Can Autocracies Guarantee Fixed Exchange Rates?

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Abstract

An autocratic ruler controls monetary and fiscal policy and expropriates wealth from society. In an Obstfeld (1994) framework extended to allow for taxes and an expropriation objective of the autocrat, reneging on a fixed exchange rate promise unambiguously produces short term benefits, but long term losses. The choice of exchange rate regime depends on the combined effect of greediness (expropriation) and impatience (political instability), though not straightforwardly. In particular, a very greedy autocrat may still not want to renege, if there is a lot of stability – as in the case of Indonesia under Suharto.

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1 Introduction

In a growing literature on the institutional determinants of exchange rate regimes, there seems to be a consensus on an empirical result by Edwards (1996) that “more unstable countries have a lower probability of selecting a pegged-exchange-rate system.” A recent study by Alesina and Wagner (2006) is more problematic because they consider political instability to be one of several indicators of institutional quality and find that “typically ... better institutions are associated with more pegged [exchange rate] regimes”. More precisely, their results suggest a “U-shaped relationship” according to which “countries that float tend to be either very low ... or very high in the institutional quality scale”. However, Alesina and Wagner’s paper cannot explain what happens when bad governance or corruption do not go together with political instability. Take a country like Indonesia which maintained fixed exchange rates for 20 years until 1997. It is haunted by corruption and defective governance, which according to Alesina and Wagner would point towards floating exchange rates. Yet there was a high level of political stability with Suharto in power for 32 years which would suggest fixed exchange rates.

This dilemma points to a problem arising in the empirically driven research on the institutional determinants of exchange rate regimes. We do not really understand what is going on, if we do not have a theory explaining the underlying mechanisms. This paper suggests one possible theory. Models by Obstfeld (1994) and Anderson (1998) are extended to allow for expropriation by an autocratic ruler while taking into account that political instability increases the autocrat’s impatience. On the one hand, we study the effect of expropriation on the choice of exchange rate regime through fiscal policy. Similar to Agell, Calmfors and Jonsson (1996), the autocrat has both control over fiscal and monetary policy. We do not model a conflict between independent monetary and fiscal authorities (nor do we model elections) as in Demertzis, Hughes Hallett and Viegi’s (2004) extended Barro-Gordon (1983) model. On the other hand, political instability – modelled as an argument of the

1 In empirical papers, Schuknecht (1999) discusses the reverse causality, i.e. the effect of exchange rate
discount factor as suggested by Edwards (1996) – has the same effect as in Méon and Rizzo (2002) who show that governments tend to renege on fixed exchange rate promises when the country becomes more unstable.

Assuming a fixed exchange rate regime as a starting point, this paper captures the autocrat’s optimal choice between reneging on or complying with the fixed regime. The autocrat has social objectives aiming at low inflation and high output, but he also expropriates wealth from society by using distortionary taxation. Reneging on a fixed exchange rate promise unambiguously produces short term benefits, because the autocrat can achieve lower real wages and boost output by deceitfully increasing inflation above agents’ expectations. However, there are long term losses since cheating only works once and inflation including its negative effects persist. It can be shown that reneging on a fixed exchange rate regime is advantageous to the autocrat only if he is sufficiently greedy (i.e. determined to exploit the country) and/or sufficiently impatient (including his fear of losing power). The main result of this paper is that the choice of exchange rate regime depends of the combined effect of greediness and impatience, though not straightforwardly. In particular, a very greedy autocrat may still not want to renege, if there is a lot of stability – as in the case of Indonesia.

The remainder of the paper is organised as follows. Section 2 presents the extended Obstfeld (1994) framework. Section 3 discusses the time line and the reneging and complying scenarios. Section 4 determines the overall gain and interprets the results. Section 5 concludes.

2 The Political Economy Model

The model extends the Obstfeld (1994) model in two ways: (i) taxation is explicitly captured and has a deadweight loss effect on output; and (ii) the autocrat adheres to inflation and regimes on fiscal policy, Alesina and Summers (1993) study the impact of central bank independence on economic performance, and Bergvall (2005) simulates output and output volatility for alternative exchange rate regimes in Sweden.
output objectives, but also has an expropriation revenue objective.

