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Andrea Cipollini and George Kapetanios

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A. Cipollini* and G. Kapetanios†
Queen Mary, University of London

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Abstract

In this paper we compared the performance of country specific and regional indicators of reserve adequacy in predicting, out of sample, the balance of payment crisis affecting the South East Asian region during the 1997-98 period. A Dynamic Factor method was used to retrieve reserve adequacy indicators. The empirical findings suggest clear evidence of financial contagion.

Keywords: Financial Contagion, Dynamic Factor Model
JEL code: C32, C51, F34

1 Introduction

The recent currency and financial crises affecting emerging market economies throughout the 1990s have attracted the attention of policymakers and academics. Of particular interest is why many of these crises which began as country specific events quickly affected countries and regions around the

*Corresponding author; Department of Economics, Queen Mary, University of London, Mile End Road, London E1 4NS. email: A.Cipollini@qmul.ac.uk

†Department of Economics, Queen Mary, University of London, Mile End Road, London E1 4NS. email: G.Kapetanios@qmul.ac.uk

globe. Most people describe this phenomenon as contagion. There are two broad approaches in measuring and defining contagion. First, authors such as Forbes and Rigobon (2002) classify contagion as a significant increase in cross market linkages after a shock to an individual country. Cross market linkages can be measured by a number of different statistics, such as the correlation in asset returns, or the transmission of volatility in asset returns. However, in order to explain the ultimate source of shocks propagation, in this paper, we prefer to concentrate on an alternative approach along the lines of Kaminsky et al. (1998), among the others. This approach focuses on the explanation of contagion across financial markets of different countries through proxies of specific transmission channels, such as trade or financial linkages. Specifically, we are interested in the analysis of the role played by capital markets in propagating balance of payment crises across Indonesia, Malaysia, Philippines, Korea, Thailand, during the 1997-1998 crisis period¹. Consequently, our focus is on the analysis of financial contagion.

Empirical studies on the predictability of contagious currency crises have been based upon two different methodologies. The study of Kaminsky and Reinhart (1999) focusing on signalling models is related to first approach. The authors (*op. cit.*) build on the study of Kaminsky et al. (1998), related to the predictability of currency crises only through country specific indicators. This approach involves monitoring the evolution of several indicators in different countries that tend to exceed a given threshold during the period preceding a crisis in a specific country. This can then be interpreted as a warning signal that a currency crisis may take place within the following months. The threshold is then adjusted to balance type I errors (that the model fails to predict crises when they actually take place) and type II errors (that the model predicts crises which do not occur). A composite contagion vulnerability index is then constructed weighting individual indicators, with larger weights assigned to the most reliable indicators.

The second approach (see Van Rijckeghem and Weder (2000), among others) looks at pooled panel data, employing discrete choice techniques in which macroeconomic and financial data of a range of countries are used to explain discrete crisis events in a specific country.

It is important to observe that the aforementioned studies tried to come

¹Throughout most of the 1990s, massive capital inflows had been pouring in the East Asian region, mainly in the form of bank lending. Most of the foreign borrowing in these economies was short-term with Japan being the country with the largest exposure.

up with leading indicators that performed well over a cross section of countries and crises. As pointed out by Berg and Patillo (1999), these indicators are based upon past information, hence they may have limited ability to predict out of sample. Consequently, the authors examine the out of sample prediction performance of both a signalling model and a probit model regarding a measure of a country specific currency pressure during the 1997 Asian crisis period. To our knowledge, no paper has, however, been concerned with the out of sample forecasting performance of an empirical model regarding contagious currency crises. In this paper, the empirical analysis of the transmission of balance of payment crises from one country to the other is based upon the comparison of out of sample performance of both country specific and regional indicators in predicting the probability of a currency turmoil in each single country. These indicators are proxies of reserve adequacy for the five Asian countries aforementioned². To retrieve an aggregate indicator of reserve adequacy both at country and regional level we use a Dynamic Factor model³. We argue that, if the predictive performance of a vulnerability indicator for country i is inferior to the one corresponding to a regional indicator (including data from all countries under consideration except country i), then there is evidence of financial contagion. As a proxy of stress on the foreign exchange market (which is the variable to predicted) we use an Exchange Market Pressure Index (EMPI). This index was first used by Girton and Roper (1977), and subsequently by a number of authors in the context of exchange rate crisis (see Tanner (2002), for a recent use).

²In light of the recent financial crises, various reports from the IMF on the "architecture" of the international financial system have been developed. These reports emphasise the importance of sound debt and liquidity management in helping to prevent external crises. (see, for instance, the IMF report on "Debt- and Reserve-Related Indicators of External Vulnerability", 2000). In particular, this report stresses on the importance of holding foreign reserves for Central Banks in order to maintaining liquidity and allowing time to absorb shocks in situations where access to borrowing is curtailed or very costly. Consequently, the focus is on indicators of reserve adequacy, which, in this paper, are constructed for the countries aforementioned.

