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How to devalue exchange rates, without building up reserves: Strategic theory for central banking

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ABSTRACT

Central banks, wanting to devalue their currency, often intervene in the foreign exchange market by buying up foreign currency. Such interventions even if effective lead to a build up of foreign exchange reserves. This paper argues that the coupling of devaluation and reserve build up can be avoided if the central bank intervention takes the form of a 'schedule', that is, commitment to buying and selling conditional on the exchange rate.

1. Introduction

On 6th September, 2011, the Swiss National Bank caused a stir by announcing a ceiling for the Swiss Franc *vis-a-vis* the Euro, and stating that "it was prepared to buy foreign currencies in unlimited quantities".[1] Similar interventions by central banks to depreciate (and occasionally appreciate) currencies have been undertaken around the world. On September 15, 2010, the world felt the tremors when, following a sharp appreciation of the yen, the Bank of Japan sold yen and bought dollars. The immediate impact of this action was to weaken the yen *vis-a-vis* the US dollar. India's Reserve Bank (RBI) has also on occasion used similar action to "correct" exchange rate fluctuations.

These strategies have been used to promote exports or the inflow of foreign investment (Paul and Lahiri, 2008) and usually central banks have intervened via a conduit such as a bank that buys the foreign exchange on its behalf. To quote from a textbook (Auerbach, 1982, p. 414): "This method of influencing exchange rates is not always easy to detect. The central bank may have parties in the private sector intervene for them". In the U.S., to effect an intervention in the foreign exchange market, the Fed will often work through a dealing bank, such as Citibank.

One consequence of such action to depreciate the domestic currency is that it causes a build-up of foreign exchange reserves, such as happened with the People's Bank of China. This smoking-gun evidence of central bank action has been a source of global criticism. Also, some nations do not want to build up such costly reserves (for welfare implications of reserves, see Basu and Morita (2006)) but are reconciled to them as a byproduct of exchange rate intervention.

The aim of this paper is to, draw on simple microeconomic theory and show that there is no need to build up reserves. By appropriately designing *the nature of intervention*, the acts of influencing the exchange rate and building up foreign exchange reserves can be separated from each other. In particular, it is possible to depreciate your currency and leave no trail of large foreign reserves.

2. The problem

Suppose there are two currencies, the domestic, 'rupees', and the foreign, 'dollars'. The domestic demand curve for dollars is

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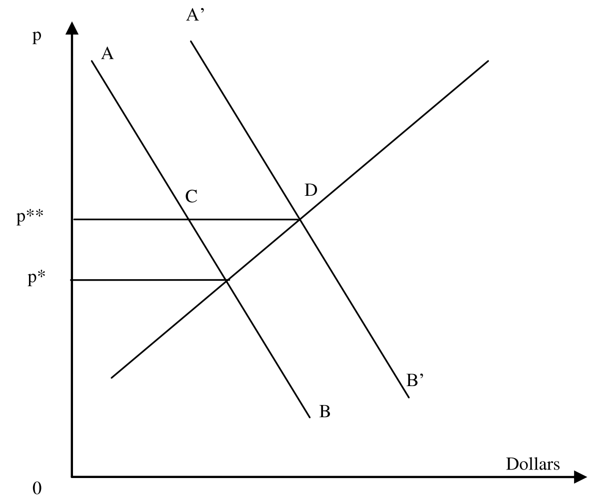

Fig. 1. Quantity intervention in foreign exchange markets.

given by AB in Fig. 1 and the supply curve by the upward sloping line. The equilibrium exchange rate is p^*.

Now suppose the central bank wants to devalue the currency to p^{**}. A natural way to achieve this is for the central bank to demand CD dollars. I shall call this a 'quantity intervention'. Such an intervention would push the demand curve out to A'B' and raise the price of dollars to p^{**}. This is exactly what central banks in many countries do. Note that, in the process, the central bank ends up acquiring CD dollars and releasing CD multiplied by p^{**} rupees in the market.

In a competitive market of this kind, a build-up of reserves is a natural concomitant of deliberate exchange rate depreciation by the central bank. The mistake that central banks make is to carry over this wisdom to other kinds of markets. In reality, most foreign exchange markets have large players co-existing with small agents. What has not been appreciated is that in such markets one can design other forms of intervention. Just as central banks worry that large agents will game the market, it is possible for central banks to game the large players.

3. Market structure and quantity interventions

To analyze formally, let p denote the rupee price of a dollar. Hence, a rise in p amounts to a devaluation of the rupee. Let the supply function of dollars in the domestic country be $s = s(p)$, where $s'(p) > 0$.

