Exchange rate misalignment and Producer Support Estimates (PSEs) of China*

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Abstract

This paper examines the effects of exchange rate misalignment on the agricultural Producer Support Estimates (PSEs) of China. Based on several time series techniques, the equilibrium exchange rate of the Chinese yuan and the corresponding misalignment of the actual rate are estimated and applied to PSE calculations. Our results show that the exchange rate has been significantly undervalued in recent years with subsequent indirect effects on the PSEs. Our model forecasts future appreciations and indicates a slow but uneven process of convergence towards long-run exchange rate equilibrium, which could inflict persistent and sometimes steep adjustment pressure on China's agricultural sector. We find a high pass-through of exchange rate movements to domestic agricultural prices, so that correction of exchange rate misalignment through appreciations would worsen production incentives to Chinese farmers.

JEL classification: Q18; F31

Keywords: Exchange rate; Cointegration; Forecast; Persistence profile; Pass-through; Agricultural Producer Support Estimates (PSEs)

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1. Introduction

Agricultural policies in developing countries play a very important role in determining domestic commodity prices and the returns to agriculture. The nature and degree of policy interventions differ across countries thereby producing different types of impacts on producers and consumers. Various agricultural policy indicators (APIs) such as the Producer Support Estimates (PSEs) have been constructed to evaluate and monitor these policy changes (Josling and Valdes, 2004). A problem with conventional analyses based on the APIs, however, is that they usually have a sector-specific focus that can miss the important linkages between economy-wide policies and the agricultural sector. By changing the relative prices of importables, exportables and home goods, some economy-wide policies, such as policies affecting exchange rates, can have impacts on agricultural incentives that might overwhelm those from sectoral policies. The different effects of sectoral and economy-wide policies on agriculture in developing countries were documented in the study by Krueger et al. (1991).

The relevance of exchange rate in the calculation of PSEs has been pointed out by a number of authors including Harley (1996), Liefert et al. (1996), Melyukhina (2002) and Cheng and Orden (2007). This issue is particularly important for some developing countries and economies in transition where drastic changes in the macroeconomic environment accompanied by insufficient adjustments in the exchange rate have generated substantial currency misalignments. Pronounced misalignments of the exchange rate potentially subsidize or tax the agricultural sector and result in misleading estimates of the level and sometimes the direction of agricultural support as measured by the PSEs.

While there is general agreement that use of misaligned exchange rates introduces a bias in the PSE calculations, and that this bias can be substantial in some cases, there is much less agreement on the appropriate alternative. Previous studies (e.g., Liefert et al., 1996, for Russia) have used certain “adjusted” exchange rates such as the purchasing power parity (PPP) exchange rate as the “equilibrium” and indicated that exchange rate misalignment had significant impacts on the calculation of the PSEs. Despite plausible results, calculations based on PPP involve a degree of discretion and the results are sensitive to the selection of a base year. Other models of the equilibrium exchange rate are potentially preferred to the PPP approach in PSE estimation (Harley, 1996).

Recently an equilibrium approach that relates the real exchange rate to underlying economic fundamentals has gained prominence among both practitioners and policy makers to address issues of exchange rate misalignment and to test for over- or under-valued currencies. We apply this approach and analyze misalignment effects on the PSEs in China, a country where agricultural support or disprotection levels are important but exchange rate effects have received little attention. We find a unique long-run cointegrating relationship between the exchange rate and basic economic fundamentals over the period 1952-2005, as suggested by the real exchange rate equilibrium theory and the cointegration approach. The empirical model suggests that the Chinese yuan has been significantly misaligned in recent years and the misalignment is persistent. We also find that future appreciation is likely and there exists a relatively high coefficient of pass-through from exchange rate movements to domestic agricultural prices.

Applying these results to recently completed PSE estimates by OECD (2005) for 1993-2003, we find that exchange rate misalignment had a substantial effect on China’s agriculture as measured by the PSEs. For the recent years 2000-2003, the indirect exchange rate effect of 11.5

percent has been greater than the direct sectoral effects (5.9 percent), indicating the dominance of economy-wide policies over sectoral-specific policies in China, and contributing to total support of 17.4 percent. Predicted exchange rate appreciation in the coming years would remove the indirect effect of misalignment but lead to deteriorating price incentives to Chinese farmers. This would exacerbate the labor adjustment transitions and rural poverty challenges China faces. The indirect effects may be long-lasting and in some periods change drastically as there is evidence that the process of adjustment towards exchange rate equilibrium is slow and uneven.

The rest of the paper is organized as follows. Section 2 empirically estimates exchange rate equilibrium and misalignment in China. It also provides a dynamic prediction of exchange rate movements and analyzes the “persistence profile” of the cointegrating relationship. Section 3 discusses the effect of exchange rate misalignment on PSEs, evaluates exchange rate pass-through, and provides estimates of the exchange rate effects on the PSEs. Summary and conclusions are provided in section 4.

2. Exchange Rate Equilibrium and Misalignment in China

2.1 A Brief Review of Literature

To address the effects of exchange rate misalignments on agricultural support levels measured by the PSE, the first step is to establish the exchange rate equilibrium. This task is fundamentally difficult because the equilibrium value of the exchange rate is not observable. Assessment is further complicated because there exist a variety of models of equilibrium exchange rate determination. Common approaches range from the simple Purchasing Power Parity (PPP) to more sophisticated models such as the Fundamental Equilibrium Exchange Rate (FEER) (Williamson, 1994), the Natural Real Exchange Rate (NATREX) (Stein, 1994), the

Behavioral Equilibrium Exchange Rate (BEER) (Clark and MacDonald, 1999) and the Real Equilibrium Exchange Rate (REER) (Edwards, 1989; Hinkle and Montiel, 1999).

The equilibrium exchange rate for the Chinese yuan has been modeled using different approaches. Chou and Shih (1998) estimate the equilibrium exchange rate of the yuan between 1978 and 1994 using both a PPP approach and an approach based on the shadow price of foreign exchange (SPFE). Their findings indicate that the real exchange rate of the yuan is mean reverting and the long-run PPP relationship holds. Zhang (2001) estimates the REER of the yuan between 1952 and 1997 using a set of fundamental determinants of the actual real exchange rate. He finds that the yuan exchange rate was chronically overvalued during most of the central planning period. However, the cumulative effect of exchange reform has led to a substantial real depreciation of the currency which essentially brought the real exchange rate close to its equilibrium during the reform period since 1981. Furthermore, Zhang shows that currency undervaluation frequently occurred from 1978 to 1997 indicating China had a proactive exchange rate policy with the nominal exchange rate used as a policy tool to attain real targets.

More recently, a series of empirical studies have emerged that specifically aim at gauging the degree of misalignment of the Chinese yuan and in particular its value against the U.S. dollar. Due to methodological and empirical differences, these studies offer a wide range of estimates of the currency’s misalignment, but in general they support the claim that the Chinese yuan has been undervalued in recent years. Frankel (2004), using a modified PPP approach, concludes that the yuan was undervalued against the U.S. dollar by approximately 35 percent as early as in 2000 and was undervalued by at least that much in 2004. Using a similar approach, Chang and Shao (2004) finds that the yuan was undervalued by 23 percent in 2003. Coudert and Couharde (2005) compare the yuan vis-à-vis dollar equilibrium rate and misalignment from the BEER and FEER approaches. They find that results from the two approaches differ substantially. While the BEER gives an estimate of misalignment of about 18 percent in 2002 and 2003, the misalignment is as high as 40 percent for the same years by the FEER approach. In the study by Benassy-Quere, et al. (2004), the yuan misalignment is found to be over 40 percent in 2003 by a panel analysis for the G20 countries including China. The results from a FEER approach by Wren-Lewis (2004) indicate less undervaluation of 23-28 percent in 2002. Even smaller misalignment is found in Funke and Rahn (2005) who use a BEER approach to show that the yuan rate was undervalued by 10-15 percent in the years 2001 and 2002.

The recent undervaluation of the yuan has stimulated a heated international debate and criticism on China's exchange rate policies. In response, the government has since 2005 taken only various small steps to reform its exchange rate system. These have included small currency revaluations against the U.S. dollar and switching from the dollar peg to a currency basket. The progress towards improving China's exchange rate policies and resolving global imbalances has been considered as inadequate and prominent analysts argue that there remains potential for much more substantial adjustments (Goldstein, 2007).

2.2 Model Description

Following Zhang (2001) (and Edwards, 1989), this paper adopts the REER approach where the real exchange rate for China is determined by a set of economic fundamentals. The fundamentals identified include four categories: (1) Domestic supply-side factors and particularly the Balassa-Samuelson effect arising from faster productivity growth in the tradable relative to the non-tradable good sector; (2) Fiscal policy, such as fiscal deficits as well as changes in the composition of government spending between tradable and non-tradable goods; (3) International economic environment, including world interest rate and terms of trade; and (4)

Commercial policy such as trade liberalization in terms of a reduction in import tariffs and export subsidies. Time series cointegration method is used to test for a stationary long-run relationship between the exchange rate and the economic fundamentals.

