A MACROECONOMIC MODEL OF THE THAI ECONOMY

APPENDIX TO:

‘Thailand’s Investment-driven Boom and Crisis’

By

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This document describes the macroeconomic model used in the above paper. A schematic overview of the model is provided in section 2 of the main paper. The strategy in this appendix is to outline the variables of the model (Section A.1), then to describe its structure (Section A.2), its behavioural equations (Section A.3), the data used in estimation and simulation (Section A.4) and its solution procedure (Section A.5). Finally, we illustrate the properties of the model by means of four sets of diagnostic simulations (Section A.6).

A.1 VARIABLE DEFINITIONS

The main notational conventions are as follows. Real variables, meaning quantities or values measured at constant baht prices,\(^1\) are denoted by upper case Roman letters (such as \(Y\) for real GDP). Nominal variables, meaning values measured at current baht prices, are denoted similarly, but with tildas above the letter (such as \(\tilde{B}^{Ct}\) for the current account balance). Parameters are denoted by Greek letters. All other variables are denoted by lower case Roman letters, including: prices denominated in baht, denoted by \(p\); interest rates, denoted by \(r\); and the exchange rate, denoted by \(e\). All prices and all nominal values are denominated in baht except those denominated in US dollars, in which case they are indicated with a superscript asterisk (*). For example, the foreign prices of Thailand’s imports, denominated in US dollars, are denoted by \(p^{M*}\). Variables relating to the three agents defined in the model, the government sector, the private sector and the foreign sector (a hypothetical agent outside

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\(^1\) The baht is the unit of the Thai currency.
Thailand who trades with agents inside Thailand), are indicated by the superscripts $G$, $P$ and $F$, respectively.

The model consists of 33 equations. It contains 44 variables, listed alphabetically below, of which 33 are endogenous and 11 are exogenous.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tilde{B}^{CA}$</td>
<td>current account balance</td>
</tr>
<tr>
<td>$C^G$</td>
<td>government consumption</td>
</tr>
<tr>
<td>$C^P$</td>
<td>household consumption</td>
</tr>
<tr>
<td>$D$</td>
<td>domestically produced goods sold in the domestic market</td>
</tr>
<tr>
<td>$e$</td>
<td>nominal exchange rate - Thai currency (baht) per unit of foreign currency</td>
</tr>
<tr>
<td>$\tilde{E}^a$</td>
<td>expenditures of agent $a$, where $a = (G,P,F)$</td>
</tr>
<tr>
<td>$\tilde{H}^{FG*}$</td>
<td>stock of government debt held by foreigners, in US$</td>
</tr>
<tr>
<td>$\tilde{H}^{GP}$</td>
<td>stock of government debt held by the private sector, in baht</td>
</tr>
<tr>
<td>$I^F$</td>
<td>foreign direct investment</td>
</tr>
<tr>
<td>$I^G$</td>
<td>government development expenditure</td>
</tr>
<tr>
<td>$I^P$</td>
<td>private domestic investment</td>
</tr>
<tr>
<td>$\tilde{J}^{FG}$</td>
<td>interest payments on foreign assets paid by the foreign sector to the government</td>
</tr>
<tr>
<td>$\tilde{J}^{GP}$</td>
<td>interest payments on government debt from the government sector to the private sector</td>
</tr>
<tr>
<td>$K^A$</td>
<td>CES aggregate of $K^F$ and $K^P$</td>
</tr>
<tr>
<td>$K^F$</td>
<td>stock of foreign-owned capital</td>
</tr>
<tr>
<td>$K^G$</td>
<td>stock of government capital</td>
</tr>
<tr>
<td>$K^P$</td>
<td>stock of private domestic capital</td>
</tr>
<tr>
<td>$L$</td>
<td>labour supply (labour force)</td>
</tr>
<tr>
<td>$M$</td>
<td>import of goods and services</td>
</tr>
<tr>
<td>$\tilde{N}^a$</td>
<td>net asset accumulation of agent $a$, where $a = (G,P,F)$</td>
</tr>
<tr>
<td>$\rho^C$</td>
<td>price of consumption goods</td>
</tr>
<tr>
<td>$\rho^D$</td>
<td>deflator for domestically produced goods sold in the domestic market</td>
</tr>
<tr>
<td>$\rho^I$</td>
<td>price of investment goods</td>
</tr>
<tr>
<td>$\rho^K$</td>
<td>rental cost of capital in the domestic market, in baht</td>
</tr>
<tr>
<td>$\rho^M$</td>
<td>price of imported good, in baht</td>
</tr>
</tbody>
</table>
\( p_{M^*} \) price of imported good, in US$

\( p_X \) price of exported good, in baht

\( p_{X^*} \) price of exported good, in US$

\( p^Y \) GDP deflator

\( r_{LIB} \) LIBOR interest rate, in baht

\( r_{TB} \) Thai treasury bill interest rate, in baht

\( \bar{R}^a \) revenues of agent \( a \), where \( a = (G,P,F) \)

\( t \) time

\( X \) export of goods and services

\( Y \) real GDP

\( \bar{Y} \) real production capacity (a constructed variable)

\( Y^P \) real private sector disposable income

\( Z^P \) real private sector assets

A.2 SCHEMATIC STRUCTURE

In this section we shall provide a schematic overview of all the equations of the model. Several identities are necessary to obtain a complete system, including equations for the evolution of asset stocks, for a number of price indices, budget constraints for the various agents, and financial flows. The model also contains estimated behavioural equations for production capacity, which includes an equation for the aggregate capital stock, consumption, investment, exports, imports, and the domestic price level. In the schematic list below, \((E)\) is used to indicate those behavioural equations whose functional forms and parameters, empirically estimated using Thai data, are described separately in Section A.3 below.