³Mody and Taylor (2002) use a dynamic factor model, based upon Kalman filter estimation of state space models, to construct country specific and regional indicators of vulnerability for a number of Asian countries. In the present paper, we are interested in retrieving indicators of reserve adequacy. For this purpose we focus on a large number of variables available only at a low frequency, that is on a biannual basis (see below). Consequently, the number of cross sections exceed the time series observations and it is not practical to use standard state space model methods to extract factors. The method we use is based on a state space model but uses alternative estimation techniques.

Girton and Roper use a simple monetary model to derive a definition of EMPI as the sum of exchange rate depreciation and reserve outflows, scaled by base money. This index summarises the flow of excess supply of money (e.g., the difference between the growth rates of the domestic component of the monetary base and money demand) in a managed exchange rate regime, reflected in both exchange rate and reserve movements. Hence an increase in the value of a country's EMPI indicates that the net demand for that country's currency is weakening and hence that the currency may be liable to a speculative attack or that such an attack is already under way. However, for the sake of comparison, we also focus on another EMPI indicator which consider nominal exchange rate changes as well as the reserve flows scaled the past value of the reserve stock (of the previous period) and it includes an additional component given by interest rates changes (measured by money market rates). The idea of combining three variables for the measurement of stress on the foreign exchange market was pioneered by Eichengreen et al. (1996).

The outline of the paper is as follows. Section 2 describes the stylised facts and review the literature on financial contagion. Section 3 the describes the empirical methodology. Section 4 describes the dataset and the empirical analysis. Section 5 concludes.

2 Financial contagion:theory

A number of theoretical studies of financial contagion stress the role of a common lender channel (see Schinasi and Smith (1999), among the others). Specifically, when a common lender country is highly exposed to a crisis country, it is likely to shift away from lending and to cut its lending to other countries in order to restore its capital adequacy.

As suggested by Sbracia and Zaghini (2000), common lender channel effect can also operate through the value of collateral (e.g. stocks or government bonds) provided by borrowers. Consider a region that is economically open but has an underdeveloped bank based financial market, and suppose that an economy in this region backs its funding by asset holdings in a neighbouring country. When a crisis hits the "collateral" economy, the lender will require a sounder backing of its claims. If this is impossible, the lender will downgrade the borrower and reduce the amount of credit issued, and it will

spread the crisis internationally.

A number of theoretical studies also stress on the role of wake up calls, which refer to a sudden shift in perceptions for an entire asset class (e.g. securities issued by a number of countries in a specific region) following an initial crisis due to reinterpretation of information and revisions of expected returns in this asset class, or due to a generalised increase in risk aversion. These effects can be magnified and are capable of spreading internationally, especially in the presence of different groups of financial investors, some of which are better informed than the others. Calvo and Mendoza (1999) use a standard mean variance model to show that costs of verifying the validity of market rumors can lead to asset sales unrelated to fundamentals. Kodres and Pritsker (1999) study a model with four type of investors, some of which are not rational, and some of which have better information than others. The explanation of contagion in Kodres and Pritsker (op. cit.) relies on cross market hedging: if some asset returns are correlated, than an adverse shock in one market can lead to selling in another market. Calvo (1999) stresses on the role played by margin calls in one market requiring that leveraged informed investors liquidate many positions, causing financial contagion. In this case, uninformed investors may mimic informed investors even though ex post it turns out that no new information about fundamentals was revealed.

It is important to observe that wake up calls are likely to arise especially in presence of maturity and currency mismatches. First, if these countries' loan contracts were of short maturity and the banks's rebalancing needs are significant, the initial crisis could trigger large capital outflows from the other borrowers. That is, not only may the bank be unwilling to extend new credits to the other borrowers, it may refuse to roll-over their existing loans, hence the capital outflow. Secondly, high unhedged foreign currency exposures (or mismatches) by banks and corporations reduce the ability of the authorities to devalue the currencies in a timely fashion, without straining their private sector's capacity to pay back debt denominated in foreign currency. In turn the perceived likelihood of a devaluation increased, firms and banks rush to buy foreign currency (or to hedge their exposures), thus increasingly sharply the demand for foreign currency. When the depreciations finally takes place, economic agents who still have high foreign currency obligations take a hard hit, thus contributing significantly to the severity of the crises.