It is assumed that two kinds of agents demand dollars. First, there is the price-taking fringe. These may be ordinary citizens or small foreign exchange bureaus. Let the aggregate demand for dollars from this class of agents be $d = d(p)$, $d'(p) < 0$. Second, there are $n\,(\geq 2)$ large foreign-exchange dealers. These are strategic agents who can affect the exchange rate by their acts of buying and selling dollars. I refer to these firms as 'dealers'. It is assumed that dealers have some special use for dollars, not available to individual citizens and the small bureaus. In particular, each of these n agents reaps a value of u for each dollar that it purchases from the domestic foreign exchange market.

If $\tilde{p}$ is the price where $d(\tilde{p}) = s(\tilde{p})$, then we assume $u > \tilde{p}$. This ensures that it is worthwhile for these dealers to buy dollars on the domestic foreign exchange market. Hence, the market structure that I am considering is an oligopsony, along with a price-taking fringe of buyers and sellers. The market structure is the one used by Encaoua and Jacquemin (1980). The equilibrium in this market is the Nash equilibrium among the n oligopsonists, with the fringe responding non-strategically to the price.

Suppose, for all i, dealer i, demands x_i dollars. Then the demand for dollars will be equal to supply of dollars if the exchange rate, p, is such that:

$$x_1 + \cdots + x_n + d(p) = s(p) \tag{1}$$

or

$$x_1 + \cdots + x_n = s(p) - d(p) \equiv \psi(p). \tag{2}$$

I shall refer to ψ as the 'net supply function', and it will be assumed that a p satisfying Eq. (2) exists. This can be achieved by placing a domain restriction on the values that x_i' s can take or by assuming that for every number z, there exists a p such that $\psi(p) = z$. Since $s'(p) > 0$, $d'(p) < 0$, for all p, $\psi'(p) > 0$, for all p. Hence, the inverse of ψ exists. Let ϕ denote the inverse. So ϕ is the 'inverse net supply function'.

Hence, if the n large forex dealers demand $x_1, \ldots, x_n$ dollars, the price of dollars or the exchange rate will be given by

$$p = \phi(x_1 + \cdots + x_n). \tag{3}$$

And, in that case, the profit, π_i, earned by the forex dealer, i, is given by

$$\pi_i(x_1, \ldots, x_n) = ux_i - x_i\phi(x_1 + \cdots + x_n). \tag{4}$$

Therefore, $x^* = (x_1^*, \ldots, x_n^*)$ is an *equilibrium* if and only if x^* is a Nash equilibrium of the n-player game. Further, p^* is the *equilibrium exchange rate,* if $p^* = \phi(x_1^* + \cdots + x_n^*)$, where x^* is an equilibrium.

We are now in a position to study quantity interventions by the central bank. Let me here ignore the fact that central banks typically work through other banks, and assume that the central bank directly buys D dollars. Once it does so, (1) has to be written as:

$$x_1 + \cdots + x_n + d(p) + D = s(p). \tag{5}$$

So a price p that equates demand and supply has to take this into account. Hence, if the central bank demands D dollars and the n large dealers demand $x = (x_1, \ldots, x_n)$, using the notation in Eq. (2), the exchange rate, p, will be given by $x_1 + \cdots + x_n + D = \psi(p)$ or $p = \phi(x_1 + \cdots + x_n + D)$.

Firm i's profit is now given by

$$\pi_i(x_1, \ldots, x_n) = ux_i - x_i\phi(x_1 + \cdots + x_n + D). \tag{6}$$

Since the equilibrium will depend on D, I shall denote the equilibrium by $(x_1(D), \ldots, x_n(D))$, where this vector constitutes a Nash equilibrium of the above game. The equilibrium exchange rate $p(D)$ is then given by

$$p(D) = \phi(x_1(D) + \cdots + x_n(D) + D). \tag{7}$$

Let us first characterize the equilibrium in the above model. Since dealer i chooses x_i to maximize π_i, described in (6), we have the following first-order condition.

$$u = \phi(x_1 + \cdots + x_n + D) + x_i\phi'(x_1 + \cdots + x_n + D). \tag{8}$$

It will be assumed that (8) has a unique solution for x_i. It is easy to place restrictions on the primitives of the model to ensure this.