A system of variables $\mathbf{x}$ consisting of the real exchange rate and the underlying fundamentals is formulated as $\mathbf{x} = [LRER, LPRO, LGEX, WIR, LTOT, LOPN]$ with each variable defined as follows. All variables are in logarithmic forms (denoted by "*L*" in front of each variable), except for the world interest rate (*WIR*); and when index numbers are used the base year is 2000. Annual data for the period 1952-2005 are drawn from the International Financial Statistics of the IMF and supplemented by various issues of the Chinese Statistical Yearbook published by the China National Bureau of Statistics.

The real exchange rate (*LRER*) is defined as the product of nominal exchange rate and the ratio of the consumer price indices: $LRER = \ln\left(e \cdot CPI^{US} / CPI^{CN}\right)$, where e is the nominal exchange rate and CPI^{US} and CPI^{CN} are U.S. and China's consumer price indices, respectively.[1] While some other studies have used the multilateral real effective exchange rate, the real exchange rate defined here is a bilateral rate expressed in domestic currencies per U.S. dollar (an increase represents depreciation). The bilateral rate can be readily applied to the later PSE calculations as the world commodity prices are generally denominated in U.S. dollars.

The Balassa-Samuelson effect caused by differential productivity growth in the traded versus non-traded good sectors is approximated by the productivity change variable (*LPRO*). To be consistent with the Balassa-Samuelson theory, an increase in the productivity in the tradable sector relative to the non-tradable sector would appreciate the exchange rate, because it creates

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[1] As a dual track exchange rate system existed from 1981 to 1993, the nominal exchange rate used for computing real exchange rate is a weighted average between the official rate and the secondary rate following Zhang (2001). From 1981 to 1985, the secondary rate is the Internal Rate for Trade Settlements. Its weight is 0.8, which is also the rate of trade in total exchange income. From 1986 to 1993, the secondary rate is the swap rate with a weight of 0.44, the exchange retention ratio.

excess demand in the non-tradable sector. This variable is proxied by the ratio of the productivity differential between labor productivity in the production of industrial goods (*PIG*) and labor productivity in the production of service goods (*PSG*): $LPRO = \ln\left(PIG/PSG\right)$. The labor productivity variables were constructed from the sectoral GDP figures measured in constant prices divided by the labor employed in that sector. The rationale for using industrial and service sectors to represent tradable and nontradable sectors and labor productivity instead of total factor productivity is merely determined by the data availability.

The government expenditure (*GEX*) as a percentage to the GDP is used to capture the effect of fiscal policies: $LGEX = \ln\left(GEX/GDP\right)$. Changes in the composition of government consumption affect the exchange rate in different ways, depending on whether the consumption is directed toward traded or non-traded goods. If an increase in government consumption is concentrated in non-traded goods, excess demand in this sector will lead to higher non-traded good price and thus real exchange rate appreciation. Depreciation will occur if expanded government consumption is concentrated in traded goods.

Two variables are defined to capture changes in the international economic environment. First the real world interest rate (*WIR*) is used, which is approximated by the U.S. real interest rate calculated by subtracting the U.S. inflation rate (measured by the CPI^{US}) from the 1-year Treasury-Bill rate (*TBR*): $WIR = TBR - (CPI^{US} - CPI^{US}_{-1})/CPI^{US}_{-1}$. It is widely accepted that world interest rate fluctuations drive real exchange rate movements in developing countries and a stylized effect associated with a reduction in the world interest rate is real exchange rate appreciation (Fernandez-Arias and Montiel, 1996).

A second international economic variable is the terms of trade (*LTOT*) which is ideally defined as the ratio of export prices to import prices. Due to lack of these price data for China the variable is proxied by the growth of export value (*EXV*): $LTOT = \ln\left(EXV / EXV_{-1}\right)$ following Zhang (2001). Previous studies (e.g., Goldfajn and Valdes, 1999) have shown that the effect of terms of trade on the exchange rate is ambiguous. An improvement in the terms of trade, for instance, through a decrease in the price of importables, increases national income which in turn increases demand for non-traded good leading to real exchange rate appreciation (an income effect). Simultaneously, the movement of production away from importables toward non-tradables can depress the price of non-tradables causing real exchange rate depreciation (a substitution effect). Therefore the net effect of terms of trade on the real exchange rate depends on the relative magnitude of the income and substitution effects.

Finally, openness of the economy (*LOPN*) is calculated as the ratio of the sum of import value (*IMV*) plus export value (*EXV*) to the GDP: $LOPN = \ln\left((IMV + EXV)/GDP\right)$. Openness reflects how connected the economy is to the rest of the world and reflects the degree of trade liberalization. Its use as a proxy for trade policy is justified because of the difficulty of obtaining good time series data on import tariffs and export subsidies and also because it may account not only for explicit trade policy but also for implicit, though very important, factors such as quotas and exchange controls. Previous studies have shown that the improvement of a country's openness (decrease in tariff and subsidy) generates a depreciation of real exchange rate due to crowding-in and subsequent reduction in non-tradable prices (Goldfajn and Valdes, 1999).

2.3 Long-run Exchange Rate Determination

The Johansen maximum likelihood method (Johansen, 1991) is used to determine the long-run equilibrium exchange rate in China after augmented Dickey-Fuller (ADF) tests on the univariate series indicates that all the variables in the system are I(1) in levels and I(0) in first differences.[2] The Johansen procedure is based on the following *p*th-order VECM:

(1) $\mathbf{\Delta x}_t = \mathbf{\Gamma}_1 \mathbf{\Delta x}_{t-1} + \mathbf{\Gamma}_2 \mathbf{\Delta x}_{t-2} + ... + \mathbf{\Gamma}_{p-1} \mathbf{\Delta x}_{t-p+1} + \mathbf{\Psi x}_{t-1} + \mathbf{\Pi D}_t + \boldsymbol{\varepsilon}_t$

where $\mathbf{x}_t$ is a $(n \times 1)$ vector of non-stationary I(1) variables, $\mathbf{\Delta}$ is the difference-operator, $\mathbf{\Gamma}_i$, $\mathbf{\Psi}$ and $\mathbf{\Pi}$ are $(n \times n)$, $(n \times n)$ and $(n \times k)$ coefficient matrices, $\mathbf{D}_t$ is a $(k \times 1)$ vector of deterministic terms and $\boldsymbol{\varepsilon}_t$ is a vector of error terms with a non-singular variance-covariance matrix $\mathbf{\Omega}$. Suppose that $rank(\mathbf{\Psi}) = h,\ 0 < h < n$ and there are *h* cointegrating relationships in $\mathbf{x}_t$. It implies that $\mathbf{\Psi}$ can be written in the form, $\mathbf{\Psi} = \boldsymbol{\alpha\beta}'$, for $\boldsymbol{\alpha}$ an $(n \times h)$ matrix and $\boldsymbol{\beta}'$ an $(h \times n)$ matrix.

The Johansen procedure provides two tests, the trace and the maximal eigenvalue tests, for the number of linearly independent cointegrating relationships among the series in $\mathbf{x}_t$:

(2) $\lambda_{trace}(h) = -T \sum_{i=h+1}^{n} \ln(1 - \hat{\lambda}_i)$ and $\lambda_{\max}(h, h+1) = -T \ln(1 - \hat{\lambda}_{h+1})$

where $\hat{\lambda}_i$ are the estimated eigenvalues of matrix $\mathbf{\Psi}$. Table 1 presents the Johansen cointegration tests under two cases: without and with an intercept in the cointegrating vector (Case I and Case II, respectively), while the vector *D* in (1) consists of a constant and three dummy variables.[3] The λ_{trace} and $\lambda_{\max}$ statistics reject the null hypothesis of zero cointegrating rank at the 0.05 significance level for each case. However, the null hypothesis that the cointegrating rank is at most 1 is accepted indicating that there is a unique cointegrating relationship among the variables ($h = 1$).

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[2] The ADF test results are not reported but are available upon request.

[3] The dummy variables are designed to capture the effects of historical events including the great famine and two major exchange rate policy interventions. The variables take the value of 1 in years 1958-61 (Dummy1), 1981 (Dummy2) and 1994 (Dummy3) respectively, and 0 otherwise.