3 Dynamic Factor Method

In this section we examine the econometric methodology we use to extract factors. We consider the following state space model.

$$\begin{aligned}x_t &= Cf_t + Du_t, \quad t = 1, \dots, T \\f_t &= Af_{t-1} + Bu_{t-1}\end{aligned}\tag{1}$$

x_t is an n -dimensional vector of strictly stationary zero-mean variables observed at time t . f_t is an m -dimensional vector of unobserved states (factors) at time t and u_t is a multivariate standard white noise sequence of dimension n . The aim of the analysis is to obtain estimates of the states f_t , for $t = 1, \dots, T$. This state space model may not appear familiar as the presence of the same error term in both the transition and measurement equations is non-standard. However, as Hannan and Deistler (1988) show, in Chapter 1, (1), referred to as the prediction error representation of the state space model, is equivalent to the following more common representation

$$\begin{aligned}x_{nt} &= Cf_t + D^*u_t, \quad t = 1, \dots, T \\f_t &= Af_{t-1} + B^*v_{t-1}\end{aligned}\tag{2}$$

where u_t and v_t are multivariate standard orthogonal white noise sequences. We concentrate on (1) as it forms the basis for deriving the dynamic factor estimation algorithm.

Subspace algorithms avoid expensive iterative techniques and rely instead on matrix algebraic methods to provide estimates for the factors as well as the parameters of the state space representation. A review of existing subspace algorithms is given by Bauer (1998) in an econometric context. Another review with an engineering perspective may be found in Van Oversee and De Moor (1996).

The starting point of most subspace algorithms is the following representation of the system which follows from the state space representation (2) and the assumed nonsingularity of D .

$$X_t^f = \mathcal{O}KX_t^p + \mathcal{E}E_t^f\tag{3}$$

where $X_t^f = (x'_t, x'_{t+1}, x'_{t+2}, \dots)'$, $X_t^p = (x'_{t-1}, x'_{t-2}, \dots)'$, $E_t^f = (u'_t, u'_{t+1}, \dots)'$,

$$\begin{aligned}\mathcal{O} &= [C', A'C', (A^2)'C', \dots]' \\ \mathcal{K} &= [\bar{B}, (A - \bar{B}C)\bar{B}, (A - \bar{B}C)^2\bar{B}, \dots]\end{aligned}$$

where $\bar{B} = BD^{-1}$ and

$$\mathcal{E} = \begin{pmatrix} D & 0 & \dots & 0 \\ CB & D & \ddots & \vdots \\ CAB & \ddots & \ddots & 0 \\ \vdots & & CB & D \end{pmatrix}$$

The derivation of this representation is easy to see once we note that (i) $X_t^f = \mathcal{O}f_t + \mathcal{E}E_t^f$ and (ii) $f_t = \mathcal{K}X_t^p$. The best linear predictor of the future of the series at time t is given by $\mathcal{O}\mathcal{K}X_t^p$. The state is given in this context by $\mathcal{K}X_t^p$ at time t . The task is therefore to provide an estimate for \mathcal{K} . Obviously, the above representation involves infinite dimensional vectors.

In practice, truncation is used to end up with finite sample approximations given by $X_{s,t}^f = (x'_t, x'_{t+1}, x'_{t+2}, \dots, x'_{t+s-1})'$ and $X_{q,t}^p = (x'_{t-1}, x'_{t-2}, \dots, x'_{t-q})'$. Then an estimate of $\mathcal{F} = \mathcal{O}\mathcal{K}$ may be obtained by regressing $X_{s,t}^f$ on $X_{q,t}^p$. Following that, the most popular subspace algorithms use a singular value decomposition of an appropriately weighted version of the least squares estimate of \mathcal{F} , denoted by $\hat{\mathcal{F}}$. In particular the algorithm we will use, due to Larimore (1983), applies a singular value decomposition to $\hat{\Gamma}^{f-1/2} \hat{\mathcal{F}} \hat{\Gamma}^{p1/2}$, where $\hat{\Gamma}^f$, and $\hat{\Gamma}^p$ are the sample covariances of $X_{s,t}^f$ and $X_{q,t}^p$ respectively. These weights are used to determine the importance of certain directions in $\hat{\mathcal{F}}$. Then, the estimate of \mathcal{K} is given by

$$\hat{\mathcal{K}} = \hat{S}_m^{1/2} \hat{V}_m' \hat{\Gamma}^{p-1/2}$$

where $\hat{U}\hat{S}\hat{V}'$ represents the singular value decomposition of $\hat{\Gamma}^{f-1/2} \hat{\mathcal{F}} \hat{\Gamma}^{p1/2}$, \hat{V}_m denotes the matrix containing the first m columns of \hat{V} and \hat{S}_m denotes the heading $m \times m$ submatrix of \hat{S} . \hat{S} contains the singular values of $\hat{\Gamma}^{f-1/2} \hat{\mathcal{F}} \hat{\Gamma}^{p1/2}$ in decreasing order. Then, the factor estimates are given by $\hat{\mathcal{K}}X_t^p$. More details on the method, including its asymptotic properties, may be found in Kapetanios and Marcellino (2003). Once an estimate of the factor is obtained then the parameters of the state space model may be estimated using standard regression techniques and the factor estimates in the measurement and transition equations. Thus, it is possible to produce forecasts for the factors.

