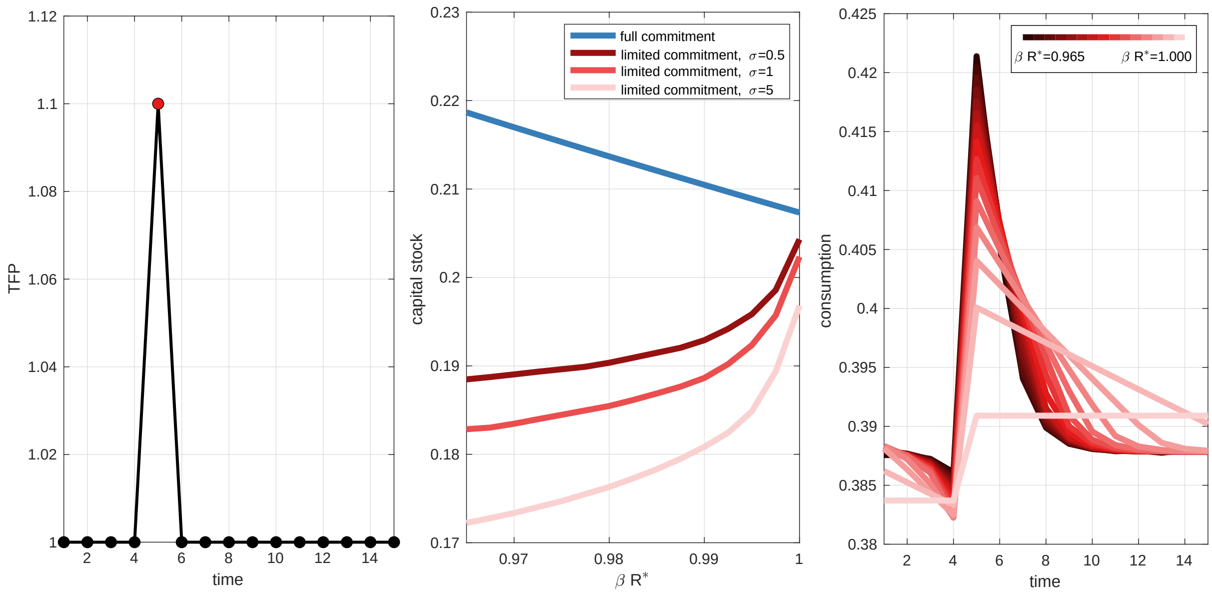
Numerical examples with concave utility. To investigate how robust the results from the linear utility case are, we now consider numerical examples for various degrees of risk aversion.

Figure 5 shows the capital stock response to a one-time increase in productivity in period 5 for various values of the international rate of return R^*_t, and for $\sigma = 0.5$, 1 and 5. In this numerical example, the limited commitment constraint always binds in period 5. In other periods shown in figure 5, the limited commitment constraint does not bind, and the capital stock is at its first best level. Panel 5b shows the capital stock in period 5, which is the period when productivity increases. In the first-best economy, the response of capital stock to the increase in the interest rate is unambiguous. Foreign investors require a higher rate of return, which decreases the capital stock.

In the second-best economy, the optimal capital stock reacts very differently. Lower interest rates lead to a decrease, rather than increase, of the capital stock. Compared to the linear utility case, the indirect effects of the limited commitment constraints are strengthened. To understand why this is the case, specialize the optimality condition (10) for zero adjustment costs to obtain an alternative equation for the optimal capital stock:

$$R^*_{t+1} = (f_{k,t+1} + 1 - \delta)\left[1 - \frac{\mu_{t+1}}{1 + \sum_{s=0}^{t+1} \mu_s} \frac{U'\left(g^{\text{aut}}_{t+1}(k_{t+1})\right)}{U'(c_{t+1})}\right]. \tag{19}$$

Relative to the linear utility case, the wedge between the return to capital $f_{k,t+1} + 1 - \delta$ and the international rate R^*_{t+1} is given not only by the severity of the limited commitment constraints, but also by the difference between the marginal utility of consumption



(a) Total Factor Productivity **(b)** Capital Stock in period 5 **(c)** Consumption, $\sigma = 1$

Figure 5: Left panel: Total factor productivity. Middle panel: Capital stock in period 5 as a function of βR^*, no adjustment costs. Right panel: consumption dynamics for various values of R and $\sigma = 1$; darker color represents lower R^*.

in autarky and on the contract. The new term typically weakens the importance of limited commitment: The limited commitment constraints usually bind in good states, and in good states the consumption in autarky $g_t^{\text{aut}}(k_t)$ tends to exceed the consumption on the contract. The marginal value of capital in autarky is thus diminished. However, this term turns out to be relatively unimportant in the numerical exercises we have performed.

