Asset-Liability Management of Foreign Exchange Reserves: A Factor Model Approach

Jorge Sabat Silva
Olin Business School
Washington University in St. Louis

December 2017
Forex reserves in EM: When are they needed?

- Eichengreen, Hausmann, and Panizza (2005): ‘original sin’ as the inability of a country to borrow abroad in its own currency
Problem?

- Reserves in EM countries are needed when countries are in:
  - Liquidity/Banking crisis; Financial contagion; Commodity swings

- Assets that are valuable in these scenarios have low yields in normal periods:
  - Gold
  - Government bonds of developed countries
  - Put derivatives

⇒ Holding reserves is costly ≈ 1% GDP (Rodrik, 2006):
  - ‘Yield give up’ example: Indian 10Y Bond (7.1%) versus US 10Y (2.3%).
Contribution of this Paper

- Normative asset-liability management model of Forex reserves:
  - Optimal factor exposure to systemic risks:
    - Yield-give up;
    - Hedge: i.e. liquidity risk in foreign currency.
  - Replicating asset portfolio (constraints);
  - Capital preservation;
  - Evaluation of strategies.

- Practical implementation of the model to the Chilean case:
  - A small-open economy with significant exposure to copper prices.
Model

1. Measuring liabilities:
   - Observables: opportunity cost (i.e. cost of government debt).
   - Unobservables:
     - liquidity provision (swaption on spread in foreign-currency).
     - bail-out cost of financial sector (put option on banks’ assets).
Methodology: Measuring explicit and contingent liabilities

- Estimated Total Central Bank liabilities composition:
The main contribution of this paper is to formalize a normative model of foreign exchange management that allows Central Banks to deal with the multi-objective problem that they face.

The model:

1. Measuring contingent and explicit liabilities that Central Banks face;
2. Identifying global systematic factors;
3. Mapping systematic/idiosyncratic risks in investable/non-investable assets;
4. Finding the portfolio of investable assets that "better" replicate the systematic exposure of the optimal factor allocation;
5. Deriving the "risk-free" allocation that is consistent with the capital preservation rule following a protective put strategy;
6. Evaluating the potential costs of exogenous constraints in terms of:
   i) Hedging;
   ii) Potential capital losses;
   iii) Yield give-up.
Risk Factors

- Global Fama-French 3 Factor: MRP + SMB + HML

- Global Fama-French 5 Factor: MRP + SMB + HML + RMW + CMA

- Chen, Ross and Roll (1986): MRP + InfSurp + IndProduSurp + TP + ExpInfl

- Macro Model I: Economic + Inflation + EM Curr

- Macro Model II: Economic + Credit + EM MRP

- Macro Model III: EM Curr + EM MRP

- Macro Model IV: Real Rates + TP

* RMW: (Robust Minus Weak) is the average return on the two robust operating profitability portfolios minus the average return on the two weak operating profitability portfolios;

** CMA (Conservative Minus Aggressive) is the average return on the two conservative investment portfolios minus the average return on the two aggressive investment portfolios,
Contribution of this Paper

The model:

3. Optimal exposure to global systematic factors;
Optimal Factor Allocation

- Given estimated liabilities:

![Graph showing optimal factor allocation across various risk aversion levels. The graph includes lines for Economic, Credit, EM, Liquidity, Real Rates, Inflation, Term Premium, Carry Trade, Commodities, and EM Currency. The allocation percentages vary based on the risk aversion level.]
Contribution of this Paper

The model:

