# Measuring External Risks for Peru: Insights from a Macroeconomic Model for a Small Open and Partially Dollarized Economy

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**Measuring External Risks for Peru: Insights from a Macroeconomic Model for a Small Open and Partially Dollarized Economy**

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**Abstract**

This paper quantifies the effects of external risks for Peru, with particular attention to two major external risks, China's investment slowdown and the U.S. monetary policy tightening. In particular, a macroeconomic model for a small open and partially dollarized economy is developed and estimated for Peru to measure the risk spillovers, and simulate domestic macroeconomic responses in different scenarios with these two external risks. The simulation results suggest that Peru's output is vulnerable to both risks, particularly the U.S. monetary policy tightening. Simulations also highlight the importance of higher exchange rate flexiblity and a lower degree of dollarization, which could help mitigate the negative spillover effects of these external risks.

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# **Contents**                                            **Page**

## I.  INTRODUCTION

**As a small open economy, Peru is exposed to external shocks from its major trading
partners, particularly China.** China is one of Peru's main trading partners, and the largest
export destination country during 2011–12 (Figure 1a). In particular, 17 percent of Peru's total
exports went to China in 2012 (about 4 percent of GDP), of which 81 percent are metals
(Figure 1b). According to data from the UN Commodity Trade Statistics, over a third of Peru's
copper exports, 64 percent of gold exports, and 22 percent of other mineral commodities went to
China during 2008–12 (Figure 1c). However, China's mineral imports from Peru including
copper and gold are still at a relatively small share in its total mineral imports (Figure 1d).

**Figure 1a. Peru: Exports by Destination**
*(Percent of total exports)*
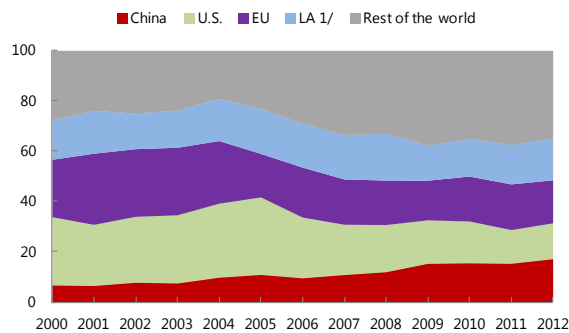


Sources: UN Commodity Trade Statistics; and Fund staff calculations.
1/ Consisting of LA6 economies, Argentina, Bolivia, Ecuador, Paraguay, and
Venezuela.

**Figure 1b. Peru's Real Exports To China: Mineral v.s. Non-Mineral**
*(Percent of real total exports to China)*
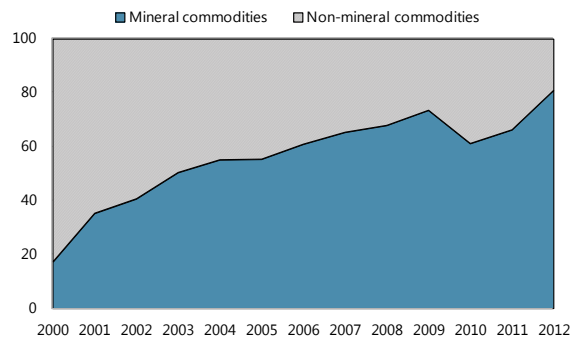


Sources: UN Commodity Trade Statistics; IFS; and Fund staff calculations.

**Figure 1c. Peru's Real Mineral Exports by Destination**
*(Percent of corresponding exports to the world during 2008-12)*
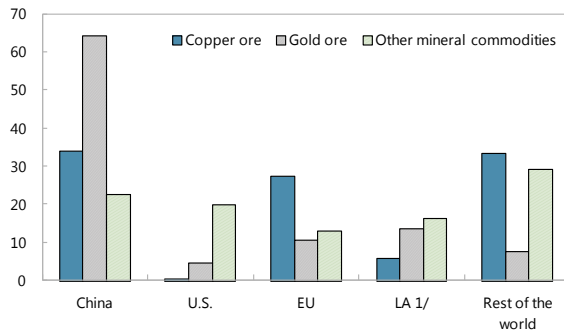


Sources: UN Commodity Trade Statistics; IFS; and Fund staff calculations.
1/ Consisting of LA6 economies, Argentina, Bolivia, Ecuador, Paraguay, and
Venezuela.

**Figure 1d. China's Real Mineral Imports by Origin**
*(Percent of corresponding imports from the world during 2008-12)*
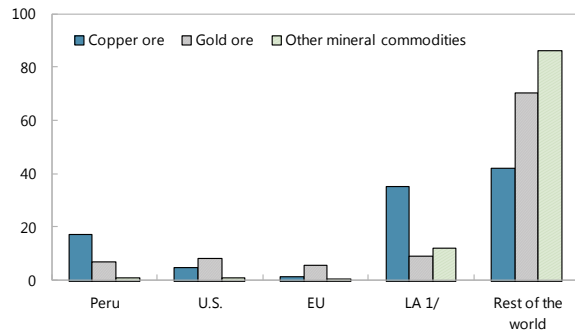


Sources: UN Commodity Trade Statistics; IFS; and Fund staff calculations.
1/ Consisting of LA6 economies (excluding Peru), Argentina, Bolivia, Ecuador,
Paraguay, and Venezuela.

**As a partially dollarized economy, Peru is exposed to the monetary policy shocks in the
U.S.** By end-2013, about 38 percent of banking system liquidity and 42 percent of bank credit to
the private sector in Peru were denominated in foreign currency, reflecting high financial
dollarization (Figure 2a). Not surprisingly, Peru's short-term interest rate denominated in U.S.

dollars is highly correlated with the U.S. federal funds rate (Figure 2b).[2] Thus, U.S. monetary policy shocks that affect the federal funds rate might lead to significant impact on dollar-denominated domestic interbank interest rate and hence economic activity.

**Figure 2a. Peru: Dollarization Ratios in the Banking System**
*(Percent)*
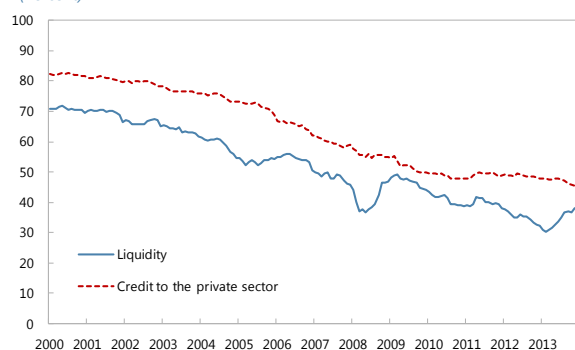


Source: Central Reserve Bank of Peru.

**Figure 2b. Peru: Dollar-Denominated Interbank Rate and U.S. Federal Funds Rate**
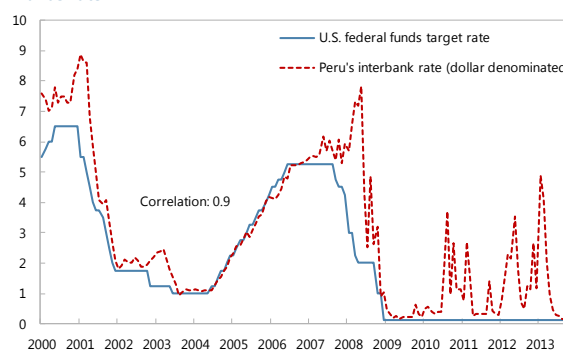


Source: Haver Analytics.

**The IMF's 2012 and 2013 Spillover Reports[3] identified China's investment slowdown and U.S. monetary policy normalization as two of the major global risks going forward.** The 2012 Spillover Report found that China has significant spillover effects on its main trading partners and world prices, mainly through investment which has been a key driver of China's economic growth and lower external surpluses. In particular, as mentioned in the 2012 Spillover Report, "a slowdown in China's investment growth, while desirable to rebalance demand towards consumption in the medium term, could in the interim hit partners and world prices, especially if the adjustment were to be sharp and disorderly." Furthermore, prompt normalization of U.S. monetary policy was also identified as one of the other main global spillover risks in the 2013 Spillover Report. As U.S. economy recovers, monetary policy should be tightened, and this will likely lead to capital flows into the U.S. and higher interest rates across the world, slowing economic growth. As a partially dollarized small open economy, Peru's exposure to the U.S. monetary policy shock might be larger than that of a typical non-dollarized small open country.