Output is determined by a modified short run expectations-augmented aggregate supply curve (Lucas supply curve with taxes):

\[
y_t = \bar{y} + \phi(\pi_t - \hat{\pi}_t) - \tau_t. \quad (1)
\]

Output \(y_t\) deviates from hypothetical trend output \(\bar{y}\) for two reasons: (i) wage inflation \(\hat{\pi}_t\) can differ from price inflation \(\pi_t\); and (ii) there are distortionary taxes \(\tau_t\).\(^2\) Hence equation (1) could also be called short run aggregate supply curve cum deadweight loss effect of taxes.

Wages are assumed to be based on expected price inflation:

\[
\hat{\pi}_t = \pi_t^e. \quad (2)
\]

Purchasing power parity links the home country to the rest of the world (foreign country \(f\)):

\[
\hat{e}_t = \pi_t - \pi_t^f, \quad (3)
\]

where the rate of depreciation \(\hat{e}_t\) depends on the inflation differential. Analogously for the expected rate of depreciation:

\[
\hat{e}_t^e = \pi_t^e - (\pi_t^f)^e, \quad (4)
\]

Assuming the home country to be small the foreign inflation rate \(\pi_t^f\) is given and normalised at 0%:

\[
\pi_t^f = \pi_t^f = 0. \quad (5)
\]

\(^2\) It is important to realise that hypothetical trend output \(\bar{y}\) is not attainable as long as the autocrat raises taxes which he does solely to satisfy his expropriation objective. Confer equation (7).
After insertions the supply function looks as follows:

\[ y_t = \bar{y} + \phi(\hat{e}_t - \hat{e}_t^e) - \tau t_t. \]  

(6)

The monetary component in the supply function now captures any deviation of exchange rates from expected exchange rates. A depreciation is not harmful for output as long as it is expected. In any credible fixed exchange rate regime (including a crawling peg), expectations would always correspond to actual depreciation rates – and there would be no effect on output.

The ruler’s linear quadratic loss function is assumed to comprise the standard components, deviation from desired inflation and deviation from hypothetical trend output, but also an expropriation component:

\[ L_t = \frac{1}{2}(\hat{e}_t^2) + \theta \frac{1}{2}(\bar{y} - y_t)^2 + \delta \frac{1}{2}(R^* - t_t y_t). \]  

(7)

The autocrat cares for inflation, for instance because inflation produces a deadweight loss and public discontent. The loss increases over-proportionately with increasing inflation. The ruler is also concerned about output, for instance because a reduction in output causes unemployment which again results in public discontent. The problem increases over-proportionately with more and more unemployment. Theoretically, this formulation implies a loss, if \( y_t \) exceeds \( \bar{y} \). However, due to the distortionary effect of taxes on output in equation (1), \( y_t \) will always be below \( \bar{y} \).\(^3\) The inflation objective (weight 1) and the output objective (exogenous weight \( \theta \)) capture the standard social objectives, here the autocrat’s interest in the economy as a whole.

The additional third term in the loss function reflects the autocratic ruler’s intention to exploit society. The exogenous weight \( \delta \) the autocrat puts on expropriation will be called greed. He is assumed to desire some level of expropriation revenue \( R^* \). The difference to the

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\(^3\) To avoid complications, \( k\bar{y} \) with \( k > 1 \) could be used. But that is not instrumental for the findings.
actual expropriation revenue $t_i y_i$ enters as a loss. The expropriation objective was chosen in linear format. A quadratic form would only drive the actual expropriation revenue closer to the desired level, but would not change anything fundamentally. There would be two problems though. The first issue is conceptual in nature. There is no clear-cut level for $R^*$ which should be reached with urgency. It does not make sense to punish deviations more and more with growing distance to this arbitrary level of $R^*$. In fact, the linear formulation allows for a gain when the actual expropriation exceeds the target level $R^*$. Thus $R^*$ could be set to 0 and effectively deleted from the equation, but is left in the equation for expositional reasons. Secondly, there is a technical issue. A quadratic form would complicate the analysis unnecessarily.

We obtain a consolidated loss function by inserting the constraint, i.e. supply function (6), into equation (7):

$$L_t = \frac{1}{2}(\hat{e}_t)^2 + \theta \frac{1}{2}(-\phi(\hat{e}_t - \hat{e}_e) + \tau t_i)^2 + \delta \frac{1}{2}(R^* - t_i(\bar{y} + \phi(\hat{e}_t - \hat{e}_e) - \tau t_i))$$.