4. Investable assets that “better” replicate the exposure to global factors;
## Factor Replication

<table>
<thead>
<tr>
<th>Factor</th>
<th>Constant</th>
<th>Economic</th>
<th>Real Rates</th>
<th>Credit</th>
<th>EM</th>
<th>Term Premium</th>
<th>Size</th>
<th>Carry Trade</th>
<th>EM Currency</th>
<th>Commodities</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barclays World Inflation Linked Bonds TR</td>
<td>0.0%</td>
<td>0.0%</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>BofA Merrill Lynch Australian Govt</td>
<td>0.4%</td>
<td>0.02%</td>
<td>0.08</td>
<td>-0.01</td>
<td>-0.01</td>
<td>0.18</td>
<td>0.22</td>
<td>0.04</td>
<td>-0.09</td>
<td>-0.01</td>
<td>0.52</td>
</tr>
<tr>
<td>BofA Merrill Lynch Canada Government Ind</td>
<td>0.3%</td>
<td>0.01%</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.02</td>
<td>0.09</td>
<td>0.28</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.67</td>
</tr>
<tr>
<td>BofA Merrill Lynch Euro Government Index</td>
<td>0.3%</td>
<td>0.00%</td>
<td>0.12</td>
<td>0.00</td>
<td>0.01</td>
<td>0.17</td>
<td>0.20</td>
<td>-0.02</td>
<td>0.09</td>
<td>-0.05</td>
<td>0.47</td>
</tr>
<tr>
<td>BofA Merrill Lynch Global Corporate Ind</td>
<td>0.1%</td>
<td>0.04%</td>
<td>0.74</td>
<td>0.15</td>
<td>-0.01</td>
<td>0.54</td>
<td>0.04</td>
<td>-0.02</td>
<td>0.06</td>
<td>0.02</td>
<td>0.86</td>
</tr>
<tr>
<td>BofA Merrill Lynch Global Government Ind</td>
<td>0.0%</td>
<td>0.00%</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>BofA Merrill Lynch Global High Yield Ind</td>
<td>0.2%</td>
<td>-0.01%</td>
<td>0.38</td>
<td>0.95</td>
<td>0.00</td>
<td>0.22</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.97</td>
</tr>
<tr>
<td>BofA Merrill Lynch Japan Government Ind</td>
<td>0.1%</td>
<td>-0.03%</td>
<td>0.10</td>
<td>0.01</td>
<td>0.01</td>
<td>0.19</td>
<td>0.04</td>
<td>0.00</td>
<td>0.08</td>
<td>-0.01</td>
<td>0.12</td>
</tr>
<tr>
<td>BofA Merrill Lynch New Zealand Govt</td>
<td>0.4%</td>
<td>0.02%</td>
<td>0.12</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.14</td>
<td>0.15</td>
<td>0.01</td>
<td>-0.09</td>
<td>-0.01</td>
<td>0.41</td>
</tr>
<tr>
<td>BofA Merrill Lynch Switzerland Government</td>
<td>0.2%</td>
<td>-0.02%</td>
<td>0.06</td>
<td>0.01</td>
<td>0.03</td>
<td>0.05</td>
<td>0.21</td>
<td>0.01</td>
<td>0.02</td>
<td>-0.03</td>
<td>0.41</td>
</tr>
<tr>
<td>BofA Merrill Lynch UK Gilt Index</td>
<td>0.3%</td>
<td>0.03%</td>
<td>0.10</td>
<td>-0.01</td>
<td>0.03</td>
<td>0.06</td>
<td>0.39</td>
<td>-0.03</td>
<td>-0.02</td>
<td>-0.04</td>
<td>0.63</td>
</tr>
<tr>
<td>BofA Merrill Lynch US Treasury Index</td>
<td>0.2%</td>
<td>-0.01%</td>
<td>0.14</td>
<td>-0.08</td>
<td>0.00</td>
<td>0.10</td>
<td>0.34</td>
<td>0.00</td>
<td>0.01</td>
<td>0.00</td>
<td>0.90</td>
</tr>
<tr>
<td>CLPUSD Spot Exchange Rate - Price of 100</td>
<td>-0.3%</td>
<td>-0.04%</td>
<td>0.51</td>
<td>0.26</td>
<td>0.13</td>
<td>0.60</td>
<td>-0.11</td>
<td>-0.01</td>
<td>0.21</td>
<td>-0.01</td>
<td>0.40</td>
</tr>
<tr>
<td>China Money Market</td>
<td>0.4%</td>
<td>-0.01%</td>
<td>0.03</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.00</td>
<td>-0.02</td>
<td>-0.02</td>
<td>-0.01</td>
<td>0.00</td>
<td>0.02</td>
</tr>
<tr>
<td>Copper</td>