**There is limited literature on quantifying the exposure of Peru to China's investment slowdown or U.S. monetary policy tightening.** Salas (2010) proposed a simple macroeconomic model resembling the Quarterly Projection Model (QPM) developed by the Central Reserve Bank of Peru (BCRP), but no external shocks were considered. Ahuja and Nabar (2012) measured the spillover effects of China's investment slowdown on main commodity exporters by estimating the direct trade exposures of each commodity exporter to China. However, as found in Annex IV of the IMF Staff Report for the 2013 Article IV Consultation with Peru (IMF, 2014), the main transmission channel of China's spillovers to Peru is through its impact on world metal

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[2] The correlation between the U.S. dollar-denominated interest rate in Peru and the U.S. federal funds target rate was 0.9 during 2000–13.

[3] See IMF (2012, 2013).

prices, and hence Peru's terms of trade and economic activity (income effect), instead of the direct trade channel.

**This paper uses a new-Keynesian macroeconomic model for a small open and partially dollarized economy to estimate and simulate Peru's macroeconomic and policy responses to a temporary slowdown in China's investment growth and a continued tightening of U.S. monetary policy.** In particular, this paper develops a simple new-Keynesian type macroeconomic model consisting of an aggregate demand equation (or IS curve), an expectations-augmented Phillips curve, a Taylor-type monetary policy rule, and an uncovered interest parity (UIP) condition based on a similar model proposed by Salas (2010). We consider a temporary slowdown in China's investment growth (henceforth, China's investment slowdown) and a continued tightening of U.S. monetary policy (henceforth, U.S. monetary policy tightening) as the external shocks to be consistent with the 2012 and 2013 IMF Spillover Reports. In the model, Chinese and U.S. variables are treated exogenously.[4] In addition, the model assumes that the spillovers from China's investment slowdown are mainly transmitted through global metal prices and trade linkages, and the spillovers from U.S. monetary policy tightening are mainly transmitted through Peru's short-term interest rate denominated in U.S. dollars and trade linkages. The model is then estimated to quantitatively measure these spillover channels, and simulated under different scenarios to generate the macroeconomic and policy responses.

**China's investment slowdown has significantly negative impact on world metal prices, and hence Peru's terms of trade, economic growth and other core macroeconomic variables.** More specifically, the model estimates suggest that a decrease in China's investment growth by one standard deviation is likely to reduce Peru's terms of trade (in gap terms) and output gap by about 2 and 0.2 percentage points, respectively, over the year after the shock cumulatively. The effect dies out in about three years.

**The U.S. monetary policy tightening has significantly negative and long-lasting spillover effects on Peru's U.S. dollar-denominated short-term interest rate, and hence economic growth and other core macroeconomic variables.** In particular, simulations using the estimated model suggest that, depending on the magnitude and persistence of the U.S. monetary policy shock, the costs to Peru's economic activity might be larger and more persistent than those from China's investment slowdown, partly due to the non-temporary feature of the shock.

**Higher exchange rate flexibility is likely to mitigate the impact of both external shocks.** By allowing more room for the exchange rate to fluctuate, Peru can better use it as the first line of defense against external shocks, and significantly reduce their adverse impact. Simulations with the macroeconomic model suggest that, a more flexible nominal exchange rate (caused by, for

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[4] This paper does not use a two-region framework such as the one developed by Berg *et al*. (2006, IMF Working Paper 06/81), because the outward spillovers from Peru to China and U.S. seem to be quite limited.

instance, less foreign exchange intervention) is likely to reduce the spillover effects of the two external shocks on Peru's output gap, particularly over the first year after the shock.[5]

**A lower degree of dollarization can reduce the exposure of Peru to U.S. monetary policy tightening, and might be even more effective than a more flexible exchange rate.** Considering the potential balance sheet effects of a more flexible exchange rate,[6] macroprudential policies aiming at reducing credit dollarization, such as reserve requirements on foreign-currency denominated deposits and short-term external liabilities, might be more desirable for policy makers. Our model simulations with less dollarization suggest that these macroprudential measures could be even more effective than allowing the nominal exchange rate to fluctuate more widely.

**This paper is organized as follows.** The next section presents the macroeconomic model. Section III describes the data and estimation strategy of the model, and presents the estimation results. Section IV discusses the simulation exercises conducted in three scenarios, i.e. a baseline scenario, China scenario (where China's investment growth slows down temporarily), and China and U.S. shock scenario (where, on top of the China scenario, the U.S. short-term interest rate rises permanently). In addition, more simulation exercises are conducted to examine the roles that exchange rate flexibility and dollarization can play. The final section concludes the paper.

## II.  A MACROECONOMIC MODEL FOR A SMALL OPEN AND PARTIALLY DOLLARIZED ECONOMY

**A new-Keynesian macroeconomic model for Peru is developed to analyze the macroeconomic responses in the context of a small open and partially dollarized economy.** The model is based on a general equilibrium and rational expectations model developed by Salas (2010) and Berg *et al*. (2008), which can be characterized by a core set of behavioral equations. Since the model is relatively small compared to the traditional dynamic stochastic general equilibrium (DSGE) models and yet has a well-grounded economic interpretation (Berg *et al*., 2008), it has been used by the BCRP for policy making. The model has four building blocks, namely: (i) an IS curve or aggregate demand equation; (ii) an expectations-augmented Phillips Curve or aggregate supply equation; (iii) a Taylor-type monetary policy rule for the short-term interest rate; and (iv) an uncovered interest rate parity (UIP) condition. Three features of the model are worth noting. First, in the context of a small open economy, terms of trade and foreign output are included as exogenous variables in the aggregate demand equation. Second, in a partially dollarized economy, agents can take loans in U.S. dollars, thus the U.S. dollar-denominated short-term interest rate also enters the aggregate demand equation as an exogenous

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[5] The effectiveness of a more flexible exchange rate depends on the assumption of the degree of flexibility; see section IV.

[6] The balance sheet effects associated to large exchange rate fluctuations have been analyzed by a large number literature. As shown by Calvo and Reinhart (2002) and Reinhart and Reinhart (2008), exchange rate depreciation can reduce the ability to repay foreign-currency denominated debt.

variable. Third, to capture the foreign exchange interventions conducted by the central bank, a backward-looking behavior in the determination of the exchange rate expectations is considered in the model.[7]

**Aggregate demand.** The aggregate demand or IS curve describing the dynamics of the output gap ($y_t$) is characterized in equation (1).

$$y_t = a_y y_{t-1} + a_r\left(\beta_r r_t + \beta_{r\$} r_t^\$\right) + a_{tot}[\beta_{tot} ToT_t + (1 - \beta_{tot}) ToT_{t-1}] + a_q q_t + a_{y^*} y_t^* + \varepsilon_t^y \quad (1)$$

In this equation, $r_t$ is the real interest rate in local currency, and $r_t^\$$ is the real interest rate in U.S. dollars. Their effects on output gap are affected by a common coefficient $a_r$ and idiosyncratic coefficients, or weighting parameters, $\beta_r$ and $\beta_{r\$}$. $ToT_t$ is the terms-of-trade gap, i.e. the gap of international relative prices[8], and this captures the indirect spillover channel from China to Peru. It is assumed that both contemporaneous and lagged terms of trade could directly affect current output gap, and $\beta_{tot}$ is the weighting parameter for current terms-of-trade gap. $q_t$ is the gap of real effective exchange rate (REER).[9] The external demand measured by foreign output gap, $y_t^*$, is also considered. We assume that Peru, as a small open economy, does not affect its terms or trade or external demand. In other words, terms of trade and external demand in equation (1) are exogenous variables. Finally, the disturbance term $\varepsilon_t^y$ denotes a demand shock. Appendix 1 provides a detailed description of the data.

**Expectations-augmented Phillips curve.** A standard new-Keynesian aggregate supply equation or expectations-augmented Phillips curve characterizing inflation ($\pi_t$) is specified in equation (2).

$$\pi_t = b_\pi \pi_{t-1} + b_{\pi^e} E_t(\pi_{t+1}) + b_y y_t + b_m (\pi_t^m + s_t - s_{t-1}) + \varepsilon_t^\pi \quad (2)$$

In this equation, inflation has both backward- and forward-looking behaviors, indicated by the two components, $\pi_{t-1}$ and $E_t(\pi_{t+1})$, respectively, where $E_t(\pi_{t+1})$ is the inflation expectation. $(\pi_t^m + s_t - s_{t-1})$ is the imported inflation measured in local currency, computed as the sum of imported inflation $\pi_t^m$ (measured in U.S. dollars), and the nominal exchange rate variation, $(s_t - s_{t-1})$. The disturbance term $\varepsilon_t^\pi$ represents a supply shock.