To improve the stochastic properties of the estimation, a likelihood ratio (LR) test developed by Johansen and Juselius (1990): $-2\ln\left(\hat{L}_R/\hat{L}_U\right) = -2\ln(Q) = T\sum_{i=1}^{\hat{h}}\ln\left\{\frac{\left(1-\hat{\lambda}_i^*\right)}{\left(1-\hat{\lambda}_i\right)}\right\}$ (χ^2 distributed with *R* and *U* denoting restricted and unrestricted models) is used to test for restrictions imposed on $\boldsymbol{\beta}$ and $\boldsymbol{\alpha}$. It can be shown that the following joint restriction:

$\boldsymbol{\beta}' = \begin{bmatrix} * & 0 & * & * & * & * \end{bmatrix}$ and $\boldsymbol{\alpha}' = \begin{bmatrix} * & 0 & 0 & 0 & 0 & * \end{bmatrix}$

cannot be rejected at 0.05 significance level with $\chi^2(5) = 6.47$ (p-value $= 0.26$). In light of this joint test, we conclude that *LPRO* can be excluded from the long-run relationship and *LPRO, LGEX*, *WIR* and *LTOT* are weakly exogenous to the system. Table 2 shows the restricted estimation results of the VECM. The cointegrating vector normalized on *LRER* can be alternatively presented as (standard errors in parentheses):

$$\begin{array}{l} LRER = -0.179 - 0.000LPRO - 1.855LGEX + 11.735WIR - 1.913LTOT + 0.769LOPN \\ \qquad\qquad\qquad\qquad (0.000) \qquad\quad (0.756) \qquad\quad (3.237) \qquad (0.593) \qquad\quad (0.112) \end{array} \quad (3)$$

In general, the parameter estimates are consistent with expectations discussed earlier. The exclusion of *LPRO* in China's equilibrium exchange rate relationship indicates a lack of the Balassa-Samuelson effect in China. This is possibly due to the fact that China's domestic prices have been highly administered in the social economy setting, and the usual link between productivity and relative prices may be distorted leading to the break-down of the Balassa-Samuelson effect in this country. Similar results are reported in Coudert and Couharde (2005). An increase in the government expenditure (*LGEX*) causes the yuan to appreciate as the government expenditures of China might have a higher content of non-traded goods than traded goods, which is consistent with Zhang (2001). The positive sign associated with *WIR* indicates that a reduction in the world interest rate appreciates the long-run real exchange rates.

The negative sign on $LTOT$ suggests the possible dominance of the income effect over the substitution effect so that improvements in the terms of trade appreciate the Chinese currency. The volume of trade, or degree of openness, as measured by the variable $LOPN$ has a positive sign, which confirms the findings in the literature that economic closedness is typically associated with overvaluation, and external liberalization aimed at reducing tariffs and eliminating trade restrictions causes currency depreciations.

2.4 Exchange Rate Equilibrium and Misalignment

To calculate the equilibrium exchange rate based on the restricted cointegration results in (3), we filter the values of the economic fundamentals by the Hodrick-Prescott (H-P) decomposing technique (Hodrick and Prescott, 1997), as the economic fundamentals themselves may be out of long-run steady-state values. The H-P method decomposes these time series into a trend μ_t and stationary component $x_t - \mu_t$ by minimizing:

$\sum_{t=1}^{T}(x_t - \mu_t)^2 + \lambda\sum_{t=2}^{T-1}[(\mu_{t+1} - \mu_t) - (\mu_t - \mu_{t-1})]^2$, where λ is an arbitrary constant reflecting the penalty of incorporating fluctuations into the trend.[4]

Figures 1 compares the actual with the equilibrium exchange rate of the Chinese yuan for 1980-2005 and the difference between the two indicates the exchange rate misalignment. The actual real exchange rate movements in China exhibited large swings during the post economic reform era. Following a series of nominal devaluations, the real exchange rate depreciated between 1980-1987 and 1990-1994. The real depreciation continued even after the nominal exchange rate was fixed (1998-2005). Two bouts of real appreciations occurred in 1988-1989 and in 1995-1997.

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[4] Hodrick and Prescott (1997) suggested a λ to be 1600 for quarterly data. However, different numbers should be used depending on the data frequencies. This number is much larger when the data set is monthly but much smaller when the data set is annual. In this analysis, λ is chosen to be equal to 10 to match our annual data set.

In general, the actual real exchange rate has moved closer to its equilibrium in the 1990s relative to the 1980s, indicating effectiveness of real targeting in China. Strong external sector performances that continued from the 1990s to the 2000s, reflected by large current account and capital account surpluses and the resulting reserve accumulations, together with a *de facto* fix exchange rate regime, have contributed to substantial currency undervaluation towards the end of the sample period. Overvaluation occurred briefly in 1996-1998, a period when some South-East Asian countries (not including China) were hit by a financial crisis.[5]

In our analysis the predicted degree of undervaluation in recent years (2000-2005) averages about 18 percent. This number is lower than predictions made by Benassy-Quere et al. (2004) and Wren-Lewis (2004), but is within the thresholds reported in Frankel (2004), Chang and Shao (2004), Funke and Rahn (2005) and Coudert and Couharde (2005).

2.5 Exchange Rate Forecasts

The VECM specified in equation (1) can be used for forecasting. There is some evidence that a VECM can outperform a random walk model but due to the lack of built-in economic structure in specification, the model's accuracy in long-term forecasts is questionable. Christofferson and Diebold (1997), Hoffman and Rasche (1996), Lin and Tsay (1996), Clements and Hendry (1995) examined the marginal improvement in the forecasting precision that was due to the introduction of error-correction terms in a VECM and concluded that the forecasting ability of a VECM cannot enjoy general acceptance but is rather dependent on the size of the sample, the time horizon of the forecast, the number of variables included in the system and finally the number of lags. However, Anderson, Hoffman and Rasche (2002) notes that the

[5] China was not totally immune from the crisis. For example, capital flows to China suffered greatly from excessive volatility and sudden withdrawals in that period. Net capital inflows dropped from its peak of $40.0 billion in 1996 to merely $2.0 billion in 2000. In 1998 China had a net capital outflow of $6.3 billion.

predictive power of a VECM can be enhanced in cases where theoretical restrictions of cointegrations are imposed in the estimation.

We perform within-sample and out-of-sample forecasts of the values of the China's real exchange rate based on our estimated VECM:

(4) $$\mathbf{x}_t = \mathbf{x}_{t-1} + \hat{\mathbf{\Gamma}}_1 \mathbf{\Delta x}_{t-1} + \hat{\mathbf{\Gamma}}_2 \mathbf{\Delta x}_{t-2} + ... + \hat{\mathbf{\Gamma}}_{p-1} \mathbf{\Delta x}_{t-p+1} + \hat{\mathbf{\Psi}} \mathbf{x}_{t-1} + \hat{\mathbf{\Pi}} \mathbf{D}_t + \boldsymbol{\varepsilon}_t$$

where parameters with ^ denote estimates. A static solution is used to produce a set of one-step ahead, within-sample forecasts over the historical data period (1952-2005) to examine the fitness of the model. It can be argued that the closer the forecasts are to the actual values the better will be the forecasting power of the VECM. In the static solution, actual values of the endogenous variables up to the previous period are used each time the model is solved. Figure 2 provides the static solution of the system that shows one-period ahead forecasts. The interval of errors (± 2 standard deviations) for the mean value that results from the forecast is very narrow and the forecasted and actual values track each other fairly closely for the whole period of the sample. Consequently, we consider the one-year ahead forecasting efficiency of the VECM as satisfactory.

To produce the set of out-of-sample forecasts (i.e., a multi-step forecast into the future), a dynamic solution is used. In this type of solution, lagged endogenous variables in the model are obtained from calculations in previous periods, not from actual historical data. Thus, an accumulating effect of forecasting errors would be expected. Figure 3 shows the results of the dynamic solution for the forecasting of exchange rate 5 years ahead. Based on this forecast, we conjecture that the exchange rate would appreciate in the coming years. The predicted mean indicates that large appreciations would take place between 2006 and 2008, and at the end of the five-year forecast period, the accumulated appreciation would be approximately 15 percent.

If our prediction is correct, the real value of the yuan in the next two years would be brought back to its early-1990s' levels. It is also interesting to note that if exchange rate misalignment had remained at the 2005 level (14 percent), appreciation of this magnitude would realign the currency to its equilibrium. As expected, when we move away from the starting point of the forecast, the spread of variance around the mean value increases. The significantly wider spreads in later periods imply the quick decay of accuracy of the VECM to produce forecasts of longer horizons, a result consistent with the existing literature. Therefore, our forecasting results should be interpreted with caution.

2.6 Persistence Profiles

While our forecasts could possibly capture changes in the exchange rate rather well in the short-run, a different question is how the identified cointegrating relationship would behave in the long-run, if the system is shocked. A commonly used method within the cointegration context is the impulse response function (Lutkepohl and Reimers, 1992). However, as in the general impulse-response methodology, the problem of identification is still unsolved and certain types of orthogonalization of the shocks (e.g., Chelosky decomposition) need to be imposed *a priori*. An alternative method to analyze the convergence of cointegration was developed by Pesaran and Shin (1996). This methodology, which is also called the "persistence profiles" approach, can provide a unique, orthogonalization-free estimate of the effects of shocks on cointegrating relations within the context of a VECM. We adopt this approach in this analysis.