<td>0.7%</td>
<td>0.25%</td>
<td>0.64</td>
<td>0.07</td>
<td>0.27</td>
<td>0.61</td>
<td>-0.76</td>
<td>-0.18</td>
<td>0.39</td>
<td>0.63</td>
<td>0.47</td>
</tr>
<tr>
<td>J.P. Morgan EMBI Plus Chile</td>
<td>0.2%</td>
<td>-0.04%</td>
<td>0.38</td>
<td>0.23</td>
<td>0.16</td>
<td>0.39</td>
<td>-0.16</td>
<td>-0.03</td>
<td>0.22</td>
<td>-0.02</td>
<td>0.38</td>
</tr>
<tr>
<td>J.P. Morgan EMBI Global Total Return Ind</td>
<td>0.7%</td>
<td>0.19%</td>
<td>-0.07</td>
<td>0.37</td>
<td>0.25</td>
<td>0.27</td>
<td>0.39</td>
<td>-0.19</td>
<td>0.13</td>
<td>0.01</td>
<td>0.55</td>
</tr>
<tr>
<td>J.P. Morgan EMBI Plus Mexico</td>
<td>0.6%</td>
<td>0.16%</td>
<td>0.02</td>
<td>0.24</td>
<td>0.14</td>
<td>0.27</td>
<td>0.52</td>
<td>-0.14</td>
<td>0.06</td>
<td>-0.01</td>
<td>0.57</td>
</tr>
<tr>
<td>JPM GBII Global Total Return Index Level</td>
<td>0.0%</td>
<td>0.00%</td>
<td>0.99</td>
<td>-0.01</td>
<td>0.00</td>
<td>1.00</td>
<td>0.01</td>
<td>0.02</td>
<td>-0.03</td>
<td>-0.01</td>
<td>0.98</td>
</tr>
<tr>
<td>Korea Money Market</td>
<td>0.0%</td>
<td>0.33%</td>
<td>0.75</td>
<td>0.07</td>
<td>0.14</td>
<td>0.34</td>
<td>-0.23</td>
<td>0.04</td>
<td>0.04</td>
<td>-0.06</td>
<td>0.30</td>
</tr>
<tr>
<td>MSCI AC Asia Pacific Index</td>
<td>0.1%</td>
<td>0.55%</td>
<td>0.47</td>
<td>0.38</td>
<td>0.35</td>
<td>0.39</td>
<td>-0.19</td>
<td>-0.10</td>
<td>-0.07</td>
<td>0.11</td>
<td>0.60</td>
</tr>
<tr>
<td>MSCI ACWI Index</td>
<td>0.4%</td>
<td>0.61%</td>
<td>0.24</td>
<td>0.53</td>
<td>0.06</td>
<td>0.32</td>
<td>-0.20</td>
<td>-0.35</td>
<td>0.13</td>
<td>0.07</td>
<td>0.73</td>
</tr>
<tr>
<td>MSCI Chile Index</td>
<td>0.6%</td>
<td>0.24%</td>
<td>0.25</td>
<td>0.69</td>
<td>0.70</td>
<td>0.84</td>
<td>-0.26</td>
<td>-0.26</td>
<td>0.31</td>
<td>0.00</td>
<td>0.59</td>
</tr>
<tr>
<td>MSCI Emerging Markets Index</td>
<td>0.4%</td>
<td>0.62%</td>
<td>0.22</td>
<td>0.52</td>
<td>0.99</td>
<td>0.32</td>
<td>-0.20</td>
<td>-0.34</td>
<td>0.12</td>
<td>0.07</td>
<td>0.88</td>
</tr>
<tr>
<td>MSCI World Index</td>
<td>0.4%</td>
<td>0.62%</td>
<td>0.22</td>
<td>0.52</td>
<td>-0.01</td>
<td>0.32</td>
<td>-0.20</td>
<td>-0.34</td>
<td>0.12</td>
<td>0.07</td>
<td>0.71</td>
</tr>
<tr>
<td>MSCI World Large Cap Index</td>
<td>0.4%</td>
<td>0.61%</td>
<td>0.23</td>
<td>0.53</td>
<td>0.00</td>
<td>0.33</td>
<td>-0.20</td>
<td>-0.38</td>
<td>0.12</td>
<td>0.07</td>
<td>0.70</td>
</tr>
<tr>
<td>MSCI World Small Cap Index</td>
<td>0.4%</td>
<td>0.61%</td>
<td>0.23</td>
<td>0.53</td>
<td>0.00</td>
<td>0.33</td>
<td>-0.20</td>
<td>0.62</td>
<td>0.12</td>
<td>0.07</td>
<td>0.77</td>
</tr>
<tr>
<td>Nikkei 225</td>
<td>0.1%</td>
<td>0.58%</td>
<td>0.26</td>
<td>0.31</td>
<td>0.05</td>
<td>0.10</td>
<td>-0.04</td>
<td>0.14</td>
<td>-0.31</td>
<td>0.16</td>
<td>0.29</td>
</tr>
<tr>
<td>Oil</td>
<td>1.1%</td>
<td>-0.11%</td>
<td>-0.16</td>
<td>-0.14</td>
<td>0.20</td>
<td>-0.99</td>
<td>-0.34</td>
<td>0.18</td>
<td>-0.22</td>
<td>1.53</td>
<td>0.58</td>
</tr>
<tr>
<td>XAUUSD Spot Exchange Rate - Price of 1X</td>
<td>0.4%</td>
<td>-0.04%</td>
<td>0.80</td>
<td>-0.20</td>
<td>0.20</td>
<td>0.60</td>
<td>0.09</td>
<td>0.15</td>
<td>-0.14</td>
<td>0.36</td>
<td>0.34</td>
</tr>
</tbody>
</table>
Optimal Replicating Portfolio

