Box 2: The Statistical Model

Let $Y^*_{2,j,t}$denotes a *latent* variable indicating a *crisis prone state* of the economy for of country j in time t. The *crisis prone state* of the economy is a *continuous* stochastic variable. If its realization is non negative, $Y^*_{2,j,t} \geq 0$, a realization of sudden stops occurs, whereas if $Y^*_{2,j,t} < 0$, the sudden stops do not occur. A realization of sudden stops is *observable.* The observable binary variable which indicates whether or not sudden stops occur, $Y_{2,j,t}$, is equal to 1 , if the sudden stops occur in a country j at time t, and 0 otherwise.

$$Y_{2,j,t} = \begin{cases} 1 & if\ Y^*_{2,j,t} \geq 0 \\ 0 & \text{otherwise} \end{cases} . \tag{1}$$

Binary indicators of the exchange rate regime, D_1 , and capital market liberalization regime, D_2 ,are denoted by:

$$D_{1,j,t} = \begin{cases} 1 & \text{if peg} \\ 0 & \text{if float} \end{cases} , \tag{2}$$

and:

$$D_{2,j,t} = \begin{cases} 1 & \text{if capital controls} \\ 0 & \text{if liberalization} \end{cases} . \tag{3}$$

The equation of the latent variable, $Y^*_{2,j,t}$, is a linear function of policy-regime dummies $(D_{1,}\ D_2)$ and a vector of controls (Z):

$$Y^*_{2,j,t} = \beta_2 Z_{j,t} + \gamma_2 D_{1,j,t} + \delta_2 D_{2,j,t} + \phi_2 Y_{1,j,t} + \varepsilon_{2,j,t}, \tag{4}$$

where, $\varepsilon_{2,j,t}$ is a country specific time variant *i.i.d.* random shock.
Let $Y_{1,j,t}$denote the GDP per capita growth rate of country j in period t. The growth rate is assumed to be linear function of the policy regime indicators $(D_{1,}\ D_2)$, and a vector of standard controls (X) , as follows.

$$Y_{1,j,t} = \beta_1 X_{j,t} + \gamma_1 D_{1,j,t} + \delta_1 D_{2,j,t} + \phi_1 \hat{Y}^*_{2,j,t} + \varepsilon_{1,j,t}, \tag{5}$$

where, $\varepsilon_{1,j,t}$ is a country specific time variant *i.i.d.* random shock and $\hat{Y}^*_{2,j,t}$ is the best predictor by the market participants of $Y^*_{2,j,t}$.
The econometerican and the market participants do not observe the "true" value of the *crisis prone state* of the economy,$Y^*_{2,j,t}$. Both use a projection of $Y^*_{2,j,t}$ based on the right hand side of Equation (5). Accordingly, let $P_{j,t} = \Pr(Y_{2,j,t} = 1 \mid \cdot)$ be the conditional probability that a country j faces sudden stops in period t. That is,

$$P_{j,t} = \Pr(\beta_2 Z_{j,t} + \gamma_2 D_{1,j,t} + \delta_2 D_{2,j,t} + \phi_2 Y_{1,j,t} > -\varepsilon_{2,j,t}). \tag{6}$$

We assume that $\varepsilon_{2,j,t} \sim N(0,1)$.

Then, the equation for $P_{j,t}$ is given by:

$$P_{j,t} = \Phi\left(\beta_2 Z_{j,t} + \gamma_2 D_{1,j,t} + \delta_2 D_{2,j,t} + \phi_2 Y_{1,j,t}\right), \tag{7}$$

where Φ denotes the cumulative distribution function of the unit normal distribution. The corresponding *projected* probability is given in the form of a Probit equation, as follows.

$$\hat{P}_{j,t} = \Phi\left(\hat{\beta} Z_{j,t} + \hat{\gamma}_2 D_{1,j,t} + \hat{\delta}_2 D_{1,j,t} + \hat{\phi}_2 Y_{1,j,t}\right) \tag{8}$$

For consistency of the $(\gamma_1,\ \delta_1)$ estimates we use lag variables of the policy regime dummies, $D_{1,j,t-1}$ and $D_{2,j,t-1}$, as instruments. To recover the parameters of interest $(\gamma_1,\ \delta_1)$ in the growth equation we end up estimating the following equation.