**Monetary (interest rate) policy rule.** A Taylor-type monetary policy rule characterizing the determination of the short-term nominal interest rate ($i_t$) is specified in equation (3).

$$i_t = c_i i_{t-1} + (1 - c_i)\{\bar{\imath} + c_y y_t + c_\pi(\pi_t - \bar{\pi}) + c_{\pi^e}[E_t(\pi_{t+1}) - \bar{\pi}]\} + \varepsilon_t^i \quad (3)$$

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[7] Central banks in several partially dollarized economies actively intervene in the foreign exchange market in order to prevent the balance sheet effects stemmed from large exchange rate fluctuations; see Calvo and Reinhart (2002) and Reinhart and Reinhart (2008).

[8] All the gap variables in this paper are computed with the Hodrick-Prescott (HP) filter.

[9] REER is also included here because Peru's terms of trade and REER are not highly correlated, and thus seem to contain differentiated information. An increase in REER indicates a real appreciation vis-à-vis its trading partners.

In this equation, $\bar{\iota}$ is the steady-state nominal interest rate or the neutral rate, and $\bar{\pi}$ is the inflation target. Following Barro (1989), an interest rate smoothing is considered when the central bank determines the interest rate, as indicated by its first lag, $i_{t-1}$. In addition, interest rate also responds to output gap $y_t$ and the deviations of inflation $\pi_t$ and expected inflation $E_t(\pi_{t+1})$ from the inflation target $\bar{\pi}$. Thus, the interest rate has a forward-looking behavior as both inflation and inflation expectations are anchored by this policy rule. The disturbance term $\varepsilon_t^i$ denotes a monetary policy shock.

**Uncovered interest rate parity condition.** The nominal exchange rate $s_t$ is determined by the uncovered interest rate parity (UIP) as expressed in equation (4).

$$4[E_t(s_{t+1}) - s_t] = i_t - i_t^* + \varepsilon_t^s \qquad (4)$$

In equation (4), the expected quarterly exchange rate variation $[E_t(s_{t+1}) - s_t]$ is multiplied by 4 to be transformed into an annual term, which is equal to the differential between the interest rate in local currency and the interest rate in foreign currency (or U.S. dollars in this paper) plus an error term $\varepsilon_t^s$. Following Salas (2010), we assume that the exchange rate expectation $E_t(s_{t+1})$ is determined by a weighted average of a backward-looking component ($s_{t-1}$) and a forward-looking component ($s_{t+1}$), as specified in equation (5), which is in line with the authorities' objective of interventions to reduce the excess volatility of the exchange rate.

$$E_t(s_{t+1}) = \gamma s_{t-1} + (1 - \gamma)s_{t+1} + \varepsilon_t^e \qquad (5)$$

The parameter $\gamma$ (between 0 and 1) implicitly measures the extent to which the exchange rate is smoothed by the central bank's foreign exchange interventions. More specifically, the higher $\gamma$, the higher the degree of exchange rate smoothing.

In addition, following Salas (2010), REER (in gap terms) in equation (1) is determined by its first lag, nominal exchange rate variation, and the differential between domestic and foreign inflation, as specified in equation (6).

$$q_t = d_q q_{t-1} + d_s(s_t - s_{t-1}) + d_\pi(\pi_t^* - \pi_t) + \varepsilon_t^q \qquad (6)$$

$\pi_t^*$ is the foreign inflation, and the disturbance term $\varepsilon_t^q$ denotes a shock to the REER.

Finally, the real interest rates $r_t$ and $r_t^\$$ in the aggregate-demand equation (1) are linked to the domestic nominal interest rates $i_t$ and $i_t^*$ in local currency and U.S. dollars, respectively, by the Fisher equation.

$$r_t = i_t - E_t(\pi_{t+1})$$

$$r_t^* = i_t^* + E_t(s_{t+1}) - E_t(\pi_{t+1})$$

**External shocks.** Terms of trade, external demand, and interest rate in U.S. dollars are the main exogenous variables in this model and the main channels that external shocks spillover to Peru.

We assume that the terms-of-trade gap follows an AR(1) process with world metal prices as an exogenous variable.

$$ToT_t = \rho_{tot}ToT_{t-1} + \rho_m M_t + \varepsilon_t^{tot} \tag{7}$$

In equation (7), $M_t$ is the world metal price (in gap terms), and $\varepsilon_t^{tot}$ is the disturbance term or the terms-of-trade shock stripping out the shocks to world metal prices.

We also assume that the domestic nominal interest rate in U.S. dollars, $i_t^*$, follows an AR(1) process with the U.S. federal funds rate $FFR_t$ as an exogenous variable, as presented in equation (8).[10]

$$i_t^* = \rho_i i_{t-1}^* + \rho_f FFR_t + \varepsilon_t^{i^*} \tag{8}$$

External demand $y_t^*$ is approximated by a trade-weighted average of Peru's top three trading partners' output gaps, including the U.S., China, and the euro area, as specified in equation (9).

$$y_t^* = w_t^{US}y_t^{US} + w_t^{EA}y_t^{EA} + w_t^{CHN}y_t^{CHN} \tag{9}$$

In equation (9), $y_t$ is the output gap of each of these three economies, and $w_t$ is the trade weight between each of the three economies and Peru (summing up to 1).

**China's investment slowdown is transmitted through its impact on China's output and world metal prices.** There are mainly two channels for the transmission of this shock in the model. First, as discussed above, China's investment slowdown directly affects China's growth and output gap $y_t^{CHN}$, and thus the external demand $y_t^*$ according to (9) (the direct channel). Second, China's investment slowdown puts downward pressures on world metal prices $M_t$ and deteriorating Peru's terms of trade according to (7) (the indirect channel).

**U.S. monetary policy tightening is transmitted through its impact on Peru's dollar-denominated nominal interest rate.** This is mainly characterized by equation (8). It should be noted that, for simplicity, the second-round impact of U.S. monetary tightening on Peru through its impact on its own output is not considered in this paper. While this is a shortcoming of the model, this assumption is motivated by the fact that the U.S. only accounts for less than 20 percent of Peru's total trade during 2011–12. If this second-round adverse impact were to be taken into account, the actual spillovers might be even larger than our model estimates.[11]

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[10] The coefficient estimates would still be consistent even if the interest rates were integrated of order 1.

[11] Since this paper is mainly interested in the impact of the rise in U.S. (short-term) interest rate, we define the U.S. scenario as one without higher demand for Peru's exports. However, if we were to define the U.S. scenario as higher interest rates and higher demand for Peru's exports, due to the Fed's announcement that the monetary policy tightening will be conditional on improved economic indicators, then the actual impact might be smaller than the projections in this paper.

### III.  DATA AND ESTIMATION

**The model is estimated with quarterly data over the sample period 2000:Q1−2013: Q3.**[12] It
has six endogenous variables, namely, output gap, inflation, interbank interest rate in local
currency, nominal exchange rate (quarterly rate of change), REER gap, and terms-of-trade gap.
All the gap variables are computed with the Hodrick-Prescott (HP) filter. The expected inflation
$E_t(\pi_{t+1})$ is proxied by the one-year-ahead inflation expectation, obtained from the BCRP's
macroeconomic expectation survey.[13] The inflation is computed as the seasonally-adjusted
annualized rate, and the inflation target $\bar{\pi} = 2$ according to the BCRP.[14] The Appendix provides a
detailed description of the data and their sources. Finally, the model is estimated as a system
using the Generalized Method of Moments (GMM), and the endogenous variables are
instrumented by their first lags in the estimation to avoid the endogeneity problem. The
weighting parameters $\beta_r$, $\beta_{r\$}$, and $\beta_{ToT}$ are not estimated but calibrated following Salas (2010):
$\beta_r = 0.3$, $\beta_{r\$} = 0.15$, and $\beta_{tot} = 0.48$.[15]

**Estimation results are presented in Tables A1–A4.** Since the level of dollarization has been
trending down and the share of Peru's exports to China has increased more notably since mid-
2000s (Figure 1a), we also use a sub-sample 2005:Q1−2013:Q3 in the estimation as a robustness
check to the full-sample estimates, whereas the results are qualitatively similar. Several points
are worth mentioning. First, the coefficient estimates all have the expected signs, and are in line
with Salas (2010). Second, world metal prices are statistically significant in terms of driving
Peru's terms-of-trade dynamics, which confirms other empirical findings.[16] Third, the U.S.
federal funds rate has a significant impact on Peru's dollar-denominated nominal interest rate,
which is consistent with the high correlation between these two series as shown by the chart in
the introduction section. Four, although local currency-denominated and dollar-denominated
interest rates seem to have insignificant impact on Peru's output gap, the impact becomes
significant if more observations are included.[17] This suggests a downward sloping IS curve for

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[12] Except equation (8) which is estimated with data over 2000:Q1–2009:Q1, before the federal funds target rate hit
the zero lower bound.