- All assets:

(a) Liabilities I
(b) Liabilities II
(c) Liabilities III
(d) Liabilities IV
Optimal Replicating Portfolio

- Fixed income only:

- Liabilities I

- Liabilities II

- Liabilities III

- Liabilities IV
Contribution of this Paper

- The model:

Protective put strategy

- Following Merton (1981):
  - Higher the risk of the portfolio → Higher the allocation in the risk-free asset.

*Risk-free asset: 3 month Treasury Bills.*
Contribution of this Paper

The model:

Ex-ante Evaluation

- Depending on:
  - Relevant systematic factors;
  - Measurement of contingent liabilities;
  - Investable assets;
- How Central Banks can decide their optimal strategy?

\[
\text{Yield give-up: } E[r_R^*] \\
\text{Capital Preservation: } \text{Max Drawdown}[r_R^*] \\
\text{Liability hedging: } \text{Var}[r_f-r_i]
\]
Ex-ante Evaluation

- Central Bank preferences can be incorporated:
  - Exogenous weights;
  - Equal weights; PCA-weighting; z-scores weights, (Chincarini, 2006).

Fixed Income Spectrum

Non-restricted Spectrum
Final Remarks

- The investment problem of Central Banks’ reserves includes:
  - Observable and unobservable liabilities that have to be hedged;
  - Risk-return trade-off subject to a usually strong capital preservation motive.
  - Institutional restrictions limit the investable asset-set.

- My normative model aboard these issues, maintains quantitative tractability, and offers an internally consistent self-evaluation methodology.

- Specifically, in the case of Chile, I find that:
  - There are potential gains of including derivatives in the foreign exchange reserves portfolio: Put options on the S&P500 or Swaptions on USD interest rate swaps.
Appendix
Modern theory on Forex reserves

- Foreign exchange intervention that are part of a development strategy (i.e. Rajan & Subramanian (2011): “dutch disease” prevention).

- Correcting occasional short-term misalignments, Daude et al. (2016).

How much reserves?