To develop the persistence profiles of our exchange rate system, we first rewrite the VECM in equation (1) into an equivalent VAR form:

$$(5)\quad \mathbf{x}_t = \mathbf{\Phi}_1 \mathbf{x}_{t-1} + \mathbf{\Phi}_2 \mathbf{x}_{t-2} + ... + \mathbf{\Phi}_p \mathbf{x}_{t-p} + \boldsymbol{\alpha} + \boldsymbol{\varepsilon}_t$$

where $\mathbf{\Phi}_i$, $i = 1, 2, ..., p$, are $n \times n$ coefficient matrices. The parameters between the VECM and the VAR are linked by $\mathbf{\Gamma}_i \equiv -[\mathbf{I}_n - \mathbf{\Phi}_1 - \mathbf{\Phi}_2 - ... - \mathbf{\Phi}_i]$, for $i = 1, 2, ..., p-1$, and $\mathbf{\Pi} \equiv \mathbf{\Phi}_1 + \mathbf{\Phi}_2 + ... + \mathbf{\Phi}_p - \mathbf{I}_n$. Thus the equalities determining $\mathbf{\Gamma}_i$ and $\mathbf{\Pi}$ can be solved for $\mathbf{\Phi}_i$ using the following recursions:

(6) $\mathbf{\Phi}_1 = \mathbf{\Gamma}_1 + \mathbf{I}_n$, $\mathbf{\Phi}_i = \mathbf{\Gamma}_i - \mathbf{\Gamma}_{i-1}$ for $i = 2, ..., p-1,$ and $\mathbf{\Phi}_p = -\mathbf{\Pi} - \mathbf{\Gamma}_{p-1}$.

If $\mathbf{x}_t$ is a first difference stationary, then the VAR has the following Wold representation:

(7) $\Delta\mathbf{x}_t = \mathbf{A}(L)\boldsymbol{\varepsilon}_t$

where $\mathbf{A}(L) = \sum_{i-0}^{\infty} \mathbf{A}_i L^i$ and L is a lag operator. Define $\mathbf{B}_i = \sum_{j=0}^{i} \mathbf{A}_j$, $i, j = 0, 1, ...$, which can be written as

(8) $\mathbf{B}_i = \mathbf{\Phi}_1 \mathbf{B}_{i-1} + \mathbf{\Phi}_2 \mathbf{B}_{i-2} + ... + \mathbf{\Phi}_p \mathbf{B}_{i-p}$, $i = 0, 1, ...$

where $\mathbf{B}_0 = \mathbf{I}_n$ and $\mathbf{B}_q = 0$ for $q < 0$.[6]

The impact of system-wide shocks on the cointegrating relations is defined as the difference between the conditional variances of the n-step and $(n-1)$-step ahead forecasts. In particular the following variance-based measure is proposed by Pesaran and Shin (1996):

(9) $\mathbf{H}_z(n) \equiv V(\mathbf{Z}_{t+n} | I_{t-1}) - V(\mathbf{Z}_{t+n-1} | I_{t-1}) \quad \text{for } n = 0,\ 1,\ ...$

where $\mathbf{Z}_t = \boldsymbol{\beta}'\mathbf{x}_t$ is the long-run equilibrium error from the cointegrating equilibrium relationship and $V(\mathbf{Z}_{t+n} | I_{t-1})$ is the conditional variance of $\mathbf{Z}_{t+n}$ given I_{t-1}. The formula for this measure can be rewritten as:

(10) $\mathbf{H}_z(n) = \boldsymbol{\beta}'\mathbf{B}_n \mathbf{\Omega} \mathbf{B}'_n \boldsymbol{\beta} \quad \text{for } n = 0,\ 1,\ ...$

where $\mathbf{B}_n$ is defined in equation (8).

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[6] The relationship between **B**s and $\mathbf{\Phi}$s is given by Pesaran and Shin (1996).

$\mathbf{H}_z(n)$ $(n = 0,\ 1,\ ...)$ are known as the "persistence profiles" which characterize the time profile of the effects of the system wide shocks on the cointegrating relationships. If the number of cointegrating vectors *h* is equal to one, the persistence measure becomes a scalar and a scaled version of $\mathbf{H}_z(n)$, denoted as $h_z(n)$, can be written as:

$$(11)\ \ h_z(n) = \frac{\boldsymbol{\beta}'\mathbf{B}_n\boldsymbol{\Omega}\mathbf{B}_n'\boldsymbol{\beta}}{\boldsymbol{\beta}'\boldsymbol{\Omega}\boldsymbol{\beta}} \qquad \text{for } n = 0,\ 1,\ ...$$

where $h_z(n) = 0$ for $n = 0$ and $h_z(n) \to 0$ as $n \to \infty$. This profile provides important information on the speed with which the impact of system wide shocks on the cointegrating relation disappear. By focusing on this measure the dynamic properties of the cointegrating relation can be investigated.

We calculate the persistence profiles for our exchange rate system by carrying out the following steps:

(i) Estimate $\boldsymbol{\Pi}$ $(\boldsymbol{\alpha},\boldsymbol{\beta})$, $\boldsymbol{\Gamma}$, and $\boldsymbol{\Omega}$ using the VECM specified in equation (1);

(ii) Calculate $\boldsymbol{\Phi}_i$, $i = 1,...,p,$ using results from step (1) and recursive equations in (6);

(iii) Compute $\mathbf{B}_i$, $i = 0,1,...$ using equation (8);

(iv) Calculate persistence measure by using equation (11).

The persistence profiles point estimates for the cointegrating relation are reported in Figure 4. The estimates suggest that convergence is achieved very slowly and the main adjustment towards the equilibrium takes around ten years. After the tenth year the marginal change in adjustments is not very significant. It can also be observed that adjustments in the first two years are actually *diverging* rather than *converging*. This initial perverse relationship between exchange rate and the fundamentals is similar to the *J*-curve effects of exchange rate on the balance of payment and is possibly due to sluggishness in real adjustments. Convergence starts in the third year and adjustment after the fourth year is about 30 percent, after the fifth year 70 percent. Nearly 90 percent of adjustment is completed by the sixth year. At the end of year 20, the equilibrium error of the cointegrating relationship reaches a level of 0.00001, which is assumed to be the truncation point in this study. This finding corroborates our results in Section 2.3 that there is a cointegrating relationship among the system of variables, since the cointegration theory proposes that the equilibrium long-run error is expected to be zero.

3. Effects of Exchange Rate Alignment on PSEs

3.1 The PSE

According to the OECD, the PSE is "an indicator of the annual monetary value of gross transfer from consumers and taxpayers to agricultural producers" (Portugal, 2002). In nominal terms the PSE can be expressed as the sum of Market Price Support (*MPS*) and Budgetary Payments (*BP*). The calculation of *MPS* is shown in equation (12):

$$(12)\quad MPS = \sum MPS_j = \sum \left(P_j^d - P_j^{ar}\right) Q_j$$

where *j* denotes commodity, P_j^d is the domestic price, P_j^{ar} is the adjusted reference price, and Q_j is the quantity. The adjusted reference price P_j^{ar} is the world market price (either a relevant import c.i.f. price or export f.o.b. price depending on whether the commodity is an importable or an exportable) expressed in domestic currency and adjusted by various transaction costs. The cost adjustment process differs by the commodity's trade status (See Orden et al., 2007, for details), but in either case, the adjusted reference price can be expressed as:

$$(13)\quad P_j^{ar} = P_j^w \times E + ADJ_j$$

where P_j^w is the world market price, *E* is the nominal exchange rate, and ADJ_j is the domestic cost adjustment factor.