The key term is the first term in the bracket that involves the Lagrange multipliers on the limited commitment constraint. It can be written as

$$\frac{\mu_{t+1}}{1 + \sum_{s=0}^{t+1} \mu_s} = 1 - \beta R_{t+1}^* \frac{U'(c_{t+1})}{U'(c_t)}. \tag{20}$$

For linear utility, this term is equal to $1 - \beta R_{t+1}^*$ and so decreases with R_{t+1}^* at rate β. For concave utility, it decreases with with R_{t+1}^* at a faster rate for the following reason. Low international interest rates are associated with a decreasing consumption when the limited commitment constraints are slack. The lower the international rate, the faster is the decline in consumption, as in Panel 5c, where darker color represents lower R^*. To satisfy the binding limited commitment constraint in period $t+1$, consumption c_{t+1} must therefore be relatively higher for lower international rates. As a result, low international rates are associated with low marginal rate of substitution $\beta U'(c_{t+1})/U'(c_t)$. This magnifies the effect of the international rates on the left-hand side of (20), which now decreases with R_{t+1}^* at a rate higher than β. This dominates the last term in (19) and completely overturns the first-best result. As Panel 5b shows, this is true for all three levels of σ. However, the effect is stronger for lower elasticity of intertemporal substitution $1/\sigma$, as expected.

In the presence of incomplete capital stock depreciation or adjustment costs, capital stock in other periods will be affected as well, stretching the impact of low interest rates to other periods, but the main result was unchanged in our examples. We have also constructed examples, where lower interest rate increases the set of binding incentive constraints. In such case, lower interest rates generate an additional downward pressure on capital stock in other periods.

5 Data and Calibration

Capital stock data. Empirical implementations of the neoclassical growth model for Argentina, as for many other countries, has been hindered by the lack of a capital stock series that could be trusted. In fact, Argentina's government statistical agencies do not report an official series for the capital stock. Thus, researchers need to construct their own series using the perpetual inventory method, starting from a year in the sufficiently distant past, for which it can be safely assumed that the capital stock was virtually zero. The extent to which the resulting capital stock series can be trusted hinges critically, however, on the availability of a sufficiently long investment series for the different components of the capital stock. In its absence, one needs to estimate the capital stock for a particular year in the not-too-distant past and then exploit more recently available investment data to construct the series for that stock going forward with the perpetual inventory method.

Fortunately, the availability of long historical investment time series for Argentina, some going back as far as 1856, made it possible to construct estimates of the capital stock with the perpetual inventory approach that are quite reliable from 1950 onward, as by then investment in the distant past was nearly completely depreciated.

The historical investment series were extracted from Tafunell (2013) for the period 1856-1950, from Hofman (2000) for the period 1950-1980, and from the Argentine National Institute of Statistics and Census (INDEC) for the period 1980-2019. Given that those sources identify separately the machinery and equipment component and the structures component of gross fixed investment, it was possible to calculate in turn the residential and non-residential sub-components of the latter following the procedures suggested by Meloni (1999) and Maia and Nicholson (2001).

The complete time series in 2003 constant national prices for each of the three gross fixed investment components, machinery and equipment, non-residential structures and residential structures, was spliced from those available for adjacent periods of different length by applying the growth rates in constant prices implied by each of them, adopting 2003 as the base year. The capital stock for each of the investment components identified above was built up with the perpetual inventory method, applying the depreciation rates that the United States Bureau of Economic Analysis (BEA) employs in the construction of that country's capital stock: 14.75% for machinery and equipment, 3.0% for non-residential structures, and 1.6% for residential structures. The aggregate capital stock was the result of simply adding up that for each component.

Working Age Population. Working age population, defined as individuals 16 years old and above is also published by the INDEC. Since that source provides only quinquennial population estimates, the data for the intermediate years were obtained by geometric interpolation.

Output. We extended the output series from Kydland and Zarazaga (2007) for the years 1998-2019, with the data published by the INDEC in 2003 prices and expressed the entire series for the period 1980-2019 with the same splicing procedure applied to the investment series outlined above.