- 1980s: three months' worth of imports rule-of-tumb.
Appendix


Figure 1: Asset allocation of the Safety Tranche

Figure 2: Wealth Tranche asset allocation

Source: Authors’ calculations
Appendix

Dur. 12.43

iShares Global Inflation Linked Government Bond

- United States: 44%
- United Kingdom: 28%
- France: 10%
- Italy: 7%
- Germany: 3%
- Canada: 2%
- Japan: 2%
- Australia: 1%
- Spain: 1%

Dur. 8.12

iShares Global Government Bond

- United States: 38%
- Japan: 29%
- France: 9%
- Italy: 7%
- Germany: 6%
- Canada: 2%
- Other: 0%
Appendix


Table 6. Asset Allocation Based on Copula with Conditional Value-at-risk (CVaR) Minimization, 2006–2012

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-term</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treasury bond (%)</td>
<td>0.86</td>
<td>0.71</td>
<td>5.71</td>
<td>10.71</td>
<td>15.70</td>
<td>20.70</td>
<td>25.69</td>
</tr>
<tr>
<td>Deposit (%)</td>
<td>7.21</td>
<td>12.20</td>
<td>17.20</td>
<td>22.20</td>
<td>27.20</td>
<td>32.20</td>
<td>37.20</td>
</tr>
<tr>
<td>Treasury bond (%)</td>
<td>35.88</td>
<td>30.88</td>
<td>25.88</td>
<td>20.88</td>
<td>15.89</td>
<td>10.89</td>
<td>10.03</td>
</tr>
<tr>
<td>Agency debt (%)</td>
<td>30.38</td>
<td>25.38</td>
<td>29.61</td>
<td>30.75</td>
<td>29.57</td>
<td>30.23</td>
<td>26.38</td>
</tr>
<tr>
<td>Corporate bond (%)</td>
<td>0.30</td>
<td>0.00</td>
<td>0.77</td>
<td>0.00</td>
<td>1.19</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Equity (%)</td>
<td>0.38</td>
<td>5.37</td>
<td>0.37</td>
<td>0.00</td>
<td>0.00</td>
<td>0.53</td>
<td>0.24</td>
</tr>
<tr>
<td>Euro (%)</td>
<td>25.00</td>
<td>25.45</td>
<td>20.45</td>
<td>15.45</td>
<td>10.45</td>
<td>5.45</td>
<td>0.45</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>-0.0028</td>
<td>0.000544</td>
<td>0.001285</td>
<td>0.001526</td>
<td>0.000317</td>
<td>0.000607</td>
<td>0.000398</td>
</tr>
<tr>
<td><strong>CVaR</strong></td>
<td>-0.15193</td>
<td>-0.17216</td>
<td>-0.3135</td>
<td>-0.17405</td>
<td>-0.19208</td>
<td>-0.09707</td>
<td>-0.04335</td>
</tr>
</tbody>
</table>

Table 7. Asset Allocation in Copula Model with Disappointment Avoidance Maximization, 2006–2012

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Short-term</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treasury bond (%)</td>
<td>1.30</td>
<td>0.04</td>
<td>4.97</td>
<td>0.15</td>
<td>0.80</td>
<td>0.06</td>
<td>0.08</td>
</tr>
<tr>
<td>Deposit (%)</td>
<td>7.13</td>
<td>11.96</td>
<td>16.92</td>
<td>17.64</td>
<td>19.46</td>
<td>14.55</td>
<td>14.16</td>
</tr>
<tr>
<td>Treasury bond (%)</td>
<td>35.91</td>
<td>30.93</td>
<td>26.49</td>
<td>31.39</td>
<td>36.31</td>
<td>41.29</td>
<td>46.26</td>
</tr>
<tr>
<td>Corporate bond (%)</td>
<td>0.32</td>
<td>0.01</td>
<td>0.72</td>
<td>0.02</td>
<td>0.11</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td>Equity (%)</td>
<td>0.15</td>
<td>5.14</td>
<td>2.33</td>
<td>2.17</td>
<td>3.61</td>
<td>8.59</td>
<td>13.58</td>
</tr>
<tr>
<td>Euro (%)</td>
<td>24.97</td>
<td>26.67</td>
<td>27.53</td>
<td>32.31</td>
<td>27.51</td>
<td>22.53</td>
<td>17.58</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>-0.0003</td>
<td>0.0005</td>
<td>0.0017</td>
<td>0.0025</td>
<td>0.0005</td>
<td>0.092</td>
<td>0.0022</td>
</tr>
<tr>
<td><strong>CVaR</strong></td>
<td>-0.1515</td>
<td>-0.1737</td>
<td>-0.3983</td>
<td>-0.2864</td>
<td>-0.4601</td>
<td>-0.3133</td>
<td>-0.2314</td>
</tr>
</tbody>
</table>
Strategic evaluation