The PSE measure can be expressed on a percentage basis (denoted by %*PSE*) using *(VOP + BP)* as the denominator, where *VOP* is the total value of agricultural production at domestic producer prices: $\%PSE = \frac{MPS + BP}{VOP + BP}$. Following the terminology of Krueger, et al. (1991), we define three types of effects using the percent PSE. The "direct effect" induced by sector-specific policies is defined as the %*PSE* calculated using the actual nominal exchange rate *E*:

(14a) $$\text{Direct Effect} = \%PSE(E) = \frac{MPS(E) + BP}{VOP + BP} = \frac{\sum\left(P_j^d - P_j^{ar}(E)\right)Q_j + BP}{VOP + BP}$$

The "total effect" induced by both sectoral and exchange rate policies is defined as the %*PSE* calculated using the equilibrium exchange rate *E**, under the *ceteris paribus* assumption holding domestic and budgetary payments constant:

(14b) $$\text{Total Effect} = \%PSE(E^*) = \frac{MPS(E^*) + BP}{VOP + BP} = \frac{\sum\left(P_j^d - P_j^{ar}(E^*)\right)Q_j + BP}{VOP + BP}$$

The difference between the total and direct effect captures the "indirect effect" of misalignment of the exchange rate:

(14c) $$\text{Indirect Effect} = \%PSE(E^*) - \%PSE(E) = \frac{\sum\left(P_j^{ar}(E) - P_j^{ar}(E^*)\right)Q_j}{VOP + BP}$$

Ignoring domestic cost adjustment (ADJ_j), it can be shown that the indirect effect is $m \cdot \frac{\sum P_j^w E^* Q_j}{VOP + BP}$, where *m* is the percentage exchange rate misalignment, $m = \left(E - E^*\right)/E^*$.[7] The

[7] Ignoring the domestic cost adjustment (ADJ_j) simplifies the expressions for the indirect effect. However, in the later PSE calculations, the ADJ_j is taken into account.

indirect effect is negative if overvaluation occurs ($m < 0$), positive if undervaluation occurs ($m > 0$), and zero if no misalignment exists ($m = 0$).

3.2 Exchange Rate Pass-through

The effects of re-alignment of the exchange rate on PSEs depend on the degree of pass-through of appreciation or depreciation movements to domestic agricultural prices. The empirical literature on exchange rate pass-though is extensive but has mostly focused on the manufacturing industries of developed economies. Among those studies that examine exchange rate pass-through to agricultural commodity prices, some have shown more complete and rapid pass-through to agricultural prices than manufacturing prices (e.g., Carter et al., 1990; Xu and Orden 2002), which is consistent with the view that agricultural commodities operate in competitive flexible-price markets. Other studies have shown incomplete pass-through for some agricultural commodities (e.g., Park and Pick, 1996). A number of reasons are offered for the incomplete pass-through of exchange rate. One explanation for this phenomenon is that importing and exporting firms choose to hold their prices constant and simply reduce or increase the mark-up on prices when the exchange rate is changing (“pricing-to-market”). Policy interventions affecting domestic prices, or domestic prices falling between import and export parity (so there is no trade) would also affect exchange rate pass-through.

To evaluate exchange rate pass-through to domestic agricultural prices in China, we estimate a fixed effects panel regression model in first-difference logarithmic form:

$$(15)\quad \Delta p_{it} = \alpha_i + \theta_t + \sum_{k=0}^{n} \left(\beta_k \Delta e_{t-k} + \gamma_k \Delta p^*_{it-k} \right) + \varepsilon_{it}$$

where Δ is difference-operator, p_i and p_i^* are domestic and world prices, respectively, e is the exchange rate, α_i and θ_t represent cross-commodity and time-specific effects, n represents the number of lagged terms, β_k and γ_k are coefficients measuring the contemporaneous or lagged pass-through of exchange rates and foreign prices to domestic prices, and ε_{it} is the idiosyncratic error term distributed with mean zero and variance σ_ε^2. This specification is a variant of the panel regression model proposed by Knetter (1993) to study pricing-to-market behaviour of exporting firms for a particular commodity.[8] If $\sum_{k=0}^{n}\beta$ or $\sum_{k=0}^{n}\gamma$ is not significantly different from one (zero) then there is complete (no) exchange rate or world price pass-through to commodity prices.

The estimation of (15) is based on a panel dataset that includes domestic and world prices of 15 commodities covered in a recent PSE study by OECD (2005) for the period of 1993-2003. The commodities include wheat, maize, rice, rapeseed, soybeans, peanuts, apple, sugar cane, cotton, milk, beef and veal, pigmeat, sheepmeat, poultry and eggs. Annual data series are used due to the fact that short-run exchange rate changes (monthly or quarterly) may not be fully passed through to prices as they can be treated as temporary. Another reason for using the annual data is that for China higher-frequency data are not available. The exchange rate data are obtained from the previous analysis.

Table 3 shows the results of the estimated exchange rate pass-through coefficient (β or $\sum\beta$). Model 1 is a simple pooled regression that does not consider either commodity or time effects. Model 2 considers the commodity effect that captures unobserved heterogeneity across commodities (e.g., consumer demands). In addition to commodity effect, model 3 takes into account the time effect that has common impacts in each time period across all commodities

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[8] A panel cointegration method is not used as the hypothesis of a panel unit root is rejected.

(e.g., national income). Two different lag structures are considered (*n* is either 0 or 1).[9] Student-*t* statistics are provided for the tests that the contemporaneous or aggregated pass-through coefficient is zero, implying no pass-through. Tests are also reported for the contemporaneous or aggregate pass-through coefficient summing to one, which is consistent with complete pass through.

The results in Table 3 show that the aggregate exchange rate pass-through to domestic agricultural prices is fairly high, but not complete, in China. Point estimates only differ slightly across the models. When there is no lag, the contemporaneous exchange rate pass-through coefficient ranges from 0.63 to 0.73. Adding one lag of the exchange rate (and world price) variable to the estimation only slightly changes the pass-through. For all model specifications, the pass-through coefficient is significant, indicating that no exchange rate pass-through is rejected. However, despite high pass-though coefficients, the null hypotheses that they are equal to one, i.e., complete exchange rate pass-through, are also rejected. We expect that individual commodities would also have high pass-through coefficients, although small sample sizes preclude estimation at more disaggregate levels. Nonetheless, visual observations on the co-movements of domestic and world prices for the 15 commodities indicate that the price transmission mechanism has worked quite well in China during this short sample period (Figure 5).

3.3 Counterfactual PSEs

A counterfactual measure of the PSE (denoted as $\%PSE^{CF}$, where *CF* denotes "counter-factual") can also be computed under the assumption that the exchange rate (*E*) moves to its equilibrium (*E**) in a given period. In place of the *ceteris paribus* assumption in (7b), the

[9] Results of aggregate pass-through for longer time lags are similar to 1 lag.

exchange rate changes can affect not only the reference prices but also the domestic prices and budgetary payments due to exchange rate pass-through. Domestic prices and budgetary payment change to $\frac{P_j^d}{1+\beta m}$ and $\frac{BP}{1+\beta m}$ when incomplete pass-through (IPT, $0 < \beta < 1$) occurs, where β and m are exchange rate pass-through and misalignment coefficients, respectively.[10] The domestic price and budgetary payment remain at P_j^d and BP with no pass-through (NPT, $\beta = 0$), but change to $\frac{P_j^d}{1+m}$ and $\frac{BP}{1+m}$ with complete pass-through (CPT, $\beta = 1$).

A comparison between the direct PSE (based on the actual exchange rate) and the counterfactual PSE (based on equilibrium exchange rate) for different exchange rate pass-through scenarios is summarized in Tables 4. The difference between the initial direct and new counterfactual measures is denoted as a "transfer" of the indirect effect to the counterfactual measure.

In the case of no exchange rate pass-through (NPT), the difference between $\%PSE^{CF}$ and the initial direct $\%PSE$ is equal to the indirect exchange rate effect shown earlier. This represents a full transfer of the exchange rate effect into the new measure of the PSE, with no change in actual incentives conveyed to producers through the domestic output prices or budgetary payments. The magnitude of the indirect effect, and thus the transfer, is determined by the initial exchange rate misalignment (m).

In contrast, when there is complete exchange rate pass-through (CPT) the transfer of the initial indirect effect into the counter-factual PSE measure is zero no matter how much the exchange rate is misaligned. Removing the exchange rate misalignment in this case affects the

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[10] This analysis assumes a common coefficient of exchange rate pass-through to commodity prices and to budgetary payments. See Cheng and Orden (2007) for relaxation of this assumption in an analysis focused on India.

price incentives producers face (as well as the budgetary payments they receive) but leaves the protection coefficient measured by the initial direct $\%PSE$ unchanged. In the case of incomplete exchange rate pass-through (IPT), the degree of transfer of the initial indirect effect into the counter-factual PSE is determined by a combination of the initial exchange rate misalignment (m) and the degree of pass-through (β).

3.4 Direct, Indirect and Total Effects and Counterfactual PSE

To evaluate the direct, total and indirect effects measured by the PSEs for China we again draw upon the recent analysis of OECD (2005) and our analysis of exchange rate equilibrium and misalignment. The actual nominal exchange rates are the annual average official rates and the nominal equilibrium exchange rates are derived from the corresponding real equilibrium rates from Section 2.[11] The PSE calculations are based on the 15 covered commodities mentioned earlier. Table 5 shows the direct, indirect and total effects measured by the PSE for the period 1993-2003. The sample period is divided into three distinct subperiods. Period one (I) covers 1993-1995 when the exchange rate was under active adjustments.[12] This period had an average undervaluation of 8.6 percent. Period two (II) from 1996-1999 spans across the Asian financial crisis year (1997) with an overvaluation of -5.4 percent. Period three (III) represents a sustained undervaluation period from 2000 to 2003 when the currency was approximately 18.0 percent undervalued.

