Developments in Business Simulation and Experiential Learning, Volume 27, 2000

VALIDATING A MODEL OF CURRENCY VALUATION

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ABSTRACT

An empirical study of the foreign-holdings model of currency valuation is conducted with 116 undergraduates taking part in an international-business gaming simulation. Results are consistent with current understanding of exchange rates. In the very long term, currency values of the model move in rough correspondence with monetary theory. In the short term, a high degree of uncertainty, with no repeating pattern, is evident. Uncertainty rose with the elapse of time between observations at the rate of about 1% per period.

INTRODUCTION

A computerized international business gaming simulation cannot be complete without incorporating currency exchange rates. For this purpose, Thavikulwat (1999) has proposed a foreign-holdings model that he proved to be self-limiting, volume-independent, and risk-compensating. The model values currencies relative to each other in direct proportion to the foreign holdings of each, that is,

$$X_{A,B} = \frac{F_A}{F_B} \tag{1}$$

where

$X_{A,B}$: Currency value of Nation A's currency with respect to Nation B's

F_A: Quantity of A's money owned without encumbrance by foreigners

F_B: Quantity of B's money owned without encumbrance by foreigners

In turn, foreign holdings are determined as follows:

$$F = IB - CB + (DA + FD) - (LA + FL) + (IA - VB) - (FI - VS) \tag{2}$$

where

IB: Initial balance

CB: Current account balance

DA: Deposits placed abroad by our nationals in foreign currencies

FD: Foreigner's deposits in our nation's currency

LA: Loans from abroad, denominated in foreign currency

FL: Foreigner's loans, issued in our nation's currency

IA: Investments abroad

VB: Value bought with investments abroad

FI: Foreigner's investments

VS: Value sold for foreigner's investments

Thavikulwat's analysis was entirely mathematical. He presented no empirical data showing that the currency value resulting from the model was valid, in the sense that it would correctly guide student analysis in a business gaming simulation.

The problem of validating a model for student analysis of a theoretical construct is different from the problem of validating a model for expert analysis of an everyday-world reality. In the latter case, the model can be said to be valid to the extent of its correspondence with its everyday-world counterpart (Peters, Vissers, & Heijne, 1998; Stanislaw, 1986). In the former case, however, the theoretical construct that the model attempts to replicate is observable in the everyday world only under exacting conditions that rarely occur. Thus, one generally observes that heavy objects fall faster than lighter ones, except under controlled experimental conditions.

Thavikulwat's foreign holdings model attempts to replicate the pricing behavior of perfectly knowledgeable international bankers operating in a crime-free world of zero transaction costs and completely rational governments. That world is idealized and nonexistent. The rationale for modeling it is the same as that for developing laws of motion for bodies in a vacuum. The vacuum does not exist, but the forces that operate in a vacuum also operate without a vacuum. The difference is that under everyday-world conditions, their effects can be confounded by situational factors.

Thus, Thavikulwat's foreign holdings model cannot be validated against the behavior of the U.S. dollar, the German mark, or the Mexican peso of the everyday world, for these currencies operate in a messy world that the model does not attempt to replicate. The model must be validated against our understanding of the forces underlying exchange rate movements. Unfortunately, those who study currency exchange rates have been notably unsuccessful in putting forth theories that have withstood the test of time. Thus, De Grauwe, Dewachter, and Embrechts (1993) noted the "situation where theories are developed to fit the exchange rate cycle in which we live, [so that] a different theory seems to be needed for every different cycle," a sentiment echoed also by Copeland (1994).