(8)

The equation contains the exogenous parameters $\theta$, $\delta$, $\phi$ and $\tau$ and the constant variables $\bar{y}$ and $R^*$. For minimising his loss, the ruler has one or two policy instruments depending on the situation (scenario). Expropriation taxes $t_i$ are always determined by the ruler, but the rate of depreciation, $\hat{e}_t$, may be fixed or used as another instrument. The formation of expectations of the rate of depreciation, $\hat{e}_e$, will be discussed in the next section. Altogether, the equation has eight components (loss items):

1. **Inflation loss:** Any depreciation relative to the stable foreign currency means a deviation from monetary stability, i.e. inflation, and carries a loss for society. Obviously, an autocratic ruler may choose to attribute only a small relative weight for inflation (by making the other weights $\theta$ and $\delta$ larger).

2. **Inflation expectation induced output “gain”:** A surprise depreciation, i.e. a switch to flexible exchange rates while private agents still believe in the fixed rate, means
decreasing real wages and, therefore, lower production costs and increasing output. Nonetheless, squaring \((-\phi(\hat{e}_t - \hat{e}^e_t))\) produces a positive term, i.e. a loss. Only the cross factor component (next item) is negative. Items 2 and 3 appear together and are only present, when there is a surprise depreciation.

3. Cross factor component: Combining 2 and 4 due to the squaring, this is negative, i.e. a gain.

4. Expropriation tax induced output loss: There is always an expropriation tax and its deadweight loss effect reduces output, thereby producing a loss for the autocrat – assuming he values society’s output at least to some degree.

5. Desired revenue loss: The loss increases with the magnitude of the expropriation revenue desired by the autocrat (target level \(R^*\)). It is, however, reduced or offset by the actual expropriation revenue (determined by items 6 to 8 together).

6. Trend output induced revenue gain (offsetting loss 5): Higher hypothetical trend output represents a gain as it reduces the gap to the desired expropriation revenue.

7. Inflation expectation induced revenue gain (offsetting loss 5): A surprise depreciation has a positive effect on output and therefore on the expropriation revenue. Thus a gain.

8. Expropriation tax induced revenue loss: The last term \(\tau_t\) signifies that the expropriation tax has a negative impact on output, thereby reducing the expropriation revenue, hence reducing the positive effect of items 6 and 7. In other words, it represents a loss.

3 Time Line and Two Scenarios

In the following, we assume that the autocracy in question has made a commitment to keep exchange rates fixed. The country holds enough foreign reserves to make this a credible
commitment. In fact, we assume that the public trusts the ruler and does not know that there might be reasons for the autocrat to renege on his promise. By contrast, the ruler acts rationally on the basis of loss function (8). To determine whether to comply with or renege on his promise the autocrat compares the losses in both cases (scenarios) and calculates his net loss for each period. Introducing a discount factor we can then consolidate the net losses of all periods and determine the overall gain from reneging (which may be positive or negative).

If the country commits to fixed exchange rates in period T monetary policies are necessarily stability-oriented. Expansionary monetary policies are not possible as they would only result in pressure on the exchange rate which would require foreign exchange market interventions, thus offsetting the expansionary policies. In a stylised setting with zero inflation abroad, this means there will be no inflation at home either. Therefore, private agents will not demand wage rises. Once wage bargaining is complete, however, the ruler can decide, if he will go along with his promise or renege on it. If he reneges, there will be short-term effects (compared to complying), because real wage costs decrease and output expands. Raising output above its optimal level will prompt the autocrat to make adjustments in his optimal choice of policy, in particular he will be able to increase the expropriation tax in period $T$ which has a negative impact on output.

Following the literature, the model is set up such that there are no intertemporal linkages. The policy game played in period T is separate from the policy game in period $T+1$, which, in turn, is separate from that in period $T+2$, etc. There is one exception though: the ruler’s decision to renege affects agents’ depreciation expectations in the future. Let us, therefore, describe the time line of events in more detail. In period T, there is wage bargaining first, then the ruler’s decision to comply (thus defining the complying scenario) or renege

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4 Another interpretation is possible. Assume that the public wants to verify, whether they can trust the ruler or not. If private agents determine that upholding his promise is not the autocrat’s best choice, then the public would stop believing in the fixed exchange rate regime and it would collapse even before the ruler can take the decision to renege on his promise.
(reneging scenario). The outcome of the wage bargaining in T+1 and all following periods is determined by the ruler’s period T decision. So is the ruler’s decision in period T+1 and thereafter.