The direct effects shown in Table 5 are equivalent to the conventional measures of the PSE as reported in OECD (2005). In general, the agricultural support in China measured by the direct effect shows a rising trend. Specifically, the direct effect was negative during the first

[11] Specifically, the nominal equilibrium exchange rate is obtained by multiplying the real equilibrium exchange rate by the ratio of China's CPI to U.S. CPI.
[12] A drastic 50 percent depreciation occurred in the beginning of 1994 followed by a series of small appreciations during this period.

period (I) but turned to near neutrality in period II. In the most recent period (III), the direct effect indicates a positive support of about 6 percent. Annual values of the direct effect, which increased from -14 percent in 1993 to 8 percent in 2003, are shown in Figure 6. These results indicate that China has transitioned out of past communist disprotection of agriculture into providing net support to the sector.

The indirect effect caused by exchange rate misalignments has had quite different impacts on China's agriculture in comparison to the direct effect (Table 5 and Figure 6). On average China's agricultural sector has been indirectly penalized by exchange rate overvaluation in periods II, but subsidized by exchange rate undervaluation in period I and III. The indirect effect counteracted the direct effect in periods I and II, but reinforced it in period III. Noticeably, the indirect effect of the exchange rate is larger in absolute value than the direct effect in all three period, indicating the dominance of economy-wide policies reflected in the exchange rate over sectoral-specific policies. This result is consistent with the study by Krueger, et al. (1991) in which they found that the economy-wide policies such as the exchange rate played a dominant role across a range of developing countries (not including China) in an earlier period to the mid-1980s. More recently due to significant exchange rate undervaluation, such an indirect effect on Chinese agriculture has become much greater in magnitude than in early periods. Together with the direct effect, the indirect exchange rate effect leads to estimated support for agriculture of 17.4 percent in China.

Estimates of counterfactual PSEs are also shown in Table 5 (and Figure 6) under the assumption of incomplete exchange rate pass-through (IPT) with a contemporaneous pass-through coefficient of 0.73 obtained from Table 4 (Model 3 with no time lag). The cases of no pass-through (NPT) and complete pass-through (CPT) are not reported explicitly, but they can be inferred directly from the reported total and direct effects.

Since the contemporaneous pass-through of exchange rate movements is relatively high in China only a small portion of the exchange rate indirect effect remains in the counterfactual PSE under the assumption of incomplete exchange rate pass-through to domestic prices and budgetary payments. For instance, despite a large indirect effect in period III, only 3.1 percent out of 11.5 percent transfers to the counterfactual PSE with 8.4 percent disappearing as a result of the exchange rate pass-through. Counterfactually, had this period of misalignment been corrected, China's agricultural support would have shown a protection rate of 9.0 percent.

3.5 Further Discussion

Our modeling results show that disequilibrium in the exchange rate system can takes a long time to die out, which means that the exchange rate effects on China's agriculture would be long-lasting. Slow movement towards equilibrium appears to provide a period of time for the sector to adjust; but since the process of convergence is rather uneven and the speed may accelerate in certain period of time, adjustment pressure for agriculture can quickly rise. Referring to our PSE results, this means the indirect effects may be persistent but may also be subject to sharp changes in some periods.

The effects of possible future appreciation on agriculture merits discussion. As is shown by the counterfactual PSEs, appreciation would partly remove positive indirect effects and lead to a lower level of agricultural support. The PSEs would indicate a higher protection rate, but Chinese farmers would nonetheless face deteriorating production incentives given that the exchange rate pass-through coefficient is high.

Appreciations may have a broad impact on China's agriculture. For agricultural tradables, appreciation will cause the prices of exported commodities in terms of foreign currency to increase, which reduces the quantity demanded in the international market. Agricultural imports will also be cheaper in domestic currency terms. Price competition between domestic products and imports will lead to lower farm-gate and consumer prices in the domestic market. At the lower prices, the quantity demanded domestically will increase while the quantity supplied will decline. Mobile resources such as labor will face pressure to exit the agricultural sector, exacerbating a substantial labor adjustment transition China is undergoing, as it's economy has grown rapidly**.**

If labor is perfectly mobile, there need not be an income problem in agriculture as a result of exchange rate revaluation. Rather, rural labor would flow out of the industry until equilibrium is reestablished at a new relative price, and the agricultural sector would be smaller than it otherwise would have been. But labor in China is not perfectly mobile, not even nearly perfectly mobile. Rigid household registration system has for many years confined labor migration and, with a continuous large pool of surplus labor, has perpetuated low returns. The adoption of new production technologies, many of which are imbedded in physical capital, has made the situation even worse. It increases the return to capital and thereby induces more of this resource into the industry relative to labor. Therefore, the agricultural labor force has to bear the burden of the whole adjustment process.

Domestic fiscal and monetary policies used to combat inflation have complicated the problem in a substantial way. In China, the response to an over-heated economy has always been an overriding concern with domestic inflation (Gu and Zhang, 2006). Monetary and fiscal policies have been kept relatively tight for a long period of time (though relatively lax in recent years). This, along with the restructuring of the heavy industry sector, has led to a constantly rising level of urban unemployment rate reaching 14 percent in 2002 (Giles, Park and Zhang, 2005).[13] It can be argued that out-migration from agriculture is quite sensitive to the level of unemployment in the urban area. Persistently high levels of urban unemployment experienced since the 1990s therefore impedes the outflow of labor from agricultural sector. Considering the enormous amount of surplus labor that already exists in the rural area and the potential migration back to agriculture because of industrial sector downturn following exchange rate revaluation, the mixed effects could be a "triple squeeze" on agriculture, particularly on the rural labor force.

The interface between exchange rate and agriculture also illustrate some of the current challenges to global economic integration. The estimated undervaluation of the yuan continues to generate bilateral trade tensions as U.S. industries call for protection to offset the perceived currency misalignment. Level heads argue that further depreciation of the dollar, appreciation of the yuan, and related currency realignments will be required to restore more balanced global trade. Were that to occur, it would provide a basis for further agricultural policy reform in the United States and a possible agricultural agreement at the Doha Round, and it would expand trade presumably in a pro-poor direction. However, if the yuan revalues, it would also cause downward pressure on agricultural prices in China, lower returns to labor and higher unemployment rates, exacerbating the challenge of ongoing rural poverty reduction as the country transitions into an industrial economy. That is an ironic outcome of the yuan's strength arising from the success so far of that transformation process, and one that could result in more direct support to agriculture and the poor in China to help ease the transition burden.

[13] Official statistics count as unemployed only those individuals who register for unemployment benefits with local governments, and are not based on representative sample surveys. Not surprisingly, the official, or registered, unemployment rate of about 4 percent significantly understates the true unemployment rate.

4. Summary and Conclusions

The alignment of exchange rates can have significant impacts on the agricultural sector. In this analysis, a real equilibrium approach to determining exchange rates is applied and effects of exchange rate misalignment on PSEs are evaluated for China for the period 1993-2003. A long-run cointegrating relationship is found between the exchange rate and economic fundamentals. This model suggests that the Chinese yuan has been significantly undervalued in recent years. The exchange rate is predicted to appreciate in the future but there is substantial forecast variance and convergence to the equilibrium is estimated to take a long time. Direct, total and indirect effects in PSEs are compared and three scenarios of exchange rate pass-through are considered: no pass-through, complete pass-through, and incomplete pass-through. Counterfactual PSEs, assuming the exchange rate is in equilibrium in a given year, indicate that the indirect effect is fully transferred to the counterfactual measure when there is no exchange rate pass-through, but that part or all of the indirect effect disappears when exchange rate re-alignment is partially or fully passed through to domestic agricultural prices.

The main empirical findings from the PSE calculations indicate that the indirect exchange rate effects dominate the direct effect of sectoral policies in China. The indirect effect of exchange rate undervaluation subsidized the agricultural sector during the periods of 1993-1995 and 2000-2003. We estimate a fairly high pass-through coefficient for China based on a fixed effect panel regression model using disaggregate prices of 15 commodities covered in the recent PSE assessment by the OECD. Thus, Chinese farmers would have to face worsened production incentives if the exchange rate appreciates.

The magnitude of indirect effects and the potential impact of exchange rate revaluation on Chinese farmers have been greater in recent years when the exchange rate is significantly misaligned. Unlike its neighbor India where exchange rate misalignment has dampened down following economic reforms, China' exchange rate has become a much more pressing issue either with respect to domestic agricultural production incentives and to broader trade and macroeconomic policy. Yet even for India recent appreciation vis-à-vis the U.S. dollar has put downward pressure on export and import-competing industries such as textiles and apparel and parts of agriculture. As concerns about the yuan undervaluation remain pervasive and its revaluation deemed likely, China's agriculture could face substantial adjustment pressure.