A.2.1 Exogenous variables

\[ C^G \quad e \quad I^F \quad I^G \quad L \quad p^K \quad p_{M^*} \quad p_{X^*} \quad r_{LIB} \quad r_{TB} \quad t \]

A.2.2 Equation system

In this schematic representation, the dynamics of estimated equations are suppressed. They are made explicit in the next section.
a) Aggregate supply

\[ \overline{Y} = f(K^G, K^A, L) \]  \hspace{1cm} (E) \hspace{1cm} (A 1)

\[ K^A = f(K^P, K^F) \]  \hspace{1cm} (E) \hspace{1cm} (A 2)

b) Aggregate demand

\[ Y = C^G + C^P + I^G + I^P + I^F + X - M \]  \hspace{1cm} (A 3)

\[ C^P = f(Y^P, Z^P) \]  \hspace{1cm} (E) \hspace{1cm} (A 4)

\[ I^P = f(p^K, Y, K^P, K^A) \]  \hspace{1cm} (E) \hspace{1cm} (A 5)

\[ X = f(\overline{Y}, p^X, p^Y, K^F, K^A) \]  \hspace{1cm} (E) \hspace{1cm} (A 6)

\[ M = f(p^M, p^X, Y, I^F) \]  \hspace{1cm} (E) \hspace{1cm} (A 7)

\[ D = Y - X \]  \hspace{1cm} (A 8)

c) Stocks of real assets

\[ \Delta K^a = I^a - \phi K_{-1}^a \]  \hspace{1cm} a = (G, P, F) \hspace{1cm} (A 9)

d) Prices

\[ p^D = f(p^C, Y/\overline{Y}) \]  \hspace{1cm} (E) \hspace{1cm} (A 10)

\[ p^C = f(p^D, p^M) \]  \hspace{1cm} (E) \hspace{1cm} (A 11)

\[ p^D = (p^D D + p^X X)/Y \]  \hspace{1cm} (A 12)

\[ ^2 \text{ This equation is the augmented Phillips curve relationship, as described in section A.3 below.} \]

\[ ^3 \text{ This equation describes the construction of the consumer price index, as described in section A.3 below.} \]
For the reasons explained in the text, it is convenient to derive a measure of macroeconomic vulnerability. The expression we shall derive is a side-calculation from the model in the sense that it does not feed back into any other equation. For the purpose of this analysis, our measure of macroeconomic vulnerability focuses on the relationship between the stock of international reserves, on the one hand, and the stock of foreign-owned, internationally mobile funds which could be presented against them. We begin with the balance of payments identity

\[ \Delta R^* = B^{Ct*} + B^{Kt*} = B^{Ct*} + B^{Kt*} + B^{Kt*} \]  

(A 16)

where \( \Delta R^* \) denotes the change in the stock of international reserves, \( B^{Ct*} \) denotes the balance on current account and \( B^{Kt*} \) represents the balance on capital account. The short-term and long-term components of this net capital inflow are denoted \( B^{Kt*} \) and \( B^{Kt*} \), respectively. As before, the asterisk superscripts (*) indicate that these variables are each measured in US$. We shall regard these two components of the net capital account balance as representing the change in the foreign-owned stocks of immobile (long-term) and mobile (short-term) capital, respectively. Vulnerability increases when the change in the stock of mobile capital exceeds the change in the stock of reserves. Rearranging this expression, we obtain

\[ \Delta V^* = B^{Kt*} - \Delta R^* = B^{Ct*} + B^{Kt*}. \]  

(A 17)

The change in vulnerability \( (\Delta V^*) \) is given by the difference between that component of the balance on capital account consisting of short-term capital (the change in the stock of mobile capital) and the change in reserves \( (B^{Kt*} - \Delta R^*) \), which is identically equal to the balance on current account plus that component of the balance on capital account consisting of long-term capital (the change in the stock of immobile capital) \( (B^{Ct*} + B^{Kt*}) \). For the purposes of this analysis we identify the long-term balance on capital account with the net inflow of foreign investment, measured in US$, \( I^{F*} = p^t I^{F} / e \). Our measure of the change in crisis vulnerability is thus\(^4\)

\(^4\) We are not advancing this as an ideal measure of crisis vulnerability, but it has the advantage of being both conceptually meaningful and tractable in terms of the variables entering our model.
\[ \Delta V^* = (\tilde{B} C^t + p^l I^F) / e. \] (A 18)

The level of vulnerability is now obtained by accumulation of equation (A 18) over a number of years, so that \( V^*_t = V^*_t + \Delta V^*_t \). Our measure arbitrarily sets the level of vulnerability at zero for an earlier year (1972 is chosen) and accumulates its value for all subsequent years.

f) Budget constraints and financial flows

Finally, we show that the model is internally consistent, in that the standard macroeconomic accounting identities are satisfied. First, consider the budget constraints for the government sector (\( G \)), the private sector (\( P \)) and the foreign sector (\( F \)). For each of these agents we shall utilise the identity:

net financial surplus (\( \tilde{N}^a \)) = revenue (\( \tilde{R}^a \)) - expenditure (\( \tilde{E}^a \)), where \( a = (G,P,F) \).