Even so, monetary theory is generally accepted as the standard for explaining currency exchange rates over the very long run of 15 or more years. The central idea of this theory is that currency is simply a medium of exchange. Its value should therefore reflect the prices of the goods and services it can buy, and these prices vary directly with the supply of money and inversely with the quantity of goods and services that can be bought. Thus:

$$X_{A,B} = a\left(\frac{M_{A,B}}{Y_{A,B}}\right)^{b} \tag{3}$$

where

$M_{A,B}$: Money supply of Nation A relative to Nation B

$Y_{A,B}$: Quantity goods and services that can be bought in Nation A relative to those quantities in Nation B

a, b: Relational parameters

More recent theories take the position that currency is not just a medium of exchange, but an asset that has a place in a balanced investment portfolio. Uncertainty is emphasized, as well as the possibility that exchange rates may be inherently unpredictable in the short-term even in the absence of chance. Although all of these recent theories remain unsettled, they do suggest characteristics that can be examined to assess the validity of models.

The task in validating a model for a gaming simulation is to show that the results of the model are not aberrant when compared to what is known about the subject. For a model of currency values, one needs to show that within the very long run interval of a gaming simulation, however that might be defined operationally in the particular implementation, the movement of currency values corresponds roughly with monetary theory. In this test, both extremes of an exact fit and a complete absence of fit would undermine validity. Moreover, one must show that within the short term currency values move in a manner consistent with a high degree of uncertainty, that no repeating pattern is evident, and that the uncertainty rises with the elapse of time between observations.

The study reported here attempts to validate Thavikulwat's foreign holdings model through those considerations. Data was obtain from a gaming simulation wherein participants were divided into three nations and allowed to trade, invest, and move short-term funds internationally, based on exchanged rates set computationally by the model. Although the behavior of the banking system in setting exchange rates was completely determined by the model, simulation participants were free to act in their own self-interest as they saw fit. Moreover, because participants were fully informed about the mathematics of the model, they were collectively in full control of its results. Thus, to the extent the model is valid, it is valid because it fits the human nature of the participants, and not because of the mathematics alone.

METHODOLOGY

Participants

Participants were 116 undergraduates enrolled in three sections of an international-business course at a comprehensive university. Each section constituted a nation. The nations were named North, South, and East, with participant populations of 40, 37, and 39, respectively.

Gaming Simulation

The gaming simulation, GEO III, was computer-assisted, as defined by Crookall, Martin, Saunders, and Coote (1986). It scored participants on a consumption-based scheme (Thavikulwat, 1990). Thus, each individual received a periodic income from his or her government, supplemented with salaries and dividends from companies and capital gains from trading stocks, and each was scored based on the points received when the individual expended monies to purchase products produced by companies that the participants themselves founded. In all, the participants founded 161 companies, of which 88 had become insolvent by the conclusion of the semester-long exercise.

Time in the gaming simulation was activity driven, advancing automatically whenever a preset count of participants had gained access to the computer system. Over the course of the semester, it advanced through 1,042 periods over 13 active weeks. Decisions were entered asynchronously, and could be executed whenever the participants got access to the local area network on which the simulation was installed. Access was usually available some time every day of the weeks.

Model

Thavikulwat's foreign-holdings model was used to determine currency values. The currency exchange rates themselves were adjustably-pegged with an incremental parameter of 0.2 in accordance with the geometrically-centered method suggested by Thavikulwat. Thus, exchanges rates moved in discontinuous steps by a factor of 1.2 (i.e., 1.2^{-n}, …, 1.2^{-2}, 1.2^{-1}, 1, 1.2, 1.2^{2}, …, 1.2^{n}). Moreover, foreign-holdings computation was simplified by assuming that the value of every investment was identical to the payment made to acquire it. Thus, Equation 2 was simplified to the following:

$$F = IB - CB + (DA + FD) - (LA + FL) \tag{4}$$

Data

Data files of the gaming simulation were archived every day that the gaming simulation was active. Because time in the gaming simulation was activity driven, the number of periods between archived data ranged from 0 to 69. Eliminating data of the early periods when activity was minimal and keeping only the most recent data set of those from the same period, 66 data sets were selected for this study. The mean number of periods between data sets was 15.8 (*SD* = 19.9).