[13] The inflation expectations in the survey are end-of-year expectations. We adopt the BCRP's weighting scheme to
compute the one-year-ahead expected inflation.

[14] The annual inflation target has been 2 percent (with a tolerance band of +/− 1 percentage point) since 2007.
However, the target was 2½ percent (with a tolerance band of +/− 1 percentage point) during 2002–06, and the target
range was 3½–4.0 percent and 2½–3½ percent in 2000 and 2001, respectively. For simplicity, we follow Salas
(2010) and assume that the annual inflation target is 2 percent over our entire sample period 2000–13.

[15] These values of the calibrated parameters are also in line with the ones in the QPM developed by the BCRP (see
Macroeconomic Models Department, 2009).

[16] See, for instance, Annex IV of the Staff Report for the 2013 Article IV Consultation with Peru, which shows that
China's investment slowdown is likely to have significant spillover effects on Peru's GDP growth through terms of
trade.

[17] However, due to data availability of the other variables, we cannot estimate the entire model with the extended
sample period.

Peru, and thus implies that the U.S. monetary policy tightening is likely to have a significant impact on Peru's real economy. Last but not least, similar to Salas (2010), we also find a significantly high degree of exchange rate smoothing, which might be partly due to the BCRP's foreign exchange interventions.

## IV.  SCENARIOS AND SIMULATIONS

**This section conducts simulations using the estimated model to examine the macroeconomic responses in three different scenarios over 2013:Q4–2018:Q4.** The first scenario is a baseline scenario with the IMF's baseline projections.[18] The second one is the China scenario where the investment growth rate of China declines temporarily by one standard deviation from the baseline in Q1 2015.[19] The third scenario is the China and U.S. shock scenario where on top of the China scenario, the U.S. federal funds target rate starts to rise since Q2 2015 following the projections made by Carpenter *et al*. (2013)[20]. The simulation horizon is 2013:Q4–2018:Q4.

**Assumptions of the external variables in the baseline scenario mainly come from the IMF projections**, except China's real GDP growth and the U.S. federal funds rate**.** We assume that the annual growth rate of Chinese real GDP stays at 7½ percent and the federal funds target rate remains unchanged at 0.15 percent p.a. throughout the simulation horizon. The other external variables including world metal prices, foreign inflation (proxied by world inflation), and the output gaps of the U.S. and euro area are obtained from the World Economic Outlook (WEO) projections of the IMF, and imported inflation (measured in U.S. dollars) and expected inflation are obtained from the projections included in IMF (2014).

**The China scenario assumes a one-standard-deviation (temporary) decline in China's investment growth compared to the baseline scenario in Q1 2015.[21]** This shock has negative impact on world metal prices and China's output gap as expected (Figure A1). First, we estimate the impact on world metal prices using a simple Vector Autoregression with exogenous variables (VARX), which includes the growth of China's real investment in fixed assets (FAI) and world metal price inflation as endogenous variables and U.S. and euro area real GDP growth as exogenous variables. The estimates suggest that a one-standard-deviation decline in China's real FAI growth is likely to reduce world metal prices by 3¼ percent over a year, similar to the

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[18] Except the assumptions of China's real GDP growth and the U.S. federal funds rate; see the detailed assumptions in the following paragraph.

[19] This is a one standard deviation negative temporary shock to China's investment growth in one quarter, equivalent to a 2.5 percent decline in China's investment levels from the baseline. This shock is the same as the shock to China's investment growth considered in the IMF's 2012 Spillover Report for a better comparison.

[20] This is a staff working paper in the Finance and Economics Discussion Series (FEDS) by the Divisions of Research & Statistics and Monetary Affairs, Board of Governors of the Federal Reserve System.

[21] Following Ahuja and Nabar (2012), we use the real investment in fixed assets (FAI) as a proxy for real investment due to the availability of quarterly data for investment.

finding in the IMF's 2012 Spillover Report and Ahuja and Nabar (2012).[22] World metal price inflation returns to its baseline level after about two years. Second, to estimate the impact of this shock on China's output gap, we estimate another simple VARX model with China's real FAI and GDP growth as endogenous variables, and U.S. and euro area real GDP growth as exogenous variables. The estimates suggest that the shock reduces China's real GDP growth by 0.3 percentage points cumulatively after one year.[23] Finally, the assumptions for the other external variables remain the same as those in the baseline scenario.

**The China and U.S. shock scenario assumes that, besides the assumptions in the China scenario, the federal funds target rate starts to rise gradually since Q2 2015**, following the projections made by Carpenter *et al*. (2013). In this scenario, the federal funds target rate is assumed to increase linearly by 107 basis points over the first year 2015:Q2–2016:Q2 and another 107 basis points over the second year 2016:Q2–2017:Q2, and plateau when it reaches 4 percent p.a. in Q4 2018 (Figure A1). With these dynamics, the impact on Peru's dollar-denominated interest rate is significant (almost one to one) and long lasting.

*China scenario*

**Simulation results suggest that a one-standard-deviation negative shock to China's investment growth is likely to reduce Peru's output gap by about 0.6 percentage points cumulatively over the simulation horizon.** The simulated dynamics for the main endogenous variables (in deviations from the baseline scenario) are shown in the Figure A2. The shock is estimated to reduce Peru's terms-of-trade gap by about 4 percentage points over the simulation horizon, and thus widen Peru's negative output gap mainly through the income effect.[24] The output gap returns to its baseline level about three years after the shock.

**The shock has negligible impact on inflation, nominal interest rate, and exchange rate.** The year-on-year inflation declines by only 0.03 percentage points at the peak over the simulation horizon, reflecting the well-anchored inflation expectation. Nominal interest rate in local currency is lowered by 6 basis points at the peak, as a response to the widened negative output gap. In particular, exchange rates (both nominal and real) only depreciate slightly, reflecting a high degree of exchange rate smoothing which is similar to the finding of Salas (2010). This might be partly due to the foreign exchange interventions conducted by the BCRP.

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[22] See Table A2 in Ahuja and Nabar (2012). The estimated impact on world metal prices is then transformed into the impact on the gap of the world metal prices by computing the new trend of metal prices with the HP filter.

[23] The estimated impact is then transformed into the impact on China's output gap by computing the new potential output with the HP filter.

[24] The shock also reduces China's output gap and affects Peru's output gap through the direct trade channel captured by $y^*$. However, this channel is not the main spillover channel, as found in IMF (2014).

*China and U.S. shock scenario*

**In this scenario, Peru's output gap is reduced significantly by about 2½ percentage points cumulatively over the simulation horizon and continues to widen.** The shock is estimated to raise Peru's dollar-denominated interest rate by about 100 basis points one year after the shock, and thus reduce Peru's output gap significantly in terms of both magnitude and persistence. The output gap does not return to its baseline level within the simulation horizon, partly due to the long-lasting feature of this federal-funds-rate shock (Figure A1).

**The shock has a much larger impact on inflation, nominal interest rate, and exchange rate than the shock to China's investment slowdown.** In particular, exchange rates (both nominal and real) depreciate substantially according to the UIP and much more than in the China scenario.[25] As a result of the shock and these relatively large depreciations, inflation first declines and then starts to rise two years after the shock. However, the impact on the year-on-year inflation is still limited (the peak impact is less than 0.2 percentage points), partly due to the well-anchored expected inflation. Nominal interest rate in local currency is lowered further by 3 basis points at the peak compared to the China scenario due to a larger (negative) output gap.

*The role of exchange rate flexibility*

**Higher exchange rate flexibility is likely to mitigate the impact of external shocks on output, but a large depreciation might put an upward pressure on inflation.** In order to better examine the role of exchange rate flexibility in the model, we make the nominal exchange rate (EXR) in the model exogenous by replacing the UIP condition (4) and the formation of exchange rate expectation (5) with exogenously specified dynamics of the EXR. Purchasing power parity is assumed to hold over the simulation horizon; the projected EXR is taken as our baseline. We then contrast this baseline EXR with a more-depreciated EXR path where the EXR converges exponentially towards its historical average during 2002–13.[26] Compared to the endogenous EXR in the China and U.S. shock scenario (Figure A2), this "depreciated EXR" path assumes more rapid depreciations at the beginning but slower depreciations later on (Figure A3). Simulation results based on these two exogenous EXR paths are presented in Figure A3. Three observations are worth mentioning. First, due to a relatively large depreciation in Q1 2015, output gap starts to rise at the beginning but turns negative as the shocks unwind. Second, a more depreciated EXR path can reduce the loss of output gap by about 0.4 percentage points cumulatively over the simulation horizon in both scenarios. Third, inflation is under pressure in

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[25] Nominal exchange rate depreciates by about 9 percent by end-2018 in the China and U.S. shock scenario, compared to a depreciation of only 0.2 percent in the China scenario.