Total Factor Productivity. This series was obtained from the output and capital stock series by applying to the production function (2) a standard growth accounting procedure, assuming a value for the constant capital income share discussed in the next subsection. The detrended TFP series was normalized by setting its value in 1980 to that which makes the average value of the series over the period 1980-2019 equal to the value of TFP in steady state, assumed to be 1 following standard practice. The corresponding detrended output and capital series were normalized by a common constant, such that the value of output would be 1 if the capital stock were at its steady state value in any particular year of the 1980-2019 period.

Real International Interest Rates. The real international interest rates were constructed from the Moody's Seasoned Aaa Corporate Bond Yield. The average quarterly values of this series between the first quarter of 1980 and the last one of 2019 were deflated by expected inflation with the approach followed by Neumeyer and Perri (2005), that is, by the inflation rate of the GDP deflator in the corresponding quarter and the three preceding ones. The annual real international interest rates were calculated as the average of the four quarters of the corresponding year. The resulting time series for the international interest rate has been shown in Figure 2 in the introductory section.

5.1 Calibration

We calibrate the model for the Argentine economy as follows. We set the coefficient of relative risk aversion $\sigma = 2$ and capital share $\theta = 0.4$. Based on the 1980-2019 period, we compute the depreciation rate $\delta = 0.0381$, net growth rate of technology $\gamma = 0.00419$ and working age population growth rate $\eta = 0.0143$.

The steady state international risk free rate R^*_{ss} is set to its average over the 1980-2019 period, which is 4.4 percent. We calibrate the discount factor β to be such that the steady state capital-output ratio is equal to 3.36, its average over the 1980-2019 period. This steady state capital-output ratio is lower than that that can be supported in a first-best economy. As a result, an implication of Proposition 2 is that the limited commitment constraints will be binding at the steady state. The resulting steady state interest rate R_{ss} faced by Argentina is 8.1 percent, which means that the steady state default rate is 3.6 percent. Finally, we set the adjustment cost parameter κ so as to match the volatility of investment over the 1980-2019 period to the data. This yields $\kappa = 2.65$. The key parameter values are summarized in Table 1.

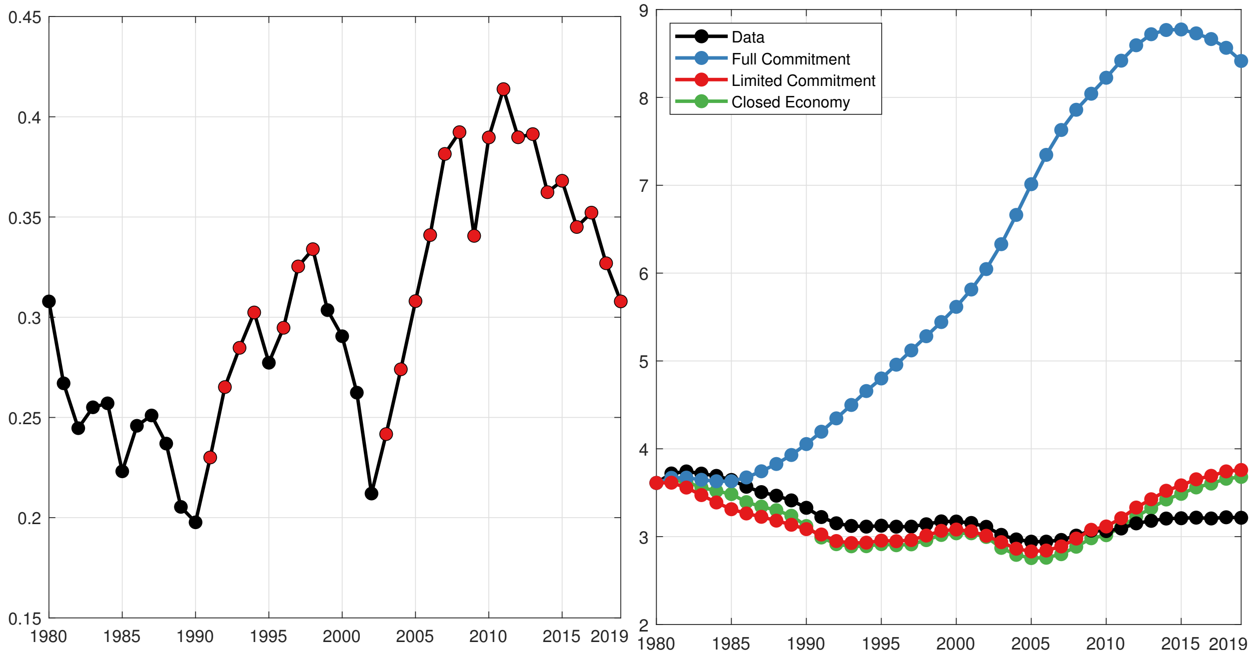
We run the experiment for the 1980-2019 period. We set the initial level of debt d_0 in 1980 to be zero, which is close to 3.2 percent of GDP, as computed by Lane and Milesi-Ferretti (2007). We feed in the actual time series for TFP, $\{a_t\}$ and assume that, after 2019, it reverts back to its mean value.