(i) Government sector

Revenue:
\[ \tilde{R}^G = \tilde{T} + \tilde{J}^{FG} = \tau(p^F Y - \pi^F p^l K^F + \tilde{J}^{GP}) + \tilde{J}^{FG} \]

Expenditure:
\[ \tilde{E}^G = p^C C^G + p^l I^G + \tilde{J}^G \]

Net revenue:
\[ \tilde{N}^G = \tilde{R}^G - \tilde{E}^G = e\Delta \tilde{H}^{FG^*} - \Delta \tilde{H}^{GP} \]

Interest payments by government:
\[ \tilde{J}^{GP} = r^{TB} \tilde{H}^{GP}_{-1} \]

The behavioural assumptions underlying this treatment may be clarified by rearranging the expression to read \( \Delta \tilde{H}^{GP} = -\tilde{N}^G + e\Delta \tilde{H}^{FG^*} \). The government's issuance of new debt to the private sector (\( \Delta \tilde{H}^{GP} \)) depends on two components. The first is the government's net financial deficit on domestic transactions (\( -\tilde{N}^G \)). The second arises when the private sector generates a surplus in foreign currency on its international transactions, to be discussed below. It is assumed that the private sector is legally required to deposit these foreign funds with the central bank, receiving additional government debt in exchange, denominated in baht. The government then deposits the foreign currency so received in its international account, thereby increasing the size of the debts owed to the government by foreigners (or reducing the size of the debt which the government owes to foreigners), denominated in foreign currency (\( \Delta \tilde{H}^{FG^*} \)) and generating \( e\Delta \tilde{H}^{FG^*} \) of government debt denominated in baht issued to the private sector.
(ii) Private sector

Revenue: \( \tilde{R}^P = p^Y Y - \pi^F p^I K^F + \tilde{J}^{GP} - \tilde{\tau} = (1 - \tau)(p^Y Y - \pi^F p^I K^F + \tilde{J}^{GP}) \)

Expenditure: \( \tilde{E}^P = p^C C^P + p^I I^P \)

Net financial surplus: \( \tilde{N}^P = \tilde{R}^P - \tilde{E}^P = \Delta \tilde{H}^{GP} \)

The behavioural assumptions which enter here are that there is only one interest-bearing domestic asset, government debt, and that there are no non-interest-bearing domestic assets. This means that no domestic agent holds assets in cash and that any financial surplus earned by the private sector is converted to interest-bearing government debt.

Private sector disposable income is given by \( p^C Y^P = \tilde{R}^P \) and real disposable income is thus

\[ Y^P = (1 - \tau)(p^Y Y - \pi^F p^I K^F + \tilde{J}^{GP}) / p^C \]

Stock of real private sector assets: \( Z^P = (\tilde{H}^{GP} + p^I K^P) / p^C \).

The expression for assets owned by the private sector appearing inside the parentheses indicates the stock of financial assets (value of government debt, \( \tilde{H}^{GP} \)) and the stock of physical assets (value of the domestically-owned capital stock, \( p^I K^P \)).

(iii) Foreign sector

Revenue: \( \tilde{R}^F = p^M M + \pi^F p^I K^F \)

Expenditure: \( \tilde{E}^F = p^X X + p^I I^F + \tilde{J}^{FG} \)

Net financial surplus: \( \tilde{N}^F = \tilde{R}^F - \tilde{E}^F = p^M M + \pi^F p^I K^F - p^X X - p^I I^F - \tilde{J}^{FG} \)

\[ = -\tilde{B}^{CA} - p^I I^F, \text{ where } \tilde{B}^{CA} = p^X X + \tilde{J}^{FG} - p^M M - \pi^F p^I K^F \] denotes the current account balance.

Changes in the stock of foreign-issued debt held by the government, denominated in US$: \( \Delta \tilde{H}^{FG*} = \tilde{B}^{CA} / e \)
Changes in the stock of foreign-issued debt held by the government, denominated in baht:

\[ \Delta H^{FG} = B^{CA} + \left[ (e / e_{-1}) - 1 \right] \Delta H^{FG} + \left[ (e / e_{-1}) - 1 \right] \Delta H^{FL} \]

This expression has two components. The first is the value of new debt (\( \Delta H^{FG} \)), denominated in US$, adjusted by the exchange rate (\( e \)) to convert it to baht. The second is the revaluation of the previous period's stock of debt (\( \Delta H^{FL} \)), to take account of exchange rate changes, which requires multiplying the old stock by the term \( [(e - e_{-1}) / e_{-1}] = (e / e_{-1}) - 1 \).

\[ \tilde{J}^{FG} = r^{LIB} \left( e / e_{-1} \right) \Delta H^{FL} \]

(iv) Sum of net financial surpluses:

A net financial surplus for one agent implies a net financial deficit for another. It follows that when net financial surpluses are summed across all agents the total should be zero. We shall demonstrate that this property is satisfied:

Total change in net financial surpluses (\( \tilde{N}^{T} \)) is given by

\[ \tilde{N}^{T} = \tilde{N}^{G} + \tilde{N}^{P} + \tilde{N}^{F} \]

\[ = \tau \left( p^{Y} Y - \pi^{F} p^{I} K^{F} + \tilde{J}^{GP} \right) + \tilde{J}^{FG} - p^{C} C^{G} - p^{I} I^{G} - \tilde{J}^{GP} \]

\[ + (1 - \tau) \left( p^{Y} Y - \pi^{F} p^{I} K^{F} + \tilde{J}^{GP} \right) - p^{C} C^{P} - p^{I} I^{P} \]

\[ + p^{M} M + \pi^{F} p^{I} K^{F} - p^{X} X - p^{I} I^{F} - \tilde{J}^{FG} \]

\[ = \left( p^{Y} Y - \left[ p^{C} (C^{P} + C^{G}) + p^{I} (I^{P} + I^{G} + I^{F}) + p^{X} X - p^{M} M \right] \right) \]

\[ = 0. \]

A.3 BEHAVIOURAL EQUATIONS

This section describes the econometric estimation of the behavioural equations identified above. Estimation was based on annual data for Thailand covering the years 1970 to 1996 and used the Shazam time series regression package.
A.3.1 Aggregate Supply

(i) Production capacity

Production capacity is determined through a production function in which the variables are the government capital stock, the aggregate private capital stock and the labour force. This aggregate production is Cobb-Douglas in all three variables. It consists of a constant returns to scale function in private sector variables (the aggregate private capital stock and the labour force), implying that the coefficients on these two variables sum to unity, with the government capital stock a shifter to this private sector sub-function. This equation was estimated simultaneously with a capital aggregation equation, which is a feature of this model. The aggregate private capital stock is a CES aggregate of the foreign-owned and domestically-owned private capital stocks. Each of these latter two capital stocks is constructed by the inventory accrual method, accumulating the levels of private domestic and foreign investment. This approach contrasts with the usual assumption that these two components of the capital stock can simply be added together, implying that the elasticity of substitution between them is infinite. If foreign and domestic capital are significantly different, this approach could be misleading. Our approach allows this elasticity of substitution to be determined empirically.

\[
\ln(Y) = \alpha_0 + \alpha_G \ln(K^G) + \alpha_A \ln(K^A) + \alpha_L \ln(L)
\]  \hspace{1cm} (A 19)

The estimated parameters were:

\[
\begin{align*}
\alpha_0 &= -2.34903 & \alpha_G &= 0.23036 & \alpha_A &= 0.73905 & \alpha_L &= 0.26095 \\
(5.73) & & (2.55) & & (3.99)
\end{align*}
\]

The constraint \( \alpha_A + \alpha_L = 1 \) (constant returns to scale in private sector production) was tested and accepted by the data. Thus \( \alpha_A \) was not estimated independently and this is why no t-statistic is reported for \( \alpha_A \).

The aggregate private capital stock, \( K^A \), is defined as a CES aggregation of the domestically-owned and foreign-owned private capital stocks, \( K^P \) and \( K^F \).
\[ K^A = [\delta (K^P)^\rho + (1 - \delta)(K^F)^\rho ]^{1/\rho}. \] (A 20)

The estimated parameters were:

\[
\begin{align*}
\delta &= 0.997 \\
\rho &= -1.4191 \\
(640) & \quad (2.18)
\end{align*}
\]

The diagnostic statistics for the two equation system were:

\[
\begin{align*}
\bar{R}^2 &= 0.99 \\
DW &= 1.64 \\
\text{Run-test} &= -0.57
\end{align*}
\]

The coefficients on both equations, taken together, were obtained by non-linear maximum likelihood estimation, which is why goodness-of-fit diagnostics are reported for the two equation system as a whole and not for each individual equation. The implied estimate of the elasticity of substitution between \(K^P\) and \(K^F\) is given by \(\sigma = -1/(1 - \rho) = 0.414\), very different from the infinite value implied by the usual procedure of simply adding the two together.\(^5\)

A.3.2  Aggregate Demand

(i)  Investment

Investment has three components in this model: public investment, foreign-owned private investment and domestically-owned private investment. The first two are exogenous to the model, but domestically-owned private investment is endogenous. The investment equation we require relates the level of domestically-owned private investment to the cost of capital and the level of output. In addition, as we show below, the exogenously given level of the foreign-owned capital stock must be recognised as a separate variable in the long-term form of this equation. We shall derive an investment equation in which the adjustment process of moving from the current stock of domestically-owned private capital to the towards the desired stock is explicitly modelled, using an error correction model.

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\(^5\)The parameter \(\delta = 0.997\), is not to be interpreted as a cost share, except in the special (Cobb-Douglas) case where \(\rho = -1\). Given the estimated value \(\rho = -1.4191\), the implied cost share for \(K^P\) in the production of \(K^A\), evaluated at the mean of the data set, is 91.68% and the share of \(K^F\) is 8.32%. These estimates approximately correspond to the cost shares for these two components of the capital stock which are implied by the raw data for these variables.
We shall derive an equation for the desired level of the domestically-owned private capital stock, denoted $\hat{K}^P$. The CES form of the capital aggregation equation complicates this derivation. The strategy below is first to derive the determinants of the desired level of the aggregate private sector capital stock, $\hat{K}^A$, by equating its marginal product to the cost of capital, then to manipulate the production function to obtain an expression for $\hat{K}^P$ in terms of the determinants of $\hat{K}^A$ and the exogenously given value of the foreign-owned capital stock, $K^F$.