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Table 1: Johansen Cointegration Test Results

Null Hypothesis	Case I λ_{trace} test	Case I λ_{trace} (0.95)	Case I $\lambda_{\max}$ test	Case I $\lambda_{\max}$ (0.95)	Case II λ_{trace} test	Case II λ_{trace} (0.95)	Case II $\lambda_{\max}$ test	Case II $\lambda_{\max}$ (0.95)
$h=0$	119.04*	103.85	98.35*	83.94	108.43*	95.75	101.84*	95.75
$h\leq 1$	72.23	76.97	57.12	60.06	62.84	69.82	64.82	69.82
$h\leq 2$	38.91	54.08	33.88	40.17	30.10	47.86	37.56	47.86
$h\leq 3$	24.65	35.19	15.56	24.28	16.33	29.80	18.61	29.80
$h\leq 4$	12.05	20.26	4.59	12.32	6.35	15.49	7.83	15.49
$h\leq 5$	2.85	9.16	1.45	4.13	0.42	3.84	1.08	3.84
D	Constant and Short-run Shocks				Constant and Short-run Shocks			
Lag Length	1				1			
Sample	1952-2005				1952-2005			

Note: * denotes rejection at 0.05 significance level. Case I: no intercept in the cointegrating equation or the VECM; Case II: intercept in the cointegrating equation and the VECM. *h* is the cointegrating rank. The lag-length of one is determined by a battery of diagnostic tests on an unrestricted vector autoregression model (VARM) including a x^2 test for the hypothesis that the *i*-period lag is zero for each equation separately; a joint *LM* test for the hypothesis that there is no heteroskedasticiy or serial correlation; and a joint x^2 test for the normality of the errors. Test results are not reported but are available upon request.

Table 2: Restricted VECM Estimation Results

Cointegration Restrictions: $\boldsymbol{\beta}' = \begin{bmatrix} * & 0 & * & * & * & * \end{bmatrix}$ and $\boldsymbol{\alpha}' = \begin{bmatrix} * & 0 & 0 & 0 & 0 & * \end{bmatrix}$

LR test for binding restrictions: Chi-square(5)=6.467; Probability=0.263

CointEq:

LRER(-1)	*LPRO(-1)*	*LGEX(-1)*	*WIR(-1)*	*LTOT(-1)*	*LOPN(-1)*	*C*
4.140	0.000	7.678	-48.584	7.920	-3.186	0.741

Error Correction	*D(LRER)*	*D(LPRO)*	*D(LGEX)*	*D(WIR)*	*D(LTOT)*	*D(LOPN)*
CointEq	-0.031*	0.000	0.000	0.000	0.000	0.042*
	(0.009)	(0.000)	(0.000)	(0.000)	(0.000)	(0.015)
D(LRER(-1))	0.087	0.276	-0.101	-0.068*	-0.166	0.141
	(0.149)	(0.277)	(0.131)	(0.028)	(0.276)	(0.245)
D(LPRO(-1))	0.059	0.274*	0.174*	0.001	-0.238*	0.115*
	(0.068)	(0.126)	(0.060)	(0.013)	(0.126)	(0.111)
D(LGEX(-1))	0.098	-0.512*	-0.153	-0.024	0.310	-0.343*
	(0.194)	(0.161)	(0.171)	(0.037)	(0.361)	(0.319)
D(WIR(-1))	-0.061	0.410	-0.431	0.054	-4.033*	0.538
	(0.913)	(1.694)	(0.801)	(0.172)	(0.694)	(1.500)
D(LTOT(-1))	0.102*	0.402*	0.115*	0.022*	0.058	0.120
	(0.097)	(0.181)	(0.085)	(0.018)	(0.181)	(0.160)
D(LOPN(-1))	0.043	-0.288*	0.054	0.000	-0.117	-0.043
	(0.107)	(0.098)	(0.094)	(0.020)	(0.198)	(0.176)
C	0.023*	0.044*	0.010	0.001	0.015	0.032*
	(0.011)	(0.021)	(0.010)	(0.002)	(0.021)	(0.009)
DUM1	-0.158*	-0.306*	-0.006	0.001	-0.141*	0.140*
	(0.056)	(0.104)	(0.049)	(0.011)	(0.104)	(0.092)
DUM2	0.146*	-0.097	-0.014	0.026*	-0.053	0.178*
	(0.072)	(0.133)	(0.063)	(0.014)	(0.133)	(0.018)
DUM3	0.269*	-0.052	-0.024	0.007	0.221*	0.231*
	(0.075)	(0.140)	(0.066)	(0.014)	(0.014)	(0.024)

Note: Standard errors are in parentheses. * denotes significance at 0.05 level.

Table 3: Pass-Through Coefficient by Fixed Effect Panel Estimation

	Model 1	Model 2	Model 3
No Lag ($n=0$)			
β	0.66	0.63	0.73
t-stat for $H_0:\beta=0$	(2.56)*	(2.83)*	(2.11)*
t-stat for $H_0:\beta=1$	(3.44)*	(3.67)*	(3.73)*
1 Lag ($n=1$)			
$\sum\beta$	0.68	0.69	0.77
t-stat for $H_0:\sum\beta=0$	(3.12)*	(2.53)*	(4.05)*
t-stat for $H_0:\sum\beta=1$	(4.45)*	(3.49)*	(3.51)*
Commodity Dummies	No	Yes	Yes
Time Dummies	No	No	Yes

Note: Calculated t-statistics are in parentheses. * denotes significance at 0.05 level.

Table 4: A Comparison between Counterfactual and Direct PSE

	Exchange Rate Pass-though		
	NPT	CPT	IPT
Counterfactual	$\dfrac{\sum\left(P_j^d-P_j^{ar}(E^*)\right)Q_j+BP}{VOP+BP}$	$\dfrac{\sum\left(\dfrac{P_j^d}{1+m}-P_j^{ar}(E^*)\right)Q_j+\dfrac{BP}{1+m}}{\dfrac{VOP}{1+m}+\dfrac{BP}{1+m}}$	$\dfrac{\sum\left(\dfrac{P_j^d}{1+\beta m}-P_j^{ar}(E^*)\right)Q_j+\dfrac{BP}{1+\beta m}}{\dfrac{VOP}{1+\beta m}+\dfrac{BP}{1+\beta m}}$
Direct Effect		$\dfrac{\sum\left(P_j^d-P_j^{ar}(E)\right)Q_j+BP}{VOP+BP}$	
Transfer	$m\dfrac{\sum P_j^w E^* Q_j}{VOP+BP}$	0	$(1-\beta)m\dfrac{\sum P_j^w E^* Q_j}{VOP+BP}$
Non-Transfer	0	$m\dfrac{\sum P_j^w E^* Q_j}{VOP+BP}$	$\beta m\dfrac{\sum P_j^w E^* Q_j}{VOP+BP}$

Note: For simplicity, the formulae shown ignore domestic cost adjustment (ADJ_j) but these adjustments are incorporated in our empirical analysis. NPT: No pass-through; CPT: Complete pass-through; IPT: Incomplete pass-through.

Table 5: Direct, Indirect and Total Effect and Counterfactual PSE

Period (% Misalignment)	I:1993-95 (8.6%)	II:1996-99 (-5.4%)	III:2000-03 (18.0%)
Direct	-2.4	0.2	5.9
Indirect	4.1	-3.4	11.5
Total	1.7	-3.2	17.4
Counterfactual (IPT)	-1.2	-0.8	9.0
Transfer	1.1	-0.9	3.1
Non-Transfer	3.0	-2.5	8.4

Note: IPT: Incomplete pass-through.