Table 1: Key parameter values

σ	β	δ	γ	η	R_{ss}	κ	d_{1980}/y_{1980}
2.000	0.933	0.0381	0.0042	0.014	1.081	2.65	0

Figure 6a shows again for convenience the total factor productivity for Argentina for 1980-2019. After a relatively rapid decrease in the 1980's, Argentine TFP recovered for most of 1990s, with a mild exception in 1995, when TFP temporarily declined. The crisis between 1998 and 2002 is visible by another drastic decline in TFP. After that, TFP recovered again. Red dots in figure 6b show periods when the limited commitment constraints bind: between 1991 and 1998, with the exception of 1995, and then after 2002. Those are periods when TFP is relatively high. As figure 6b shows, binding limited commitment constraints imply that the capital stock is relatively low. In contrast, in the first-best economy, investors accumulate a large amount of capital: in the absence of the limited commitment constraints, the capital stock would have been about more than 100% higher in 2019.

In other words, the calibrated model traces the decline that Argentina's capital stock experienced during the 1980s with remarkable accuracy because, as predicted by theory,



(a) Total Factor Productivity

(b) Capital Stock

Figure 6: TFP and capital stock for Argentina, 1980-2019, benchmark calibration. Red dots in panel (a) denote years when the limited commitment constraint binds.

the limited commitment constraints were almost never binding during that decade. At the same time, the limited enforcement frictions were often binding in the subsequent decades, resulting in a capital stock, represented by the red line in Figure 6b, that accounts for virtually all that stock missing from the Argentine economy in whole period, as captured by the distance between the blue and black lines in that same figure.

Notice also, as discussed in detail below, that the calibrated model is successful at replicating Argentina's capital stock asymmetric response to positive and negative changes of total factor productivity and its seemingly subdued reaction to lower international interest rates.

Response to TFP changes. Figure 6b also shows how the capital stock responds asymmetrically to changes in productivity. While the decline in the 1980s is about the same as in a full commitment economy, the reversal in 1990s is substantially stronger in the full commitment economy. By 1994, capital stock in the full commitment economy is well above that observed in 1980, but remains substantially below that level in the limited commitment economy. A similar pattern is repeated after 2002, when the capital stock increases rapidly above its 2002 level under full commitment, while under limited commitment it falls instead. The asymmetric response of the limited commitment economy is reminiscent of the closed economy, also depicted in Figure 6b.

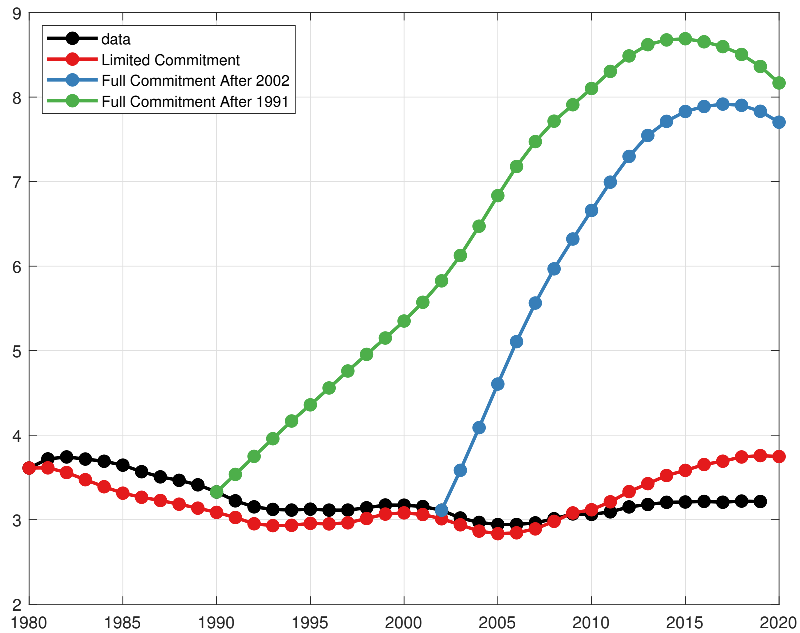


Figure 7: Capital stock in a second best economy, and in an economy where the limited commitment constraints are unexpectedly relaxed either in 1991 or in 2003.