The desired level of the aggregate private capital stock, $\hat{K}^A$, is easily derived from the first-order conditions for profit maximisation,

$$\hat{K}^A = \alpha_A Y^Y / p^K$$  \hfill (A 21)

where $\alpha_A$ and $Y$ are defined as before and $p^K / p^Y$ is the real rental cost of capital. From equation (A 20),

$$\ln(K^A) = (1 / \rho) \ln[\delta (K^P)^\rho + (1 - \delta) (K^F)^\rho ]$$  \hfill (A 22)

and equivalently,

$$\ln(K^A / K^F) = (1 / \rho) \ln[\delta (K^P / K^F)^\rho + (1 - \delta )]$$  \hfill (A 23)

Now applying a McLaurin series approximation to this expression we obtain the quadratic equation

$$\ln(K^A / K^F) = \delta \ln(K^P / K^F) + [\rho \delta (1 - \delta ) / 2][\ln(K^P / K^F)]^2$$  \hfill (A 24)

This equation has two solutions for $\ln(K^P / K^F)$, of which one is negative and one positive. Dropping the negative solution and rearranging,

$$\ln(K^P / K^F) = \{[\delta^2 + 2 \rho \delta (1 - \delta ) \ln(K^A / K^F)]^{1/2} - \delta \} / \{\rho \delta (1 - \delta )\}.$$  \hfill (A 25)

We now rearrange this expression to obtain only $K^P$ on the left hand side and interpret the result as an expression for the desired level of $K^P$:

---

6 The data series for the exogenous value of the rental cost of capital was constructed from the data base from the expression $p^K = p^b (r^b + \Delta \ln p^l + \varphi_R + \varphi_D)$, where the last two terms correspond to a risk premium and the rate of depreciation, set at 0.10 and 0.05, respectively.
\[
\ln(\hat{K}^P) = \left\{[\delta^2 + 2\rho\delta(1-\delta)\ln(\hat{K}^A / K^F)]^{1/2} - \delta\right\} / \{\rho\delta(1-\delta) + \ln(K^F)\}.
\]

(A 26)

We can now substitute for the desired value of \( K^A \), from equation (A 21), to obtain the desired value of \( K^P \) in terms of the variables determining the desired value of \( K^A \) and the exogenously given value of \( K^F \).

We estimated the following investment equation, in which the adjustment process of moving from the current stock of domestically-owned private capital to the towards the desired stock is explicitly modelled, using an error correction model:

\[
\Delta \ln(K^P_{t+1}) = \beta_0 + \beta_1 \Delta \ln(K^P) - \beta_2 \Delta \ln(p^P / p^Y) \\
+ \beta_3 \Delta \ln(Y) - \beta_4 [\ln(K^P) - \ln(\hat{K}^P)] + \beta_5 t
\]

(A 27)

where \([\ln(K^P) - \ln(\hat{K}^P)]\) is an error correction term which captures the long run relationship involving the adjustment of the actual value of \( K^P \) towards its desired value, given by equation (A 26). This device is used to incorporate costs of adjustment in the process of approaching the desired capital stock. Note that the estimated coefficient of the error correction term is exceptionally small.

The estimated parameters and the diagnostic statistics were:

\[
\begin{align*}
\beta_0 &= -0.06844 & \beta_1 &= 0.7206 & \beta_2 &= -0.02780 & \beta_3 &= 0.2858 & \beta_4 &= -0.0394 & \beta_5 &= 0.002624 \\
(3.98) & & (8.17) & & (1.70) & & (2.67) & & (3.30)
\end{align*}
\]

\[\bar{R}^2 = 0.9546\]
\[DM = 2.27\]
\[\text{Run-test} = 0.49\]

(ii) Consumption

Private sector consumption depends on private disposable real income \((Y^P)\) and private real wealth \((Z^P)\). There is also a shifter variable for the size of the foreign-owned capital stock.

\[
\Delta \ln(C^P) = 0.543 \Delta \ln(Y^P) + 0.145 \Delta \ln(Z^P) - 0.662 \ln(C^P_{t+1}) - 0.0507 \ln(K^P_{t+1})
\]

(A 28)

(6.02) (1.51) (5.29) (3.79)
- 0.9 \ln Y_{-1}^P - 0.1 \ln (Z_{-1}^P) + 0.3651 \quad (A 28)

(3.12)

\bar{R}^2 = 0.64

DW = 1.88

Run-test = 0.48

The imposed coefficients of 0.9 and 0.1 on \( Y_{-1}^P \) and \( C_{-1}^P \), respectively, imply that in the long run real consumption is homogeneous of degree one in real income and real wealth, so that a doubling of both these variables will lead to a doubling of real consumption, a constraint suggested by economic theory. The constraint was accepted by the data.

(iii) Exports

The specification of the export sector is influenced by the debate between Muscatelli, Srinivansan and Vines (1992), and Athukorala and Riedel (1991). See also Reidel 1995 and Muscatelli 1995.