Figure 1: The Actual and Equilibrium Real Exchange Rates

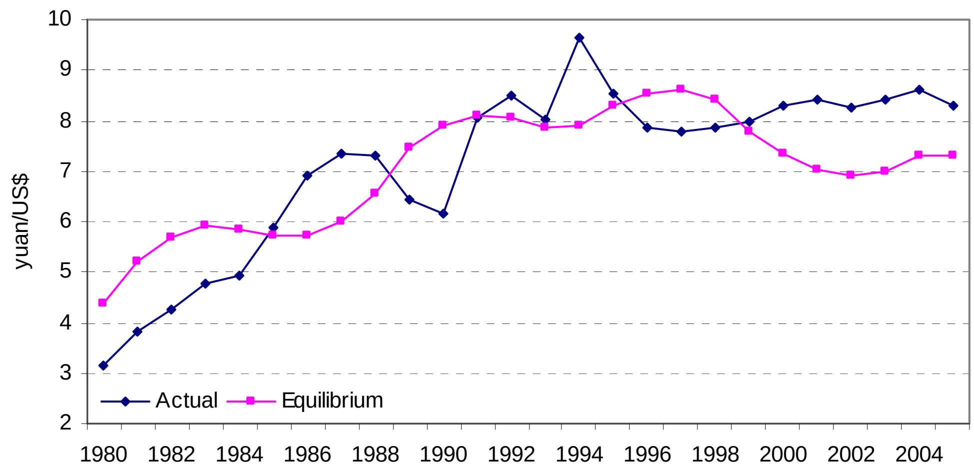

Figure 2: Static Solution of Model (One-step ahead Forecasts)

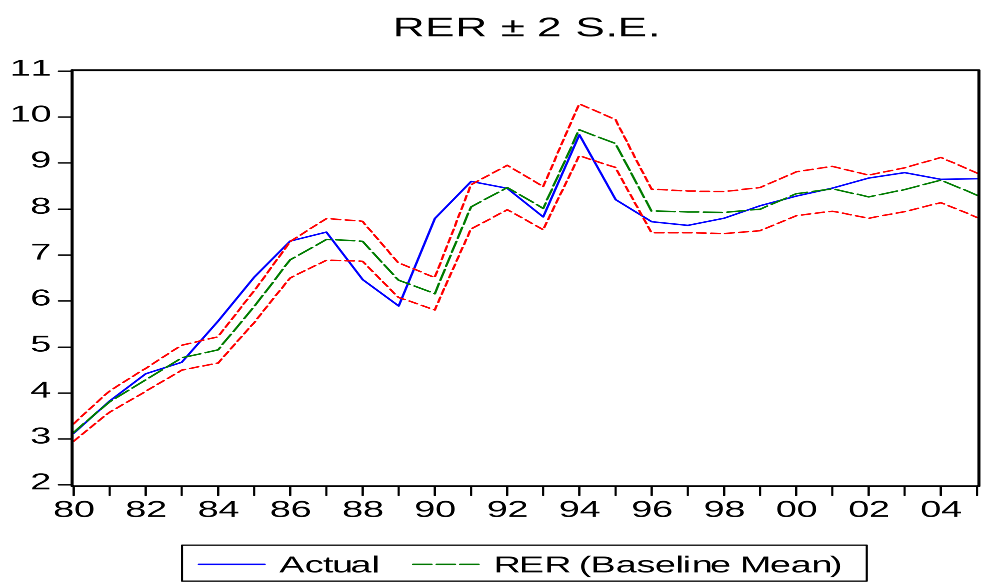

Figure 3: Dynamic Solution of Model (Multi-step ahead Forecasts)

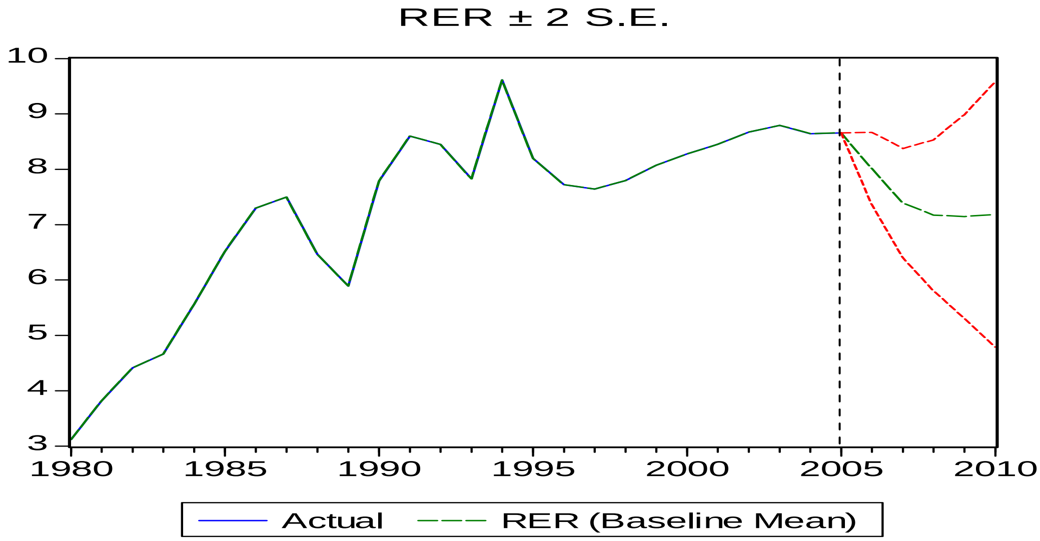

Figure 4: Point Estimates of Persistence Profiles of the Cointegrating Relation

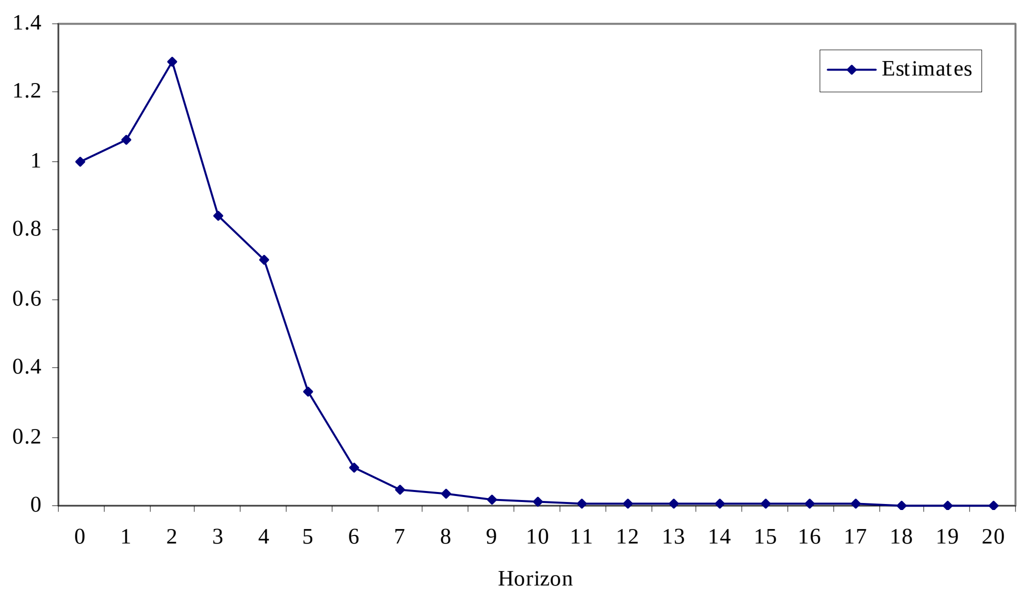

Figure 5: Comparison of Domestic and World Prices (1993-2003)

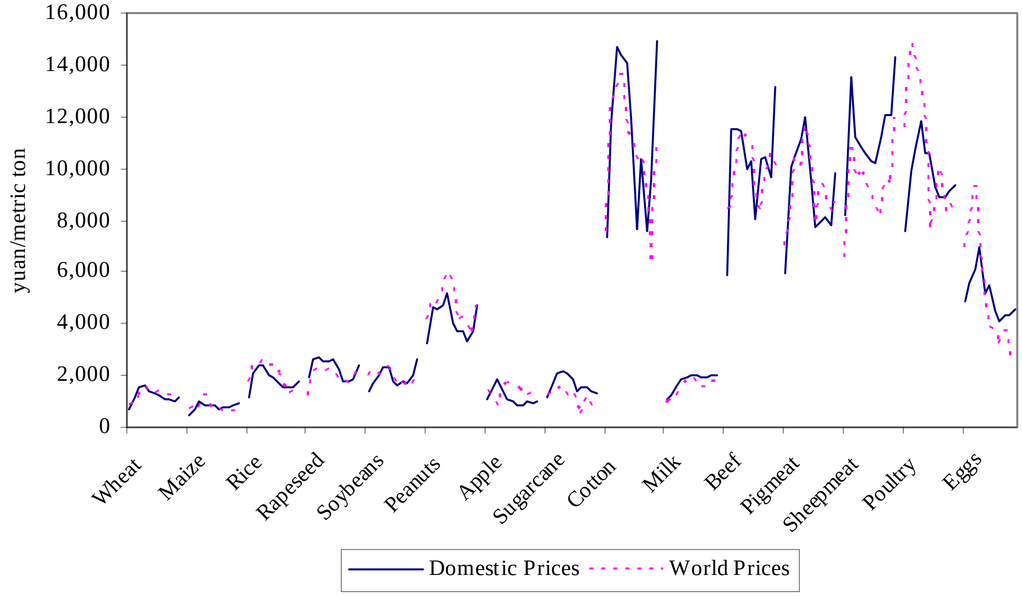

Figure 6: Direct and Indirect Effect and Counterfactual PSE