[26] This is merely an illustrative assumption of a more flexible EXR since EXR does not generally have the mean-reverting property. This more-depreciated assumption translates to about 11 percent depreciation compared to the baseline EXR over the simulation horizon.

the first year after the shocks due to the "front-loaded" depreciation,[27] and as a response, interest rate in local currency shoots up by about 25 basis points at the same time.

*The role of dollarization*

**A lower degree of dollarization significantly reduces the adverse impact of the shock to U.S. federal funds rate, without inducing substantial inflationary pressures.** The parameter $\beta_{r\$}$ can be interpreted as a rough measure of the degree of dollarization. In an extreme case where $\beta_{r\$} = 0$, the model becomes a standard macroeconomic model for a small open economy without dollarization, and there is no direct impact of federal funds rate on domestic economic activity. Based on this observation, we can lower the degree of dollarization by assigning a smaller value to $\beta_{r\$}$. A simulation exercise is done with $\beta_{r\$} = 0.075$, a half of the calibrated value (Figure A4). Three points are worth noticing. First, the lower degree of dollarization does not affect the China scenario. Second, the loss of output gap in the China and U.S. shock scenario is significantly reduced by about 1 percentage point cumulatively over the simulation horizon, and output gap starts to converge towards its baseline level. Second, the depreciations of both nominal and real EXRs are similar to those in Figure A2. Third, the year-on-year inflation is slightly higher than in the high dollarization case, but is only 0.2 percentage points above the baseline scenario at the peak. As a result, interest rate in local currency does not decrease as much as in the high dollarization case.

## V. CONCLUDING REMARKS

**This paper finds that Peru's economic activity is vulnerable to both China's investment slowdown and U.S. monetary policy tightening, with a larger and long-lasting impact from the latter.** A macroeconomic model for a small open and partially dollarized economy is developed and estimated to simulate the impact of these two external risks. The simulation results suggest that: (1) a one-standard-deviation temporary decline in China's investment growth is likely to reduce Peru's output gap by about 0.2 percentage points cumulatively one year after the shock; and (2) a rising federal funds rate since Q2 2015 (increasing by some 100 basis points per year) might have substantial and persistent effects on Peru's output.

**Higher exchange rate flexibility or less dollarization could enhance Peru's resilience against the external risks.** Simulations with a more flexible exchange rate produce smaller negative spillovers to Peru for both external risks. One of the findings of this paper and some other literature such as Salas (2010) is the significant exchange rate smoothing, achieved by the BCRP's frequent interventions in the foreign exchange market. Thus, less foreign exchange intervention might lower the degree of exchange rate smoothing and increase the flexibility of exchange rate. Furthermore, we find that a lower degree of dollarization can reduce the negative spillovers of the U.S. monetary policy tightening more effectively than higher exchange rate flexibility. The macroprudential policy aiming to reduce credit dollarization, such as reserve

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[27] The peak impact on year-on-year inflation is about ½ percentage points in both scenarios.

requirements on foreign-currency denominated deposits and short-term external liabilities, might be more desirable for policy makers in terms of reinforcing Peru's resilience against external interest rate shocks.

### Table A1. Estimation Results: Aggregate Demand Equation

$$y_t = a_y y_{t-1} + a_r\left(\beta_r r_t + \beta_{r\$} r_t^\$\right) + a_{tot}\left[\beta_{tot} ToT_t + (1 - \beta_{tot})ToT_{t-1}\right] + a_q q_t + a_{y^*} y_t^* + \varepsilon_t^y$$

| | Estimated Parameters | | | |
|---|---|---|---|---|
| Parameter | GMM estimates | Std. error | GMM estimates (2005:Q1–2013:Q3) | Posterior mode in Salas (2010) |
| $a_y$ | 0.71*** | 0.08 | 0.65*** | 0.49 |
| $a_r$ | -0.26 | 0.36 | -0.97*** | -0.28 |
| $a_{tot}$ | 0.03*** | 0.01 | 0.02** | 0.04 |
| $a_q$ | -0.04 | 0.14 | 0.08 | -0.06 |
| $a_{y^*}$ | 0.31* | 0.17 | 0.86*** | 0.08 |
| | Calibrated Parameters | | | |
| $\beta_r$ | 0.3 | — | 0.3 | 0.3 |
| $\beta_{r\$}$ | 0.15 | — | 0.15 | 0.15 |
| $\beta_{tot}$ | 0.48 | — | 0.48 | 0.48 |

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

### Table A2. Estimation Results: Expectations-Augmented Phillips Curve

$$\pi_t = b_\pi \pi_{t-1} + b_{\pi^e} E_t(\pi_{t+1}) + b_y y_t + b_m \pi_t^m + \varepsilon_t^\pi$$

| | Estimated Parameters | | | |
|---|---|---|---|---|
| Parameter | GMM estimates | Std. error | GMM estimates (2005:Q1–2013:Q3) | Posterior mode in Salas (2010) |
| $b_\pi$ | 0.12** | 0.05 | 0.15 | 0.65 |
| $b_{\pi^e}$ | 0.21*** | 0.02 | 0.19*** | 0.30 |
| $b_y$ | 0.10*** | 0.03 | 0.14*** | 0.10 |
| $b_m$ | 0.06*** | 0.01 | 0.06*** | 0.05 |

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Table A3. Estimation Results: Monetary Policy Rule**

$$i_t = c_i i_{t-1} + (1 - c_i)\{\bar{\iota} + c_y y_t + c_\pi(\pi_t - \bar{\pi}) + c_{\pi^e}[E_t(\pi_{t+1}) - \bar{\pi}]\} + \varepsilon_t^i$$

| Estimated Parameters | | | | |
|---|---|---|---|---|
| Parameter | GMM estimate | Std. error | GMM estimates (2005:Q1–2013:Q3) | Posterior mode in Salas (2010) |
| $c_i$ | 0.73*** | 0.04 | 0.73*** | 0.66 |
| $c_y$ | 0.70*** | 0.26 | -0.09 | 0.51 |
| $c_\pi$ | 0.71* | 0.41 | 5.54 | — |
| $c_{\pi^e}$ | 0.15 | 0.28 | -0.20 | 1.93 |
| $\bar{\iota}$ | 3.30*** | 0.38 | 3.07*** | — |

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Table A4. Estimation Results: Exchange Rate Expectation Equation**

$$E_t(s_{t+1}) = \gamma s_{t-1} + (1 - \gamma)s_{t+1} + \varepsilon_t^e$$

| Estimated Parameters | | | | |
|---|---|---|---|---|
| Parameter | GMM estimate | Std. error | GMM estimates (2005:Q1–2013:Q3) | Posterior mode in Salas (2010) |
| $\gamma$ | 0.61** | 0.26 | 0.73*** | 0.66 |

Note: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

**Figure 1. External Shocks and Simulation Scenarios 1/**

**China Scenario: Dynamics of China's Real FAI Growth 2/**
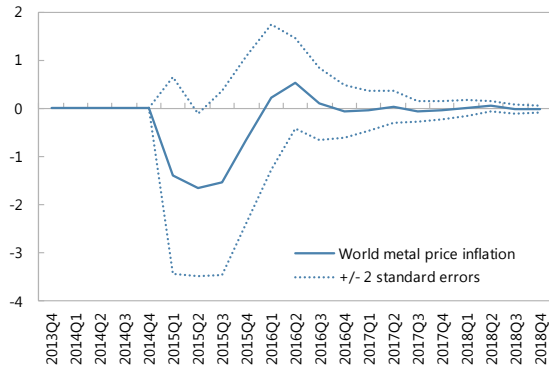*(Quarter-on-quarter percent change; deviation from baseline scenario)*
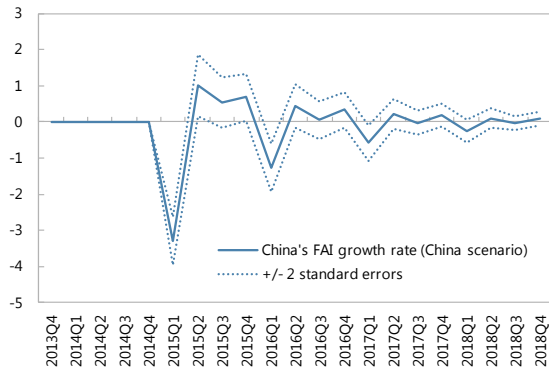