Besides foreign holdings, the data included a measure of each nation's money supply (M1), gross domestic income (GDP), and consumer price index (CPI). M1 was computed by adding together the cash balances of individuals and companies. It was a snapshot of the simulation's economy at the time each data set was archived. The CPI was an average of consumer payments for products on a payment-per-point basis. It and the GDP were aggregated from the beginning of the exercise to the current period of each data set.

Results

The full monetary model of Equation 3 requires both *M* and *Y* on its right-hand side. For *Y*, economists commonly use the annual GDP of the preceding year, adjusted for inflation by a price index taken over the same interval. With that approach, the inflation-adjusted GDP is a proxy for the desired measure, which is the quantity of goods and services that can be bought with *M*. The proxy is convenient, considering especially the impossibility of directly measuring things that *can be* bought. Nevertheless, it introduces error that may be worse than simply dropping *Y* from the formulation, equivalent to assuming that relative changes in *Y* are negligible when compared to relative changes in *M*.

To test the fit of monetary theory to the model-derived currency values of the gaming simulation, Equation 3 was transformed logarithmically as follows:

$$\ln(X_{A,B}) = \ln(a) + b\ln\left(\frac{M_{A,B}}{Y_{A,B}}\right) \tag{5}$$

Data from the gaming simulation were then fitted to the model by regression in two trials. Trial 1 included *Y* adjusted for inflation using the CPI; Trial 2 omitted *Y*. The results are presented in Table 1, for North Nation with respect to South Nation, and Table 2, for North Nation with respect to East Nation.

As Tables 1 and 2 show, the full monetary model, with *Y,* is not a statistically significant fit for the currency values of the gaming simulation in both cases, but the simplified model, excluding *Y*, is a statistically significant fit in the case of North vs. South, but not in the case of North vs. East. Nevertheless, the sign of the *b* parameter is positive in all instances, as required by monetary theory. Thus, the data may be said to correspond roughly with monetary theory.

As for the uncertainty and possible pattern in the movements of currency values, Figure 1 plots currency value and money supply for North Nation with respect to South Nation over the course of the exercise, and Figure 2 plots the corresponding values for North Nation with respect to East Nation over the same interval. Consistent with theory, the plots evidence a high degree of uncertainty, with no obvious repeating pattern to currency values. A measure of the increase in uncertainty that rises with the elapse of time between observations can be obtained by fitting the data to the following equation:

$$\frac{\max(X_t, X_{t-n})}{\min(X_t, X_{t-n})} = an^b \tag{6}$$

where

X_t, X_{t-n}: Currency values observed at times *t* and *t-n*, respectively

n: Number of periods between two observations of currency values

a, b: Relational parameters

Transforming Equation 6 logarithmically results in:

$$\left|\ln(X_t) - \ln(X_{t-n})\right| = \ln(a) + b\ln(n) \tag{7}$$

TABLE 1
REGRESSION OF NORTH NATION WITH RESPECT TO SOUTH NATION

Trial	ln(*a*)	*b*	r^2
1 (with *Y*)	0.244 (t = 1.27)	0.211 (t = 0.89)	0.01
2 (without *Y*)	-0.206 (t = -1.91)	0.681*** (t = 4.00)	0.20

***$p < .001$

TABLE 2
REGRESSION OF NORTH NATION WITH RESPECT TO EAST NATION

Trial	ln(a)	b	r^2
1 (with Y)	0.546*** (t = 4.70)	0.199 (t = 1.39)	0.03
2 (without Y)	0.416** (t = 3.30)	0.309 (t = 1.67)	0.04