Export Supply

The export supply equation relates the quantities of exports to the full capacity output of the economy, the prices of exports relative to other goods produced within Thailand and to the level of the foreign capital stock within Thailand relative to the total privately-owned capital stock (foreign plus domestic). The purpose of this last variable is to capture the possibility that foreign-owned firms are more export oriented than domestically-owned firms.

\[
\Delta \ln (X / \bar{Y}) = 0.4613 \Delta \ln (p^X / p^Y) - 0.4153 \ln (X_{-1} / \bar{Y}_{-1}) + 04393 \ln (p^X_{-1} / p^Y_{-1})
\]

\[
+ 0.0117 \ln (K_{-1}^F) + 0.0236 t - 1.049 \quad (A 29)
\]

(1.73) (4.36) (1.82) (0.15) (3.80) (1.16)

\bar{R}^2 = 0.3716

DM = 1.69

Run = -1.56
S-Run elasticity = 0.4613
L-Run elasticity = (0.4393)/(0.4153) = 1.0578

*Export demand*

Within the model export demand is treated as being infinitely elastic. This implies acceptance of the 'small country' assumption, where Thailand is facing a perfectly elastic demand for its export such that any amount of export from Thailand will have no effect on its price.

*(iv) Imports*

The import demand function relates the demand for imports relative to the demand for other goods to their respective relative prices and also to a shifter variable representing the share of foreign investment in GDP. The latter allows for the possibility that foreign investment is more import-intensive than the rest of GDP. The import demand equation imposes homogeneity of degree zero with respect to prices, both in the short run and the long run by including only relative prices on the right hand side.

\[
\Delta \ln(M) = 2.2637 \Delta \ln(Y) - 0.7004 \Delta \ln(p^M / p^Y) - 0.02957 \ln(I^F / Y)
\]

\[
\text{(3.07)} \quad \text{(3.035)} \quad \text{(1.638)}
\]

\[-0.3127 \ln(M_{-1}/Y_{-1}) - 0.5296 \ln(p^M_{-1} / p^Y_{-1}) - 0.01245 \tau - 0.6522
\]

\[
\text{(2.24)} \quad \text{(2.49)} \quad \text{(2.15)} \quad \text{(2.82)}
\]

\[
\bar{R}^2 = 0.6871
\]

\[
DM = 2.45
\]

Run-test = 1.242

S-R demand elasticity = - 0.7004
L-R demand elasticity = - (-0.5296)/(-0.3127) = - 1.694
A.3.3 Price Adjustment

(i) Domestic Output Price Index

The price adjustment equation is a Phillips curve relationship between changes in the domestic price level, changes in price expectations and the level of capacity utilization. This equation reflects the consequences of disequilibrium in the labour market; we formalise it in terms of capacity because data on unemployment is unreliable. Its interpretation in terms of labour market disequilibrium will be helpful, because labour supply remains an area of considerable uncertainty in the post-crisis economic environment in Thailand. The form of the equation is

\[
\Delta \ln P^D = \Delta \ln P^e + \gamma_0 \ln(Y / \bar{Y}) + \gamma_1 \Delta \ln(Y / \bar{Y})
\]  \hspace{1cm} (A 31)

where \( \Delta P^e = \gamma_2 \Delta P^C \) is a measure of expected inflation.

This behavioural equation is the only one of the system which is not based on original econometric estimation. Its parameters were determined by a program of diagnostic simulations, as described in section A.6, below.

(ii) Consumer price index

The equation

\[
p^C = (p^D)^\alpha (p^M)^{1-\alpha}
\]  \hspace{1cm} (A 32)

was estimated by regression using data on the respective Thai series for \( p^C \), \( p^D \) and \( p^M \). The estimated value of \( \alpha = 0.75194 \) was obtained and this value was used in the model. The implied value of \( 1 - \alpha \) approximately corresponds to the mean share of imports in final consumption.

A.4 DATA

A fully balanced macroeconomic data set was constructed, satisfying the above accounting identities, using data from the Thai national accounts and macroeconomic data published by the Bank of Thailand. The balancing of data derived from different sources was accomplished through the inclusion, where necessary, of residual adjustment variables, not listed above, which are treated as exogenous in all simulations performed with the model. The aggregate capital stock variables \( K^P \), \( K^F \) and \( K^G \) were formed by the inventory accumulation method. A base year, 1960, was chosen at which the capital stock was deemed to be low. The depreciation rates \( \varphi^P \), \( \varphi^F \) and \( \varphi^G \) were each set to 0.05.
A.5 MODEL SOLUTION,

The model is solved using simulation software provided by Oxford Economic Forecasting (1995). This software enables the model to replicate exactly the historical evolution of the Thai economy, by automatically adding residuals to all equations to ensure that it does so. This is known as the model baseline. One kind of counterfactual simulations is performed by shocking an exogenous variable (for example variables such as the level of direct foreign investment or a policy instrument like the exchange rate or government consumption expenditure). Another kind of counterfactual involves changing the residual in an equation, such as the risk premium in the investment equation or evolution of wealth.

A thumbnail description of the way the model solves is as follows. First, consider the identity for real GDP, the final equation listed under "endogenous variables" above. In this equation for \( Y \), each of the right hand side variables is either exogenous (\( C^G \) and \( I^G \)) or is a function of \( Y \) itself (\( C^P \), \( I^P \), \( X \) and \( M \)). Thus, the GDP identity reduces to an equation in a single variable, \( Y \), the solution to which determines the level of GDP. Second, this level of GDP feeds into the Phillips curve equation, which determines the level of domestic prices and in turn has second round effects on the levels of \( C^P \), \( I^P \), and \( M \). The algorithm which solves the model is known as the Gauss-Seidel procedure.