**U.S. Scenario: Dynamics of U.S. Federal Funds Target Rate**
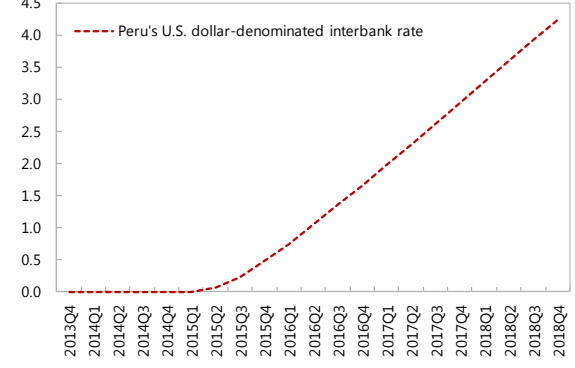*(Percent p.a.; deviation from baseline scenario)*
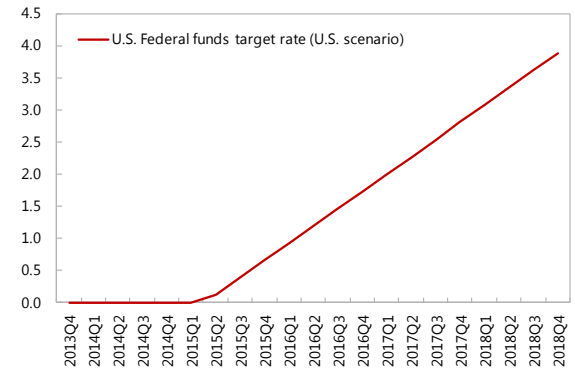


**World Metal Prices: Impact of China Scenario 2/**
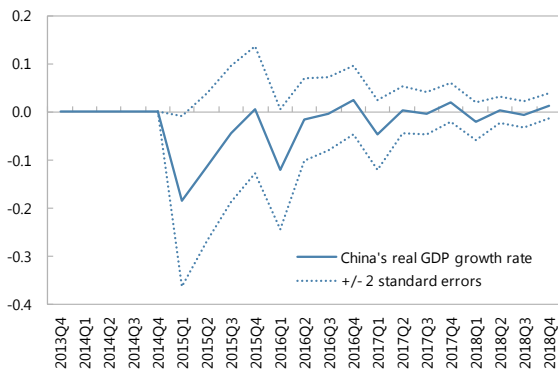*(Quarter-on-quarter percent change; deviation from baseline scenario)*



**Peru's U.S. dollar-Denominated Interest Rate: Impact of U.S. Scenario**
*(Percent p.a.; deviation from baseline scenario)*



**China's Real GDP: Impact of China Scenario 3/**
*(Quarter-on-quarter percent change; deviation from baseline scenario)*
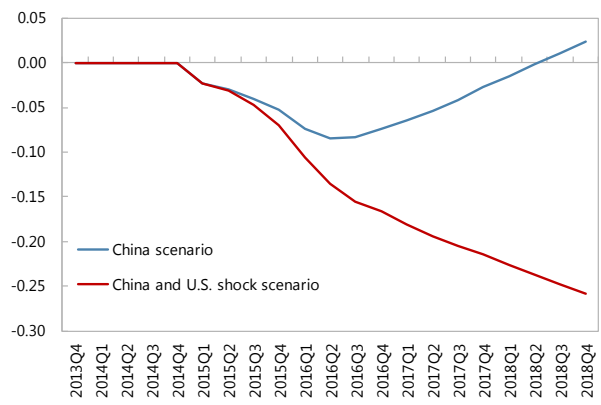


1/ Three different scenarios of external shocks are considered in this simulation exercise over the simulation horizon of 2013:Q4–2018:Q4:
(1). Baseline scenario: mainly assumptions from the IMF's Global Assumptions (GAS) and World Economic Outlook (WEO) databases, as well as the baseline assumptions made by the IMF's Peru team;
(2). China scenario: A one-standard-deviation temporary decline in China's investment growth in Q1 2015 compared to the baseline scenario. (A one-standard-deviation decline in growth is equivalent to a 2.5 percent decline in China's investment levels from the baseline scenario.)
(3). U.S. scenario: The federal funds target rate starts to rise in Q2 2015 and follows the projections made by the IMF's U.S. team.
2/ Impulse responses of China's FAI growth to its own one-standard-deviation shock in Q1 2015 estimated with a VARX model including China's FAI growth rate and world metal price inflation as endogenous variables and U.S. and euro area real GDP growth as exogenous variables. Lag length is chosen according to the Akaike's information criterion (AIC). Shocks are identified in the VARX by the Cholesky decomposition and the impulse responses are not affected by the Cholesky ordering.
3/ Impulse responses of China's real GDP growth to a one-standard-deviation shock to the FAI growth in Q1 2015 estimated with a VARX model including China's real FAI and GDP growth as endogenous variables and U.S. and euro area real GDP growth as exogenous variables. Lag length is chosen according to the AIC. Shocks are identified in the VARX by the Cholesky decomposition and the impulse responses are not affected by the Cholesky ordering.
Sources: Central Reserve Bank of Peru; National Institute of Statistics; Haver Analytics; International Financial Statistics, Information Notice System, World Economic Outlook database and Global Assumptions database of the IMF; and Fund staff estimates.

**Figure A2. Peru's Macroeconomic Responses: Impact of External Shocks 1/**

**Peru's Terms-of-Trade Gap: Impact of China Scenarios**
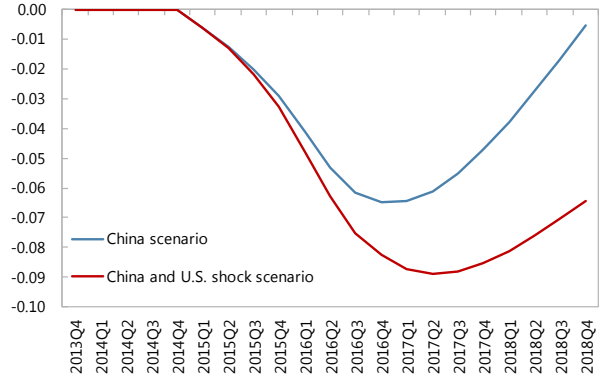*(Percent of equilibrium TOT; deviation from baseline scenario)*
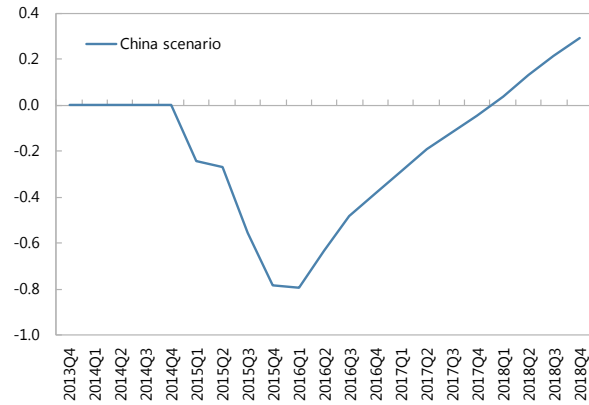


**Peru's Output Gap: Impact of China and U.S. Scenarios**
*(Percent of potential output; deviation from baseline scenario)*



**Peru's Inflation: Impact of China and U.S. Scenarios**
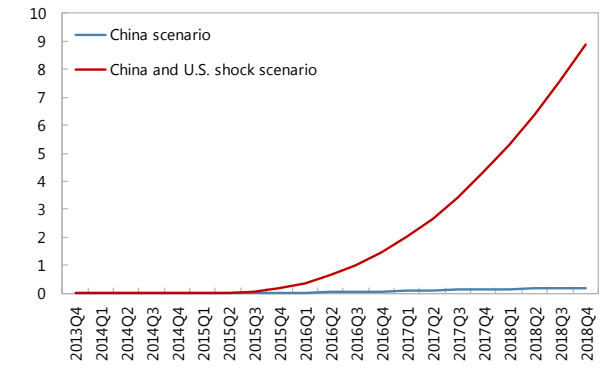*(Year-on-year percent change; deviation from baseline scenario)*
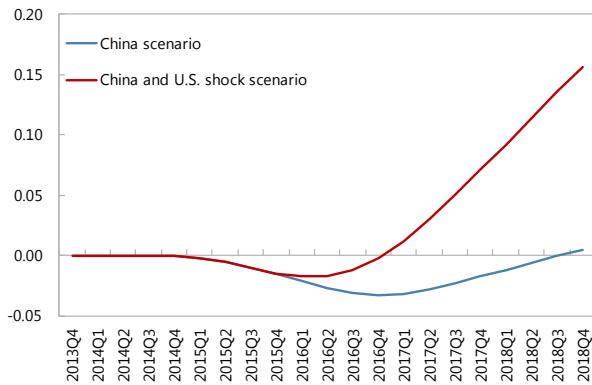