It can be checked that in equilibrium all dealers will choose the same quantity. Hence, $x_1 = x_2 = \cdots = x_n \equiv x(D)$. In other words, each dealer demands $x(D)$ dollars. The equilibrium exchange rate is given by

$$p(D) = \phi(nx(D) + D). \tag{9}$$

Let us now check how p changes in response to changes in D. As is familiar from standard IO theory, the answer depends on the strategic relationship between the forex dealers. The standard central bank policy works when there is strategic substitutability among the dealers. Fortunately, this is the natural assumption for firms dealing in the same product and for a wide class of demand and supply functions, $d(\cdot)$ and $s(\cdot)$, including, for instance, when these are linear (Singh and Vives, 1984). Strategic substitutability means that for every firm i, if another firm j increases, firm i will prefer to decrease x_i. Differentiating through Eq. (8) with respect to x_j, the strategic substitutability condition reduces to

$$\phi'(\cdot) + x_i\phi''(\cdot) > 0. \tag{10}$$

From now on I assume this to be true. However, for the main policy prescription that will emerge from this paper, this condition will not be needed. The consequence of the central bank entering the forex market is now easy to see. Note that in equilibrium, condition (8) reduces to: $u = \phi(nx(D) + D) + x(D)\phi'(nx(D) + D)$.

Using $y(D)$ to denote the aggregate demand for dollars, this can be rewritten as:

$$u = \phi(y(D)) + \left(\frac{y(D) - D}{n}\right)\phi'(y(D)). \tag{11}$$

Differentiating through with respect to D and rearranging terms we get

$$\frac{dy(D)}{dD} = \frac{\phi'(y(D))}{n[\phi'(y(D)) + x(D)\phi''(y(D))]}.$$

Strategic substitutability implies that $\frac{dy(D)}{dD} > 0$. Since $\phi' > 0$, it follows that, as D increases, p rises, that is, the rupee loses value. This is the justification behind the common practice of depreciating the domestic currency by buying up foreign currency on the domestic forex market.

The above intervention entails the central bank acquiring additional reserves of D dollars and injecting $p(D)D$ rupees into the economy. As we know, this reserve build up can have undesirable implications. This raises the question: Can we conceive of other ways of intervening in the foreign exchange market, which influences the exchange rate without building up large reserves? The answer, as the next section shows, is yes.

4. Schedule intervention

The key is to use what will here be called a 'schedule intervention', that is, one in which the central bank announces a *function*, or a *schedule*, f, which states, for every market price, p, the quantity of dollars, $f(p)$, that it seeks to buy. Since only one price will prevail in equilibrium, this amounts to stating contingent behavior — what it would have done if the price were different. Interestingly, that is what makes all the difference.

This alters the game played by the dealers, who will now take the new net demand function into account and respond in their own interest.[2] It is obvious that, with this new intervention, a price p will cause demand and supply to be equal if, instead of (5), we have the following:

$$x_1 + \cdots + x_n + d(p) + f(p) = s(p). \tag{12}$$

The price, p, that solves this equation can be written as a function of the total demand of the dealers and the intervention function, f. Hence,[3]

$$p = \hat{\phi}(x_1 + \cdots + x_n, f). \tag{13}$$

The payoff function of dealer i, is now given by:

$$\pi_i(x, f) = ux_i - \hat{\phi}(x_1 + \cdots + x_n, f)x_i. \tag{14}$$

An 'equilibrium', x^*, is a Nash equilibrium of this game, and an 'equilibrium exchange rate' is $p^* = \hat{\phi}(x_1^* + \cdots + x_n^*, f)$, where x^* is an equilibrium.

The central bank's problem is to influence p^* by choosing an appropriate schedule intervention, f. It can be shown that the central bank can now depreciate the currency with no build up of foreign exchange reserves. First define "no intervention" to be a schedule intervention, f^0, such that, for all p, $f^0(p) = 0$. Define $p^0 \equiv \hat{\phi}(x_1^* + \cdots + x_n^*, f^0)$, where x^* is a Nash equilibrium. Clearly p^0 is the equilibrium exchange rate of Section 3. Next, define $\tilde{p}$ to be such that $s(\tilde{p}) = d(\tilde{p})$.