For simplicity, we assume that the ruler has only got one chance of reneging in period T. If he does, he is stuck with a flexible exchange rate in the future. The ruler can no longer exploit private agents’ trust. From T+1 onwards, agents correctly expect the inflationary policies of the ruler and demand wage increases accordingly. Going back to fixed exchange rates is not possible, because the presence of inflationary wages means that the ruler’s stability-oriented policies would only cause real wage increases and output losses. Thus it is optimal for the ruler to stick to the high inflation (depreciation) scenario. We also assume that complying in period T means complying in all future periods. The argument is that, if it were optimal for the ruler to comply in period T, there would be no reason why it should not be optimal in T+1 or thereafter.

Consider what happens in the complying scenario. There are no demands for wage increases and the ruler sticks to monetary commitment throughout. In period T as well as in periods T+1, T+2, ... he optimises with respect to the expropriation tax only. The ruler’s expropriation revenue will be smaller than desired because taxes also have a negative impact on output, thus trading off the negative output effect for the positive expropriation revenue effect. The loss in each period (confer appendix A) consists of the expropriation tax induced output loss (aforementioned loss item 4), the desired revenue loss (item 5), the trend output gain (item 6), and the expropriation tax induced revenue loss (item 8).

Next, let us look at the reneging scenario. The ruler reneges on his monetary commitment in period T which leads to a permanent switch to flexible exchange rates. In period T agents had not asked for a wage increase because they still believed in the ruler’s promise. Once wage bargaining is complete, the ruler reoptimises with respect to taxes and inflation. He can boost output by increasing inflation above the expected level. While doing so, it is optimal to increase expropriation taxation which damages output. Overall, there is an
increase in output in period T. In period T+1 agents do not trust the ruler and will demand wage increases in accordance with the ruler's optimal ex post decision irrespective of the autocrat's intensions. Therefore, it will be optimal for the ruler to optimise and validate private agents' expectations. Inflation will be higher now, but there will be no beneficial effect on output. Hence expropriation taxes will be set optimally at the same level as in the complying scenario.

The loss in the reneging scenario is different in T and the subsequent periods (confer appendices B and C). In period T, there is – compared to the complying scenario – an additional inflation loss (aforementioned loss item 1), but at least partly offset by inflation expectation induced gains both in terms of output (item 2 and 3) and revenue (item 7). At higher levels of taxation there will also be higher expropriation tax induced losses both in terms of output (item 4) and revenue (item 8). In period T+1 and all other future periods, taxes are back to "normal" (complying scenario level) even though inflation has increased (with inflation correctly being anticipated). Therefore, inflation expectation induced gains and additional expropriation tax induced losses will be gone – compared to period T.

4 Greed, Impatience and Overall Gain

We can now compare the two scenarios quantitatively in each period. Concerning any future period (T+1, T+2, etc.) the loss in the complying scenario is smaller than the loss in the reneging scenario. In other words, it would be advantageous to keep the monetary commitment. In each future period, permanently switching to flexible exchange rates produces a higher loss because of the additional negative inflation loss (item 1). There are no offsetting positive effects. The situation is very different when comparing the complying and the reneging scenarios in period T. Effects are countervailing. The reneging scenario again bears the additional negative inflation loss (item 1). However, there are further additional positive and negative induced output effects (items 2, 3 and 4) and induced revenue effects
Nonetheless, the comparison for period $T$ is unambiguous as well. Reneging on the monetary commitment is advantageous in period $T$ because the gain from increases in terms of output and expropriation revenue dominate the additional inflation loss.

So far, we know that reneging produces a net gain in period $T$ and a net loss in all future periods – compared to the complying scenario. To determine which scenario is more advantageous overall for a ruler (and hence chosen by him) we must make assumptions about how the ruler discounts his future. It is straightforward to assume a constant time preference rate. However, the effective discount factor $\rho$ ($0 < \rho < 1$) will also be influenced by the ruler’s chances to stay in power. This may depend on more or less rigged elections (like in Egypt) or on the chances for a revolution or a coup d’état (like in most Latin American countries in the 1980s). In any case, modeling the chance to stay in power as a response to the ruler’s behaviour is difficult and somewhat arbitrary. Even in democracies election outcomes are often strongly influenced by random events like foreign policy incidents, terror attacks (e.g. Madrid bombings in Spain) or natural disasters (e.g. river Oder flooding in Germany). A simpler alternative is to assume a constant (or variable) exogenous chance of losing power in each period. Even more simplistically, one could model the chance of losing power just once. No matter how this is modeled, incorporating political instability into the analysis has only one effect: the effective discount factor $\rho$ is reduced.\footnote{This is straightforward, because the (non-discounted) net loss of reneging relative to complying is identical for all future periods. – This is confirmed by Méon and Rizzo (2002) who discuss explicitly the effects of political instability on a government’s choice of the exchange rate regime. But it also applies in other contexts, for instance, in the government finance decision under political instability discussed in Bohn (2006).}