$^{**}p < .01$, $^{***}p < .001$

FIGURE 1
PLOT OF NORTH NATION'S CURRENCY VALUE AND MONEY SUPPLY RELATIVE TO SOUTH'S

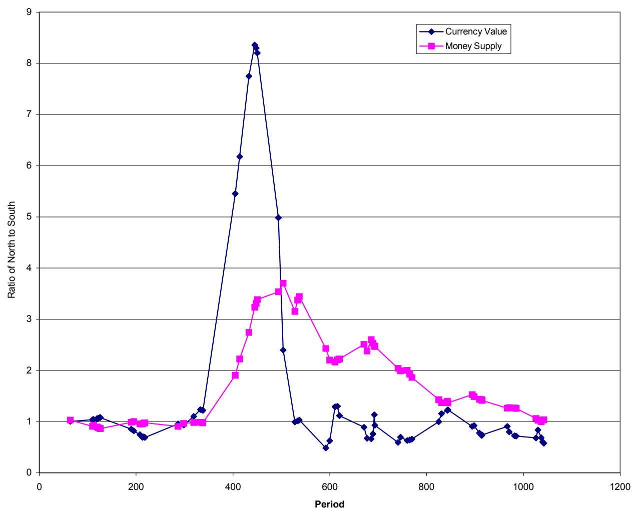
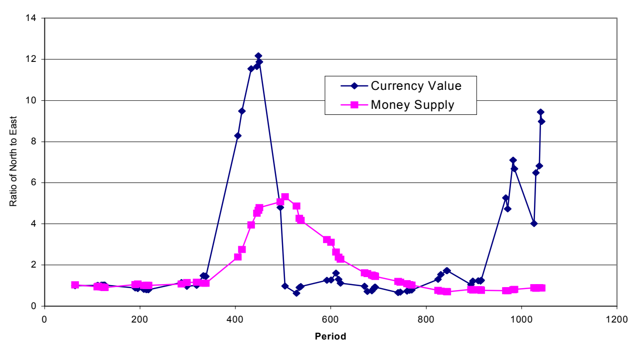


FIGURE 2
PLOT OF NORTH NATION'S CURRENCY VALUE AND MONEY SUPPLY RELATIVE TO EAST'S



Fitting Equation 7 to the data by regression gave rise to the results of Table 3. The fit is remarkably strong. Considering that the b parameter is within one standard error of 1.0 (SE = 0.125 for North vs. South; SE = 0.156 for North vs. East) and that the regression estimated value of a averages to 0.01 ($e^{-4.522}$ = 0.0109 and $e^{-4.731}$ = 0.0088), the data may be said to be consistent with the following result:

$$\frac{\max(X_t, X_{t-n})}{\min(X_t, X_{t-n})} = 0.01n \quad (8)$$

TABLE 3
REGRESSION OF CHANGES IN CURRENCY VALUES OVER TIME

Series	ln(a)	b	r^2
North vs. South	-4.522*** (t = -15.53)	0.882*** (t = 7.03)	0.44
North vs. East	-4.731*** (t = -13.04)	0.960*** (t = 6.14)	0.37

$^{***}p < .001$

Thus, currency values in the gaming simulation diverge at the rate of about 1% per period. This is a measure of the time-dependent risk of holding foreign currencies in the gaming simulation.

CONCLUSION

This study shows that a simplified version of the foreign holdings model performed in a manner consistent what is know about currency exchange rates. The data roughly fits monetary theory, as would be expected from a sufficiently valid model. Currency values move in a manner consistent with a high degree of uncertainty, with no evident repeating pattern, and with an uncertainty that increased at the approximate rate of 1% per period.

The degree to which uncertainty increases with elapsed time depends upon the initial-balance value of the model. Thavikulwat (1999) did not suggest an initial-balance value. By the logic of the mathematics, however, larger initial-balance values must give rise to lower time-dependent risks of holding foreign currencies, but additional studies will be needed to determine the precise relationship.

When understanding of a subject is weak, as it clearly is in the subject of currency valuation, any model of that subject area is likely to be somewhat incorrect. Thus, Thavikulwat's foreign-holdings model is probably incorrect in some degree. It may have few applications in everyday-world settings. Applied to gaming simulation, however, this study shows that any incorrectness it may have is not evident. The consideration that participants may be forgiving even if an algorithm should be incorrect in some way, as Wolfe and Jackson (1989) has demonstrated, adds another level of comfort to its use.

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