Proposition. *For any price $\hat{p} \in (\tilde{p}, u)$, there exists a schedule intervention, f, such that the equilibrium exchange rate moves to $\hat{p}$ and the net purchase of dollars by the central bank is zero.*

To prove this, consider a $\hat{p} \in (\tilde{p}, u)$. The proof is unchanged whether we are interested in deflating or inflating the currency. Here is the intervention function that does the job:

$$f(p) = s(p) - d(p) - \left[\frac{s(\hat{p}) - d(\hat{p})}{n(u - \hat{p})}\right]p - \left[\frac{s(\hat{p}) - d(\hat{p})}{n(u - \hat{p})}\right][n(u - \hat{p}) - \hat{p}]. \tag{15}$$

For a pictorial representation, see Fig. 2. The line going north-east from $\tilde{p}$ is the net supply curve, $s(p) - d(p)$, that is, the excess supply, above what is demanded by the price-taking fringe. When the central bank is absent, let p^0 be the equilibrium exchange rate. We are looking for an intervention function, f, such that the central bank entering the foreign exchange market with that demand function drives the market price to $\hat{p}$ (for some arbitrarily chosen point, $\hat{p}$, between u and $\tilde{p}$); and the market clears with zero demand from the central bank.

To see that (15) does the job, note that $f(p) < 0$, for all $p > \hat{p}$, and $f(p) > 0$, for all $p < \hat{p}$. Hence, the graph of f looks like the line AB. (15) was constructed so that $s(p) - d(p) - f(p)$ is a straight line. This is shown by line EF, which goes through the point $(s(\hat{p}) - d(\hat{p}),\ \hat{p})$.

To complete the proof, insert the $f(p)$ function (15) in (12). This gives us

$$x_1 + \cdots + x_n = \left[\frac{s(\hat{p}) - d(\hat{p})}{n(u - \hat{p})}\right][p + n(u - \hat{p}) - \hat{p}] \tag{16}$$

$$p = [x_1 + \cdots + x_n]\frac{n(u - \hat{p})}{[s(\hat{p}) - d(\hat{p})]} - [n(u - \hat{p}) - \hat{p}]. \tag{17}$$

Using (14) we know that for every dealer, i, $\pi_i = ux_i - px_i$, where p is as given by (17).

By writing each firm's first order conditions and solving the n equations, it is easy to check that each dealer will demand as defined below.

$$\hat{x} = [s(\hat{p}) - d(\hat{p})]/n. \tag{18}$$

Hence, total demand by the dealers is $n\hat{x} = s(\hat{p}) - d(\hat{p})$. By (15), $f(\hat{p}) = 0$. Hence, $\hat{p}$ is the equilibrium exchange rate. The central bank buys no dollars and sells no dollars at the equilibrium.

The intuitive idea behind this result is obvious. The central bank is like a first mover who can alter the game that the n dealers play. By suitably altering the elasticity of the supply curve that the dealers face, the central bank directs them to the equilibrium

[2] The idea of an agent entering an oligopoly with a function as opposed to a quantity or price was developed in the 1980s (see Bresnahan, 1981; Klemperer and Meyer, 1988).

[3] Strictly, this can be multi-valued and so be a correspondence. However, the particular f function that we will use will ensure that $\hat{\phi}$ is a function; and so it is harmless to treat this as a function from the start.

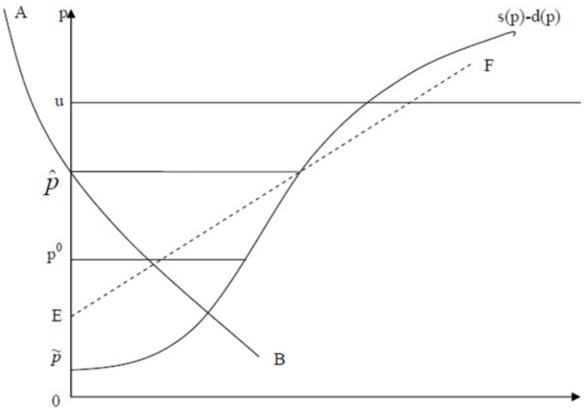

Fig. 2. Schedule intervention in foreign exchange markets.

it wishes without actually having to buy up foreign currency. Its commitment to buy suitable amounts of foreign currency should the exchange rate be different ensures that the exchange rate will not be different.

While the schedule intervention (15) results in zero reserve accumulation, we do not *have* to use this schedule. Essentially, the advantage of a schedule intervention is that we can set separate targets for the exchange rate and the level of reserve accumulation. So if we wanted to build up reserves without moving the exchange rate, even for that we could use an appropriate schedule intervention.

Further, if a nation feels that its currency needs to be revalued, under quantity intervention policy it has reason to be concerned that it may run out of foreign exchange reserves because, under quantity intervention, the way to revalue is to use foreign exchange reserves to buy up domestic currency. What the result in this paper suggests is that it need not have such a concern. By designing a suitable *schedule* intervention, it can make its own currency appreciate without having to drain its own foreign exchange reserves.

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