A.6 MODEL PROPERTIES AND MODEL VALIDATION

The model was tested, and the plausibility of its properties investigated, by means of a large number of diagnostic “standard simulations”. These simulations were used simultaneously for two purposes: to check that the simulation properties of the model were reasonable, and to determine plausible values for the three parameters of the one non-estimated behavioural equation entering the model, the Phillips curve (equations (A 10) and (A 31)). Writing \( \gamma = (\gamma_o, \gamma_1, \gamma_2) \) for this vector of Phillips curve parameters, and \( \gamma^* \) for the vector of values selected, the chosen values were \( \gamma^* = (0.2, 0.4, 1.0) \). The diagnostic simulations were performed using \( \gamma^* \) and a large number of variants not described here. The final values of \( \gamma^* \) were selected so as to ensure ‘sensible’ values for the Phillips curve parameters themselves, meaning values considered plausible elsewhere in the literature, and also ‘sensible’ simulation properties for the overall model, meaning properties consistent with well-established a priori expectations about model behaviour. A large number of such standard simulations was performed; we report on the four most important of these here\(^7\).

\(^7\) Additional checking of the robustness of the model involved us in carrying out the standard simulations not only with a range of Phillips curve parameters but also with a range of different (non-estimated) values of parameters in other equations – e.g. the investment equation and the consumption equation.
A sustained increase in government consumption expenditure (Figure A1). The shock applied was a permanent increase in annual government consumption expenditure, of constant absolute value, equal in the first year (1977) to one percent of GDP. In a fixed-exchange-rate regime, and with the interest rate pinned down by international capital mobility, a sustained increase in government consumption would be expected to cause (i) a temporary demand- induced increase in output, (ii) a gradual increase in prices, with the consequence that (iii) output gradually falls back to its “natural”, supply-constrained level. This is indeed what we find. Given the degree of short-run price stickiness represented by \( \gamma \), the size of the short-run aggregate-demand multiplier depends almost entirely on the income-responsiveness of consumption, investment and imports: the outcome is a first-year multiplier no larger than unity. This outcome can be explained by the very large short-run import leakage which almost exactly cancels income-induced increases in consumption and investment.

After the first year, the delay required for output to converge to equality with aggregate supply depends on both the responsiveness of price inflation to deviations of output from supply and the size and speed of the response of aggregate demand (and thus output) to changes in prices. In this model the most important component of the latter is the effect on net trade of changes in competitiveness and the full effect is lagged: the sum of the price elasticities of exports and imports with respect to the real exchange rate is approximately 1.2 in the short run and 2.7 in the long run. The speed of return of demand to supply is also slowed because periods in which output is above its natural level stimulate echoing increases in the natural level of output itself as a result of capital accumulation. The parameters in the Phillips curve equation were chosen so as to ensure that demand and output return into equality with base in year seven.

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8 Recall that aggregate demand (and output) can be in excess of aggregate supply in the short-run because we assume that employment can be greater than the (given) level of labour supply at the (momentarily) sticky level of wages, it is this labour-market imbalance which causes wages (and prices) to rise when aggregate demand exceeds aggregate supply.

9 Short-run price stickiness, and lags in real balance effects on consumption and in the effects of competitiveness on export means that effects on effects on consumption and exports are mainly delayed until after the first year.

10 Compare the findings in Bryant et al (1993).

11 The short income elasticity of demand for imports is above two, a common finding in estimated import equations studies. We deliberately imposed a unit income elasticity in the long-run, a constraint accepted by the data.

12 Note that the error correction mechanism for the capital stock contained in the estimated investment equation is very small. Experiments with an imposed, more rapid, adjustment of the capital stock to its long-run value made the short-run multiplier implausibly large and the behaviour of the economy pronouncedly cyclical, producing, in effect, multiplier-accelerator business-cycle process. The speed of capital stock-adjustment is crucial for our investigation through modelling the time path through which an increase in foreign investment induces an increase in domestic investment. There is an argument that an accelerator-induced boom in demand is exactly what might be expected in the face of a large increase in FDI, with monetary policy pinned down by a fixed exchange rate. But in the absence of firm empirical evidence we were reluctant to impose this feature on our simulations.
- both longer and shorter periods gave the model simulation properties which seemed implausible in this respect.\textsuperscript{13}

It was necessary, in order to achieve convergence in as short a time as seven years, to introduce the term in $\Delta \ln(Y/\bar{Y})$ into the Philips curve and to set its coefficient $\gamma_1$ equal to twice the level of $\gamma_0$. This “derivative-control” term was necessary in order to prevent the model from having a cyclical resonance, resulting from the interaction of the lag associated with gradual adjustment of prices to high demand interacting with the lag associated with the gradual adjustment of demand to higher prices. This derivative term can be thought of as representing the effects of “short-run hysteresis” in the labour market, a common feature of wage-equation modelling in OECD countries.\textsuperscript{14}

As expected, the increase in the current account deficit was approximately one-for-one with the government consumption shock, settling as exports respond, with a lag, to price overshooting and gradually converging to one-for-one as interest obligations incurred with the accumulating debt rise at approximately the same rate as GDP in the base run.