**Peru's Nominal Interest Rate: Impact of China and U.S. Scenarios**
*(Percent p.a.; deviation from baseline scenario)*



**Peru's REER Gap: Impact of China and U.S. Scenarios**
*(Percent of equilibrium REER; deviation from baseline scenario; decrease=depreciation)*
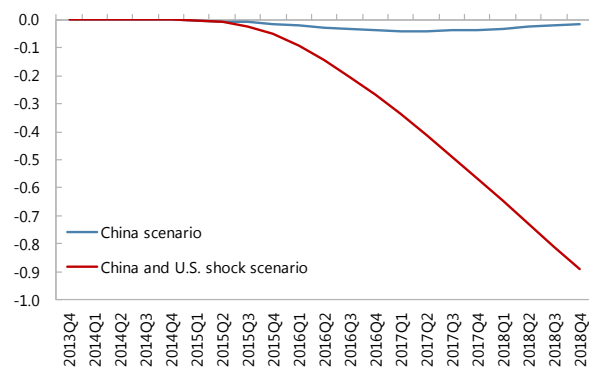


**Peru's Nominal Exchange Rate: Impact of China and U.S. Scenarios**
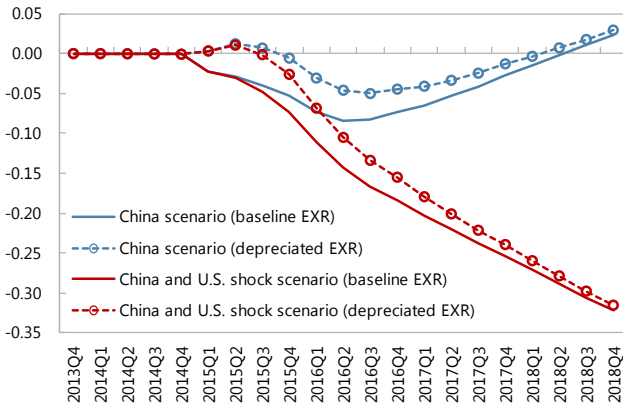*(Percent deviation from baseline scenario; increase=depreciation)*



1/ Three different scenarios of external shocks are considered in this simulation exercise over the simulation horizon of 2013:Q4–2018:Q4:

(1). Baseline scenario: mainly assumptions from the IMF's WEO database and IMF (2014);

(2). China scenario: A one-standard-deviation temporary decline in China's investment growth in Q1 2015 compared to the baseline scenario. (A one-standard-deviation decline in growth is equivalent to a 2.5 percent decline in China's investment levels from the baseline scenario.)

(3). China and U.S. shock scenario: On top of the assumptions in the China scenario, the U.S. Federal funds target rate starts to rise in Q2 2015 and follows the projections made by Carpenter *et al.* (2013).

Sources: BCRP; National Institute of Statistics; Haver Analytics; IFS, INS, and WEO databases of the IMF; and Fund staff estimates.

**Figure A3. Peru's Macroeconomic Responses with Exogenous Exchange Rate: Impact of External Shocks 1/**

**Peru's Output Gap: Impact of China and U.S. Scenarios**
*(Percent of potential output; deviation from baseline scenario)*
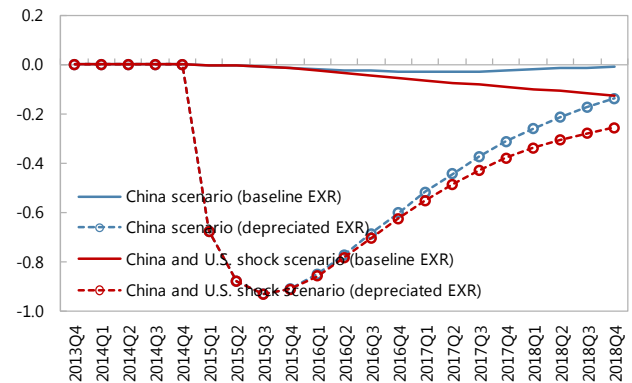


**Peru's Inflation: Impact of China and U.S. Scenarios**
*(Year-on-year percent change; deviation from baseline scenario)*



**Peru's Nominal Interest Rate: Impact of China and U.S. Scenarios**
*(Percent p.a.; deviation from baseline scenario)*
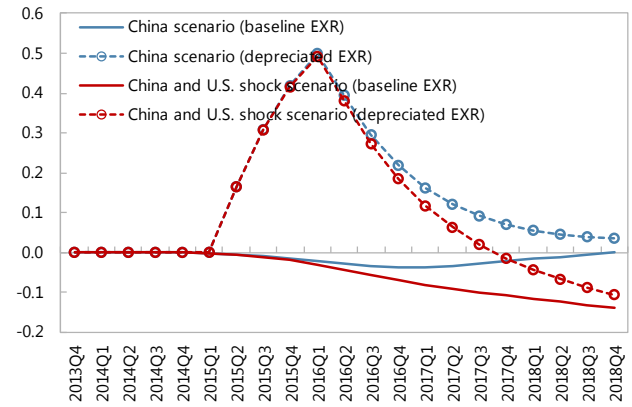


**Peru's REER Gap: Impact of China and U.S. Scenarios**
*(Percent of equilibrium REER; deviation from baseline scenario; decrease=depreciation)*
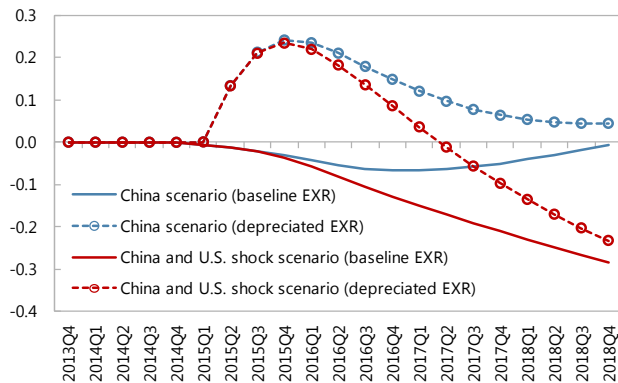