Following Edwards (1996) we assume, therefore, that the effective discount factor is a function of political instability. So, effective discount factor $\rho$ captures both normal impatience and political instability. Henceforth, effective discount factor, impatience and political instability will be used interchangeably.

The overall gain $G^{O}$ from a permanent switch to flexible exchange rates, i.e. the net gain in
T minus the discounted net losses in all future periods \((T+1, T+2, \text{etc.})\), turns out to be:

\[
G^O = \frac{A[(1 - 2\rho)B + \rho C]}{B^2[B - C](1 - \rho)}
\]  

(9)

with

\[
A = \frac{1}{2} \left( \frac{1}{2} \bar{y} \right)^2 \phi^2 (\theta \tau + \frac{1}{2} \delta)^2 > 0,
\]

\[
B = \tau (\theta \tau + \delta) > 0,
\]

\[
C = \phi^2 (\frac{1}{2})^2 \delta^2 > 0.
\]

\[
B - C > 0 \quad \text{according to appendix B.}
\]

The exogenous parameters \(\theta, \delta, \phi\) and \(\tau\) as well as exogenous discount factor \(\rho\) determine, if the overall gain of switching is positive or negative. Hypothetical trend \(\bar{y}\) only matters for the magnitude of the overall gain or loss. Expropriation objective \(R^*\) does not matter at all. If the overall gain is positive the ruler chooses to switch to flexible exchange rates in period \(T\) and sticks with flexible rates thereafter. If there is a negative gain, the ruler chooses to uphold his fixed exchange rate commitment indefinitely.

Since \(0 \leq \rho \leq 1\) the denominator must be positive. The numerator is positive for \(\rho \leq \frac{1}{2}\), but may or may not be positive otherwise:

\[
G^O > 0 \iff \rho < \frac{1}{2} + \frac{C}{2(2B - C)}
\]  

(10)

with \(0 \geq \frac{C}{2(2B - C)} < \frac{1}{2}\) since \(B > C\).

For given exogenous parameters \(\theta, \phi\) and \(\tau\), equation (10) establishes a relationship between \(\rho, \delta\) and \(G^O\) which is sketched in figure 1. As the ruler becomes more and more greedy, i.e. \(\delta\) goes up, he is expropriating the economy more and more by increasing expropriation tax
t_t, thereby choking back output. The sufficient condition for the minimisation problem in period $T$ of the reneging scenario requires that $B > C$. Confer appendix B. The limiting case $B = C$ defines a quadratic equation in $\delta$ which has only one positive root, $\delta^{\text{max}}$. We can show that $\delta$ must be smaller than $\delta^{\text{max}}$. The overall gain $G^O$ goes to infinity for $\delta$ approaching $\delta^{\text{max}}$, but decreases for smaller values of $\delta$. Realistically, we cannot be close to $\delta^{\text{max}}$, however, because there would be a lasting effect on output capacity and hence output in the following periods. This is not envisaged in this model since we treat all periods as independent. We would also assume that the effective discount factor is below .95, even if there is no political instability at all.

**Figure 1: Greed and Impatience**

Figure 1 shows the region of positive overall gain in a $\rho - \delta$ diagram. As long as $\rho \leq \frac{1}{2}$ (extreme discounting), the overall gain will always be positive. This means that a fixed exchange rate regime can never be an option for a rational ruler in a very unstable environment. For $\rho > \frac{1}{2}$, the overall gain will turn negative at some stage for decreasing values
of $\delta$. A smooth and slightly concave curve connecting the points $(\frac{1}{2},0)$ and $(1,\delta_{\text{max}})$ defines the border between positive (above) and negative overall gains (below). This implies that even a very greedy ruler would want to stick to fixed exchange rates, as long as there is very little political instability. This is the Indonesian case. It would also be rational to keep fixed exchange rates, if greed is low, even though there is quite a lot of political instability (but $\rho > \frac{1}{2}$). Between those two extremes, political stability can be traded off for greed.