The role of international rates. Figure 6a shows that the limited commitment constraints were binding between 1991 and 1998, and then again starting in 2003, until the end of the period under study. Those time periods coincide with periods of low international interest rates, as previously shown in figure 2. The examples in section 4 suggest that the low interest rates should contribute to the decline of the capital stock, rather than increase it, as it would in an economy without commitment problems.[7]

6 What if Argentina gains commitment?

To the extent that the inability to commit to honor its external debt obligations is a feature inherent to Argentina's economy, that country seems doomed to stagnation. But the limited commitment constraints in the model economy can be thought as a shortcut for a poor institutional configuration or social norms that prevent Argentina's governments, and the citizens who vote for them, to visualize the benefits of no longer belonging to the list of nations perceived as prone to "opportunistic defaults." Knowledge of the gains brought about by that change of perception in international credit markets could help to gather support for the structural reforms needed to remove Argentina from such a list.

Thus, suppose now that that nation, magically as it were, had implemented in 2003 those reforms. How much more capital it would have accumulated as a result? The answer is shown in Figure 7. There would be a gradual buildup of the capital stock

[7] The quantitative relevance for Argentina of the dampening effects of lower real international rates on the capital stock has been shown by Kapička et al. (2020) in a previous version of this paper.

which, due to the adjustment cost, would take about two decades two reach its new steady state level. In any case, that level would be substantially higher, about double, than that predicted by the model in the presence of limited commitment constraints.

The implication for workers is that their real wages, assuming the calibrated capital share of 0.4, would have experienced a large gain in 2019, as they would have been 35% higher than with the limited commitment friction.

A similar message emerges from performing the same exercise after 1990, that is, if starting in 1991 foreign investors would have been convinced of the commitment of the Argentine society not to confiscate their capital.

7 Final remarks

This paper has been motivated by the desire to identify some of the factors potentially responsible for the secular economic decline of Argentina, a country that belonged to the exclusive club of the top ten richest nations in the world at the beginning of the 20th century, only to descend to the status of mediocrity at the end of it.

A useful clue in this endeavor were empirical regularities observed in the responses of that country's capital stock to changes in total factor productivity and international real interest rates in the period 1980-2019. Particularly noticeable is the asymmetric nature of those responses to decreases and increases of TFP, and the fact that the international real interest rates declined contemporaneously with the rising TFP observed in the mid 1990s and mid 2000s, yet they failed to boost capital accumulation in Argentina.

Our results show that a model with limited commitment constraints, calibrated to Argentina's economy, can account for both of those features, and replicate Argentina's capital stock rather well. Sepcifically, the model can account not only for that country's capital shallowing in the lost decade of the 1980s, but also for the failure of its capital stock to show any significant recovery between 1992-1998 and 2002-2011, when TFP grew strongly and international interest rates were falling, reaching in the latter period low levels by historical standards. The relatively good quantitative performance of the model is especially noteworthy given that the paper stays away from introducing exogenous costs of default to improve the matching between the model predictions and the data, as most of the existing literature does.

At the same time, the model generates several predictions that do not fit data well. First, it produces the counterfactural result that net exports will be procyclical, when they are acyclical or countercyclical in the data. The inability of limited commitment models to match data along this dimension is well known. Second, in a decentralized economy, the intertemporal wedge Δ_{t+1} must be implemented by means of a capital income tax. We do not have any evidence that such a tax has been implemented. However, quantitative analysis not reported herein has revealed that the intertemporal wedge is rather small. It is therefore likely that a version of the model without the capital wedge will produce results that are quantitatively similar.

In any case, the paper demonstrates the overall ability of the limited commitment constraints to account for the capital that seems to have been missing from Argentina's economy in the period under study, despite unusually favorable domestic and international conditions. This finding questions the often-expressed view that the limited enforcement friction doesn't play a quantitatively important role in accounting for important aspects of the evidence of small open economies.

A future research agenda should examine if a stochastic version of the model economy studied in this paper, appropriately extended to include, for example, endogenous labor input, can do an equally good job at accounting for other dimensions of the evidence not explicitly considered in this paper.

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