$$Y_{1,j,t} = \beta_1 X_{j,t} + \gamma_1 D_{1,j,t-1} + \delta_1 D_{2,j,t-1} + \phi_1 \Phi^{-1}\left(\hat{P}_{j,t}\right) + \varepsilon_{1,j,t}, \tag{9}$$

Note that the term $\hat{P}_{j,t}$, (in $\Phi^{-1}\left(\hat{P}_{j,t}\right)$) is the projection of the probability of sudden stops that market participants also use when they make investment decisions. This is in contrast to another case in econometrics where the market participants do observe the latent variable but the econometrician does not. In other words, the econometrician and an individual market participant do share in the *same* information set concerning realizations of aggregate variables. Therefore, in the regression equation (9) there is also no need to correct the standard errors estimates of $(\gamma_1,\ \delta_1)$, as typically done in the standard case where the market participants and the econometrician do not share the same information.

The confounding effect of policy regimes

What happens if one ignore the crisis probability variable in the growth equation, as has been the case in the literature?
In this case, the estimated growth effects of the instrumented policy-regime dummies $D^{IV}_{1,j,t},\ D^{IV}_{1,j,t}$ is given by:

$$E\left(\hat{\gamma}^{IV}_1\right) = \frac{\partial E\left(Y_{1,j,t} \mid X_{j,t},\ D^{IV}_{1,j,t},\ D^{IV}_{2,j,t}\right)}{\partial D_{1,j,t}} = \frac{1}{1-\phi_1\phi_2}\left(\gamma_1 + \phi_1 \frac{\partial \Phi^{-1}\left(\hat{P}_{j,t}\right)}{\partial D_{1,j,t}}\right)$$

and:

$$E\left(\hat{\delta}^{IV}_1\right) = \frac{\partial E\left(Y_{1,j,t} \mid X_{j,t},\ D^{IV}_{1,j,t},\ D^{IV}_{2,j,t}\right)}{\partial D_{2,j,t}} = \frac{1}{1-\phi_1\phi_2}\left(\delta_1 + \phi_1 \frac{\partial \Phi^{-1}\left(\hat{P}_{j,t}\right)}{\partial D_{2,j,t}}\right)$$

.
Typically, the crisis state has a negative net effect on growth:

$$\phi_1 < 0.$$

Assume that , $\phi_1\phi_2 < 1$.
Because the peg increases the sudden stops probability , whereas the imposition of capital controls lowers the probability, we get:

$$\begin{aligned} \frac{\partial \Phi^{-1}\left(\hat{P}_{j,t}\right)}{\partial D_{2,j,t}} &> 0 \\ \frac{\partial \Phi^{-1}\left(\hat{P}_{j,t}\right)}{\partial D_{2,j,t}} &< 0. \end{aligned}$$

Therefore, the IV estimate for the marginal effect of exchange-rate regime on growth is equal to:

$$(1-\phi_1\phi_2)\, E\left(\hat{\gamma}_1^{IV}\right) = \gamma_1 + \phi_1 \frac{\partial E\left(\Phi^{-1}\right)}{\partial D_{1,j,t}} < \gamma_1 > 0.$$

Similarly, the IV estimate for the marginal effect of the imposition of capital controls on growth is equal to:

$$(1-\phi_1\phi_2)\, E\left(\hat{\delta}_1^{IV}\right) = \delta_1 + \phi_1 \frac{\partial E\left(\Phi^{-1}\right)}{\partial D_{2,j,t}} > \delta_1 < 0.$$

This means that if the econometrician ignores the effect on growth of the projected probability of sudden stops the estimate of the direct effect of the peg on growth is biased towards zero. Similarly, the direct effect on growth of the imposition capital controls is also biased towards zero.

Note also that the $\partial E\left(\Phi^{-1}\right)/\partial D_{1,j,t}$ and $\partial E\left(\Phi^{-1}\right)/\partial D_{1,j,t}$ are the *sample average* effects of policy regimes on the crisis probability. But because of the assumption of a normal distribution for the residual of the Probit equation, the effect is *non linear*. This means that , $\frac{\partial E\left(\Phi^{-1}\right)}{\partial D_{2,j,t}} > \frac{\partial\left(\Phi^{-1}\right)}{\partial D_{2,j,t}}$ for countries with strong fundamentals, whereas $\frac{\partial E\left(\Phi^{-1}\right)}{\partial D_{2,j,t}} < \frac{\partial\left(\Phi^{-1}\right)}{\partial D_{2,j,t}}$ for country with weak fundamentals.