(ii) \textit{A sustained step devaluation of the currency} (Figure A2). The shock was a permanently maintained depreciation of the exchange rate of ten percent, occurring in 1977. In a model such as this, one would expect a step devaluation of the currency peg to lead to equi-proportionate rises in all nominal variables and to have no long-run real effects, reflecting the long-run neutrality of money in a fixed-exchange rate regime. Figure A2 shows that this is what happens in our model. The speed at which neutrality returns will depend partly on the proportionate share of import prices in the determination of consumer prices (here 0.25; see equation (A 23), above), partly on the extent and the rate of transmission of transient improvements in competitiveness to increased aggregate demand\textsuperscript{15} and partly on the parameters of the Phillips curve,\textsuperscript{16} which determine how quickly the increased aggregate demand leads to higher prices. With the Phillips curve parameters $\gamma^*$, the model has the property that only half of a nominal depreciation remains as a real depreciation within 2 years, and less than 20 percent remains after three years. Experimenting with a slower adjustment lag – for example in the effect of past inflation on current inflation - made prices and quantities in the full model interact in a cyclical manner following a devaluation.\textsuperscript{17} Slower lags were thus discarded.

\textsuperscript{13} For a review of Phillips curve parameters used in other studies, see Bryant \textit{et al.} (1993).
\textsuperscript{14} See IMF (1999).
\textsuperscript{15} This has been discussed above under heading (i) above.
\textsuperscript{16} This includes the lag with which previous price inflation affects current price inflation, which has been set at one year.
\textsuperscript{17} With this longer lag, prices rise only slowly after a devaluation but increase gradually, acquiring a momentum which then leads to an overshooting of the price-level above that consistent with long-run neutrality.
The current account balance showed a small initial positive response, but then, in all subsequent periods, it is more negative than in the base run, an outcome which deserves some comment. During the temporary real depreciation exports rose by 3 per cent, whilst imports rose by no more than one percent. The relatively small, positive, effect on imports was a consequence of the increased relative price less – which lowered demand – being offset by the effects of higher output. Since both export and import prices rose in proportion to the devaluation, the trade balance improved; as one would expect. However this was more than offset by higher interest obligations on net outstanding foreign debts. A depreciation increases the domestic currency value of outstanding foreign obligations. 18

(iii)  *An temporary increase in government investment* (Figure A3). The shock applied was an increase in government investment expenditure, equal in the first year (1977) to one percent of GDP, sustained for four years only. The stock of government capital is an argument in the aggregate production function, and so an increase in government investment, even if only temporary, will cause a sustained increase in aggregate supply.19 It will also cause, for the period during which the government investment continues, a temporary increase in aggregate demand. One might expect that the demand effect would dominate in the first year because “time-to-build” means that the supply effect takes a year to come through,20 that it might continue to dominate for more than one year,21 but that eventually the (cumulating) supply side effect would dominate, especially once the temporary increase in government investment was reversed. The results confirm these expectations. Notice that prices are beginning to fall in the fourth period, even while the level of government investment expenditure remains above base.

The aggregate demand effects of the temporary government investment shock cause negative effects on the current account. After the investment increase stops, the current account effect vanishes as the supply effects of the higher government capital stock are roughly matched by wealth-induced increases in private consumption.

(iv)  *An temporary increase in foreign direct investment.* (Figure A 4). The shock applied was an increase in FDI, equal in the first year (1977) to one percent of GDP, sustained for four years only. The

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18 See the expression for the current account deficit in section A.2.2.f (iii), above.
19 The effect builds up as government investment adds to the stock of government capital and is long-lasting, but decays at a rate determined by the rate of depreciation, which is 5 percent per annum in the model here.
20 In the model, investment in one year does not affect output capacity until the next year.
21 The balance of effects would depend on the size of the multiplier relative to the elasticity of output with respect to government capital in the production function times the share of government capital in output. The balance would also be complicated by induced increases in domestic investment (which would be stimulated by the increase in government investment), something which would also influence both supply and demand.
accumulated stock of foreign direct investment (FDI) is an argument in the aggregate production function and so a temporary increase in FDI will cause a quasi-permanent increase in aggregate supply.\textsuperscript{22} It will also cause, for the period during which the government investment continues, a temporary increase in aggregate demand. One might initially expect a balance between supply and demand effects similar to that in the case examined previously. This is not what happens. Figure A4 shows that, after a one-period time-to-build lag, prices immediately begin to fall. The reason is that, unlike in the case of government investment, the demand effect is heavily damped by imports, as one might expect because of the very high import content of FDI. But foreign investment also stimulates exports (see equation (A 29)) which begin to rise as a consequence. Also, because foreign capital and domestic capital are net complements in the production function,\textsuperscript{23} an increase in the stock of foreign capital will increase the productivity of domestic capital and will stimulate domestic investment. These effects take over and mean that by the end of 12 years prices are back to where they started.

The aggregate demand effects of the temporary increase in FDI cause negative effects on the current account, just as in the case of increased government investment. However the positive aggregate supply effects develop more quickly, and are larger, because the effect of foreign capital in the aggregate production function is so important. This effect is also augmented by the directly positive effects of FDI on export supply.

\textsuperscript{22} This effect builds up as foreign investment adds to the stock of foreign-owned capital, but then only remains in place quasi-permanently because it will decay at a rate determined by the rate of depreciation, here 5 percent per annum.

\textsuperscript{23} Recall that the estimated elasticity of substitution between home capital and foreign capital is 0.45.
Figure A1 Government Consumption Simulation
Figure A2 Exchange Rate Simulation
Figure A3 Government Investment Simulation
Figure A4 Foreign Investment Simulation