5 Conclusion

In an extended Obstfeld (1994) model we have investigated autocratic rulers’ rational choice of the exchange rate regime. The results suggest that it can be rational for an autocratic ruler to stick to fixed exchange rates despite high levels of political instability (if he is not very greedy) or despite high levels of greed (if there is little political instability). The latter case reflects the situation in Indonesia before 1997.

Despite mounting empirical evidence, it may still be useful to explain the determinants of exchange rate regimes in theoretical papers. This can help us understand the underlying mechanisms and explain real world observations which might be washed out in econometric studies. At the same time, empirical papers based on institutional variables are still facing some serious problems. For instance, there are unresolved endogeneity issues, there are problems based on the fact that some variables are only available as time-invariant data, and often data sets are not sufficiently large. For all these reasons, it would be worth while exploring the impact of other institutional variables in theoretical models. There is still a long way to go before we really understand the impact of institutions on the choice of exchange rate regimes.
6 References


Appendix

A Complying Scenario

The ruler’s minimisation problem is identical in all periods:

$$\max_{t_t} L_t \quad \text{s.t.} \quad \pi_t = 0 \quad t = T, T + 1, T + 2, ....$$

$$\iff \max_{t_t} \begin{array}{l}
\frac{1}{2} \tau^2 t_t^2 + \delta \frac{1}{2} (R^* - t_t \bar{y} + \tau t_t^2)
\end{array} \quad t = T, T + 1, T + 2, .... \quad (A.1)$$

The loss in each period is:

$$L_t = \frac{1}{2} R^* - \frac{1}{2} \frac{(\frac{1}{2} \delta y)^2}{\tau (\theta \tau + \delta)} \quad t = T, T + 1, T + 2, .... \quad (A.2)$$

B Sufficient Condition for Reneging Scenario, Period T

To ensure that our problem is a well-defined minimisation problem, we have to check the semi-definiteness condition:

$$L_{t_t t_T} L_{\pi_T \pi_T} > (L_{\pi_T t_T})^2$$

$$\iff \tau (\theta \tau + \delta) > \phi^2 \left( \frac{1}{2} \right)^2 \delta^2 \quad (B.1)$$

This condition will be imposed. It implies that the denominator in equation (C.2) is positive.
C Reneging Scenario

The ruler's minimisation problem in period $T$ is:

$$\max_{t} L_T \quad \text{s.t.} \quad \pi_T^e = 0$$

$$\iff \max_{t} \frac{1}{2}(\hat{e}_t)^2 + \theta \frac{1}{2}(-\phi \hat{e}_t + \tau t)^2 + \delta \frac{1}{2}(R^* - t(\bar{y} + \phi \hat{e}_t - \tau t)) \quad (C.1)$$

The loss in period $T$ is:

$$L_T = \delta \frac{1}{2} R^* - \frac{1}{2} \frac{(1/2 \delta \bar{y})^2 (1 + \theta \phi^2)}{B - C} \quad (C.2)$$

with

$$B = \tau (\theta \tau + \delta) > 0,$$

$$C = \phi^2 \left( \frac{1}{2} \delta^2 \right) > 0.$$

$$B - C > 0 \quad \text{according to appendix B.}$$

The ruler's minimisation problem in the following periods is:

$$\max_{t} L_t \quad t = T + 1, T + 2, ....$$

$$\iff \max_{t} \frac{1}{2}(\hat{e}_t)^2 + \theta \frac{1}{2}(-\phi (\hat{e}_t - \hat{e}_i^*) + \tau t)^2$$

$$+ \delta \frac{1}{2}(R^* - t(\bar{y} + \phi (\hat{e}_t - \hat{e}_i^*) - \tau t)) \quad t = T + 1, T + 2, .... \quad (C.3)$$

The loss in each period is:

$$L_t = \delta \frac{1}{2} R^* - \frac{1}{2} \frac{(1/2 \delta \bar{y})^2 (\tau (\theta \tau + \delta) - \phi^2 (\theta \tau + \frac{1}{2} \delta))}{\tau^2 (\theta \tau + \delta)^2} \quad t = T, T + 1, T + 2 ...(C.4)$$