**Peru's Nominal Exchange Rate: Assumptions**
*(Nuevo soles per U.S. dollar)*
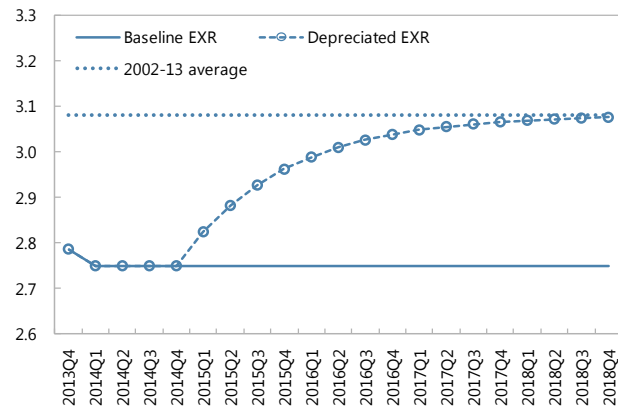


1/ Nominal exchange rate (EXR) is assumed to be exogenous in this simulation exercise over the simulation horizon of 2013Q4–2018Q4. Three different scenarios of external shocks and two different EXR dynamics are considered and specified as follows.
(a1). Baseline scenario: mainly assumptions from the IMF's WEO database and IMF (2014);
(a2). China scenario: A one-standard-deviation temporary decline in China's investment growth in Q1 2015 compared to the baseline scenario. (A one-standard-deviation decline in growth is equivalent to a 2.5 percent decline in China's investment levels from the baseline scenario.)
(a3). China and U.S. shock scenario: On top of the assumptions in the China scenario, the U.S. Federal funds target rate starts to rise in Q2 2015 and follows the projections made by Carpenter *et al.* (2013).
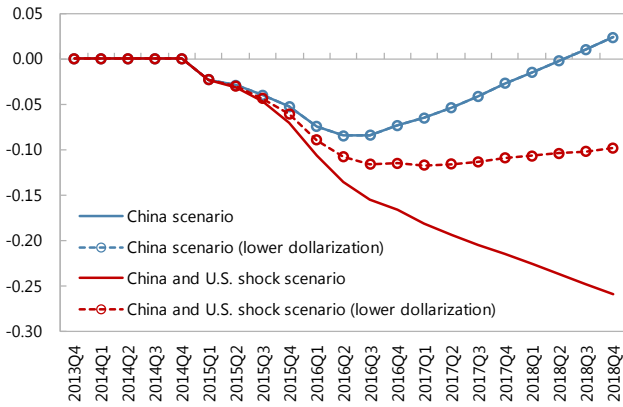(b1). Baseline EXR is calculated assuming that the purchasing power parity (PPP) holds during 2014:Q1–2018:Q4.
(b2). EXR starts to depreciate gradually towards its 2002–13 average when China's investment growth declines in Q1 2015.
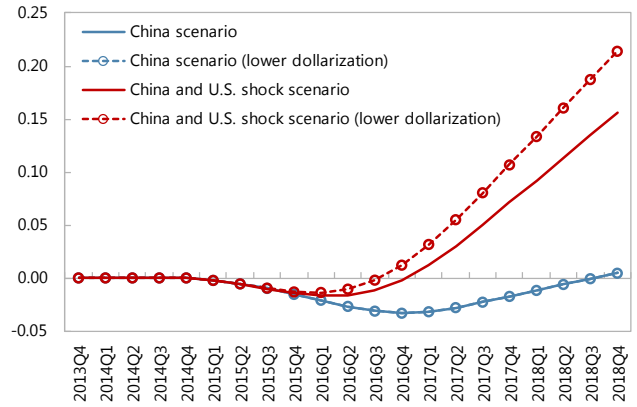Sources: BCRP; National Institute of Statistics; Haver Analytics; IFS, INS, and WEO databases of the IMF; and Fund staff estimates.

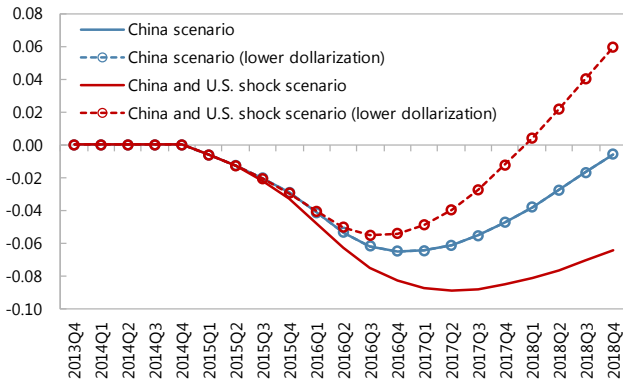**Figure A4. Peru's Macroeconomic Responses with a Lower Degree of Dollarization: Impact of External Shocks 1/**

**Peru's Output Gap: Impact of China and U.S. Scenarios**
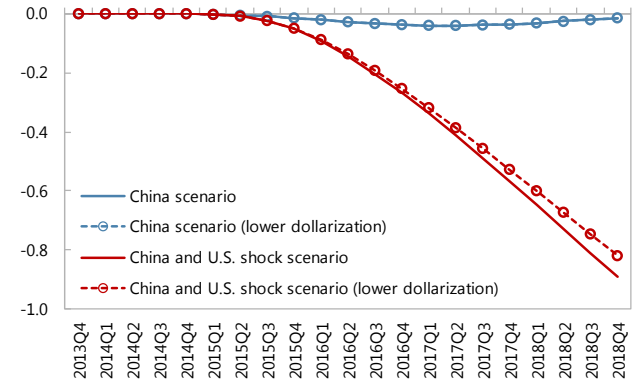*(Percent of potential output; deviation from baseline scenario)*

- China scenario
- China scenario (lower dollarization)
- China and U.S. shock scenario
- China and U.S. shock scenario (lower dollarization)

**Peru's Inflation: Impact of China and U.S. Scenarios**
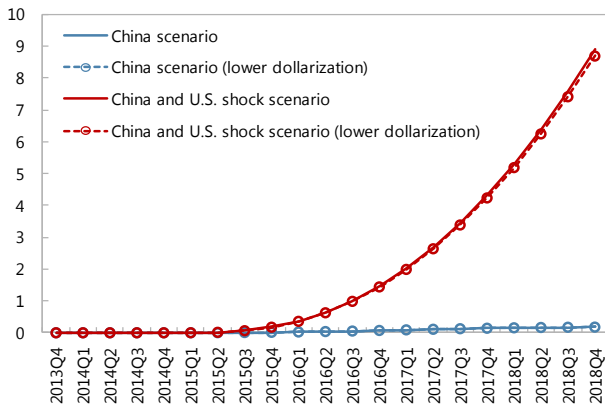*(Year-on-year percent change; deviation from baseline scenario)*

- China scenario
- China scenario (lower dollarization)
- China and U.S. shock scenario
- China and U.S. shock scenario (lower dollarization)

**Peru's Nominal Interest Rate: Impact of China and U.S. Scenarios**
*(Percent p.a.; deviation from baseline scenario)*

- China scenario
- China scenario (lower dollarization)
- China and U.S. shock scenario
- China and U.S. shock scenario (lower dollarization)

**Peru's REER Gap: Impact of China and U.S. Scenarios**
*(Percent of equilibrium REER; deviation from baseline scenario; decrease=depreciation)*

- China scenario
- China scenario (lower dollarization)
- China and U.S. shock scenario
- China and U.S. shock scenario (lower dollarization)

**Peru's Nominal Exchange Rate: Assumptions**
*(Nuevo soles per U.S. dollar)*

- China scenario
- China scenario (lower dollarization)
- China and U.S. shock scenario
- China and U.S. shock scenario (lower dollarization)

1/ A lower degree of dollarization in this simulation exercise is characterized by a smaller value of the calibrated parameter $\beta_{r\$}$ in the model. More specifically, $\beta_{r\$}$ is set to be a half of the calibrated value, i.e. 0.075. In addtion, three different scenarios of external shocks are considered in this simulation exercise over the simulation horizon of 2013:Q4–2018:Q4:
(1). Baseline scenario: mainly assumptions from the IMF's WEO database and IMF (2014);
(2). China scenario: A one-standard-deviation temporary decline in China's investment growth in Q1 2015 compared to the baseline scenario. (A one-standard-deviation decline in growth is equivalent to a 2.5 percent decline in China's investment levels from the baseline scenario.)
(3). China and U.S. shock scenario: On top of the assumptions in the China scenario, the U.S. Federal funds target rate starts to rise in Q2 2015 and follows the projections made by Carpenter *et al.* (2013).
Sources: BCRP; National Institute of Statistics; Haver Analytics; IFS, INS, and WEO databases of the IMF; and Fund staff estimates.

## APPENDIX. DATA

| Variable | Data and Source |
| --- | --- |
| Output gap | Gross domestic product (millions of 1994 nuevos soles), seasonally adjusted by Haver Analytics. Gap computed with the HP filter. Source: Haver Analytics. |
| Terms-of-trade gap | Export price index relative to import price index (1994=100, quarterly average, seasonally adjusted). Gap computed with the HP filter. Source: Central Reserve Bank of Peru. |
| Real effective exchange rate (REER) gap | Gap computed with the HP filter. Source: Informational Notice System. |
| Foreign output gap | A weighted average of the output gaps of the U.S., euro area, and China using the trade shares between each of the three economies with Peru as the weights. Sources: IMF's World Economic Outlook databases; and International Financial Statistics. |
| Inflation | CPI inflation (Dec. 2001=100, quarterly average, seasonally adjusted). Source: Central Reserve Bank of Peru. |
| Imported inflation | Computed with the import price index (1994=100, quarterly average, seasonally adjusted). Source: Central Reserve Bank of Peru. |
| Foreign inflation | World inflation (quarterly average, seasonally adjusted). Source: International Financial Statistics. |
| World metal price gap | World metal price index (2005=100, quarterly average, seasonally adjusted). Source: International Financial Statistics. |
| Nominal interest rate in local currency | Interbank interest rate (quarterly average). Source: Central Reserve Bank of Peru. |
| Nominal interest rate denominated in U.S. dollars | U.S. dollar-denominated interbank interest rate (quarterly average). Source: Central Reserve Bank of Peru. |
| Nominal exchange rate | Quarterly average. Increase denotes depreciation. Source: Central Reserve Bank of Peru. |
| Federal funds rate | Quarterly average. Source: Haver Analytics. |
| Expected inflation | One-year-ahead inflation expectations (quarterly average). Source: The Macroeconomic Survey of the Central Reserve Bank of Peru. |
| Expected nominal exchange rate | One-year-ahead expectations of nominal exchange rate (quarterly average). Source: The Macroeconomic Survey of the Central Reserve Bank of Peru. |
| China's investment in fixed assets | Source: National Bureau of Statistics of China. |

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