- Finally, we can perform an evaluation of the decision to impose a restriction on the investable assets:

<table>
<thead>
<tr>
<th></th>
<th>Reserves All Assets</th>
<th>Reserves Restricted Assets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hedging</td>
<td>5.4%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Yield give-up</td>
<td>0.6%</td>
<td>0.8%</td>
</tr>
<tr>
<td>Capital Preservation</td>
<td>-18.7%</td>
<td>-10.4%</td>
</tr>
</tbody>
</table>

* i) The hedging metric is calculated as the historical standard deviation of the excess of return of the portfolio of reserves over the liabilities; ii) The yield give-up is equal to the product between the estimated betas and the risk-premium (in-sample); iii) The capital preservation metric is equal to the maximum drawdown of the reserves portfolio.
Anexos


<table>
<thead>
<tr>
<th>Currency</th>
<th>Benchmark allocation (%)</th>
<th>Tactical deviation range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USD</td>
<td>25</td>
<td>+/- 5</td>
</tr>
<tr>
<td>EUR</td>
<td>25</td>
<td>+/- 5</td>
</tr>
<tr>
<td>JPY</td>
<td>5</td>
<td>+/- 5</td>
</tr>
<tr>
<td>GBP</td>
<td>15</td>
<td>+/- 5</td>
</tr>
<tr>
<td>CAD</td>
<td>10</td>
<td>+/- 5</td>
</tr>
<tr>
<td>AUD</td>
<td>20</td>
<td>+/- 5</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>VaR limit NZD 5 m$</td>
</tr>
</tbody>
</table>
Optimal factor allocation
Diversification of foreign reserves

- During Bretton Woods (BW), Central Banks invested mainly in gold.

*Rodrik (2006) shows that the cost of holding reserves for EM countries can be easily account for 1% GDP.
Diversification of foreign reserves

- During Bretton Woods (BW), Central Banks invested mainly in gold.
- After the Asian Crisis, the literature started analyzing the trade-off between the ability to hedge sudden-stop risk, and the yield-give up cost.*
- Post-BW: Countries started diversifying away from the US dollar. Starting from European currencies (in the pre-Euro era), Great Britain Pound, Japanese Yen and the Swiss franc. Lately, countries have started including the Korean Won, Brazilian Real, Polish Złoty and Renminbi.
- Even more, some countries such as China, Japan, Korea, Switzerland (15%), Denmark, Italy, Isreal (10%) and the Czech Republic have included stocks in their reserves’ portfolio.

*Rodrik (2006) shows that the cost of holding reserves for EM countries can be easily account for 1% GDP.
Diversification of foreign reserves

- During Bretton Woods (BW), Central Banks invested mainly in gold.
- After the Asian Crisis, the literature started analyzing the trade-off between the ability to hedge sudden-stop risk, and the yield-give up cost.*
- Post-BW: Countries started diversifying away from the US dollar. Starting from European currencies (in the pre-Euro era), Great Britain Pound, Japanese Yen and the Swiss franc. Lately, countries have started including the Korean Won, Brazilian Real, Polish Złoty and Renminbi.
- Even more, some countries such as China, Japan, Korea, Switzerland (15%), Denmark, Italy, Isreal (10%) and the Czech Republic have included stocks in their reserves’ portfolio.

*Rodrik (2006) shows that the cost of holding reserves for EM countries can be easily account for 1% GDP.
Diversification of foreign reserves

- BIS (2014) identifies “pseudo monetary zones”: USD, Yen y EUR.

---

The dollar share is calculated in two steps. First, for a given currency, its weekly percentage change against the dollar is regressed on the weekly percentage change of the euro/dollar and yen/dollar rates. The dollar zone weight is calculated as 1 minus the corresponding regression coefficients.
Methodology: Systematic risk of CB Liabilities

- Given the estimated historical returns of the portfolio of CB’s liabilities, we can decompose the variance into systematic and idiosyncratic components:

\[ r_t^n = c^n + B^n \tilde{f}_t + \tilde{\varepsilon}_t \]

where, \( c \) is constant, \( \tilde{f} \) are systematic factors, \( B^n \) is a vector of factor loadings and \( \tilde{\varepsilon} \) is the unexplainable component.
The case of Chile

- During the 80s, foreign Exchange reserves were used intensively in order to face the balance of payment crisis that Latin American countries faced as consequence of currency pegs and the monetary policy tightening in the US.
- During the 90s the CB accumulated reserves in order to maintain the exchange rate between a floating band.
- After the Asian Crisis the CB tried to defended the peso. The CB reacted raising rates from 9% to 19%, and selling US$ 4 bn. The unsuccessful efforts ended up with a liberalization of the Exchange rate in September 1999.
- Since the Asian crisis, we have seen 4 sterilized interventions that have intended to tackle possible short-term misalignments.
- During the 2008 financial crisis played a different role. The CB offered repos/swaps in the local financial market as a response of the liquidity shock.
Market value of liabilities

- Explicit debt: Bond index of Government issued securities (49%).
- Contingent financial bail-out: Ronn & Verma (1986) methodology on publicly-traded Banks (3%).
- Foreign liquidity guarantee: Swaption valuation under Vasicek model on the IMF’s foreign currency credis spread (48%).
Systematic and idiosyncratic risk decomposition of liabilities

- Time series regression of liabilities’ returns on factors:

```
<table>
<thead>
<tr>
<th></th>
<th>Economic</th>
<th>Credit</th>
<th>EM</th>
<th>Liquidity</th>
<th>RealRates</th>
<th>Inflation</th>
<th>TermPremium</th>
<th>Carry</th>
<th>Commodities</th>
<th>EM Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit Debt</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Financial Bail-Out</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foreign Liquidity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

```
<table>
<thead>
<tr>
<th></th>
<th>Economic</th>
<th>Credit</th>
<th>EM</th>
<th>Liquidity</th>
<th>RealRates</th>
<th>Inflation</th>
<th>TermPremium</th>
<th>Carry</th>
<th>Commodities</th>
<th>EM Currency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weighted Liabilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```
## Risk premium parameters

### Panel A: USS Dollar Returns

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Period</th>
<th>Mean</th>
<th>Median</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economic</td>
<td>Feb-90/Jun-16</td>
<td>0.04%</td>
<td>0.35%</td>
<td>3.09%</td>
</tr>
<tr>
<td>Credit</td>
<td>Feb-90/Jun-16</td>
<td>0.25%</td>
<td>0.31%</td>
<td>2.51%</td>
</tr>
<tr>
<td>Emerging Markets (EM)</td>
<td>Feb-90/Jun-16</td>
<td>0.20%</td>
<td>0.20%</td>
<td>4.35%</td>
</tr>
<tr>
<td>Liquidity</td>
<td>Feb-95/Jun-16</td>
<td>0.20%</td>
<td>0.31%</td>
<td>2.39%</td>
</tr>
<tr>
<td>Real Rates</td>
<td>Jan-97/Jun-16</td>
<td>0.51%</td>
<td>0.62%</td>
<td>2.14%</td>
</tr>
<tr>
<td>Inflation</td>
<td>Jan-97/Jun-16</td>
<td>-0.09%</td>
<td>-0.13%</td>
<td>1.37%</td>
</tr>
<tr>
<td>Term Premium</td>
<td>Feb-90/Jun-16</td>
<td>0.47%</td>
<td>0.48%</td>
<td>2.73%</td>
</tr>
<tr>
<td>Carry Trade</td>
<td>Feb-90/Jun-16</td>
<td>0.28%</td>
<td>0.48%</td>
<td>2.60%</td>
</tr>
<tr>
<td>Commodities</td>
<td>Feb-91/Jun-16</td>
<td>-0.17%</td>
<td>-0.09%</td>
<td>4.27%</td>
</tr>
<tr>
<td>Emerging Markets Currencies (EMC)</td>
<td>Nov-96/Jun-16</td>
<td>-0.98%</td>
<td>-0.43%</td>
<td>3.32%</td>
</tr>
</tbody>
</table>