3.1 Dealing with large datasets

Up to now we have outlined an existing method for estimating factors which requires that the number of observations be larger than the number of elements in X_t^p . Given the work of Stock and Watson (2001), on modelling very large datasets with factor models, this is rather restrictive. We therefore follow Kapetanios and Marcellino (2003) who suggested a modification of the existing methodology to allow the number of series in X_t^p be larger than the number of observations. The problem arises in this method because the least squares estimate of \mathcal{F} does not exist due to rank deficiency of $X^{p'}X^p$ where $X^p = (X_1^p, \dots, X_T^p)'$. As we mentioned in the previous section we do not necessarily want an estimate of \mathcal{F} but an estimate of the states $X^p\mathcal{K}'$. That could be obtained if we had an estimate of $X^p\mathcal{F}'$ and used a singular value decomposition of that. But it is well known (see e.g. Magnus and Neudecker (1988)) that although $\hat{\mathcal{F}}$ may not be estimable $X^p\mathcal{F}'$ always is using least squares methods. In particular, the least squares estimate of $X^p\mathcal{F}'$ is given by

$$\widehat{X^p\mathcal{F}'} = X^p(X^{p'}X^p)^+X^{p'}X^f$$

where $X^f = (X_1^f, \dots, X_T^f)'$ and A^+ denotes the unique Moore-Penrose inverse of matrix A . Once this step is modified then the estimate of the factors may be straightforwardly obtained by applying a singular value decomposition to $\widehat{X^p\mathcal{F}'}$. Kapetanios and Marcellino (2003) choose to set both weighting matrices to the identity matrix in this case. In our results below we will pursue two alternative subspace methods. Method 1, denoted in the tables below as SS1, relies on the singular value decomposition of $X^p(X^{p'}X^p)^+X^{p'}X^f = \hat{U}\hat{S}\hat{V}'$. Then, the factor estimates are given by $\hat{U}_m\hat{S}_m^{1/2}$. Method 2, denoted SS2, relies on the singular value decomposition of $(X^{p'}X^p)^+X^{p'}X^f = \hat{U}\hat{S}\hat{V}'$. Here the factor estimates are given by $X^p\hat{U}_m\hat{S}_m^{1/2}$. Note that $X^p(X^{p'}X^p)^+X^{p'} = I$ when the number of columns of X^p exceeds its number of rows. We therefore see that SS1 essentially decomposes X^f , and resembles the approximate dynamic factor methodology of Stock and Watson (2001) based on principal components. The SS2 method, on the other hand is genuinely dynamic in that it exploits the dynamic relationship between X^f and X^p to estimate the factor. We use the method SS2 in our empirical work.

4 Empirical analysis

4.1 The Data

The reserve adequacy indicators are first measured as ratios of foreign exchange reserves in dollars to various measures of external debt. Consolidated statistics on external debt are obtained from the Bank of International Settlements (BIS) on biannual basis from 1983:II to 2002:I⁴. These data measure, on a worldwide consolidated basis, the foreign claims of banks headquartered in the reporting area. Specifically, we concentrate on disaggregated data on external debt.

First, an important component of the consolidated banking statistics are the foreign claims of BIS reporting banks vis-a-vis individual countries. As explained above, it is important to gauge information on the distribution of bank claims by nationality of bank, in order to measure potential contagious effects operating through a common creditor channel. We concentrate on external borrowing from: France, Germany, Japan, Switzerland, UK, US, Italy, Belgium and Netherlands. Secondly, in light of the discussion above it is also important to have information on the external debt maturity structure. The consolidated banking statistics provide data on the total external debt with maturity: up to and including one year; over one year up to two years; over two years. Furthermore, the IMF Financial Stability Forum in year 2000, pointed out that the Asian financial crisis of 1997-98 highlighted the importance of monitoring the external positions of the financial and corporate sectors separately from that of the public sector. The consolidated banking statistics allows for a breakdown of international claims by the following three sector: banks, public sector and non banks.

We also include the undisbursed credit commitments component of the consolidated banking statistics. They refer to unutilised portions of binding contractual obligations, including guarantees; and commitments which reporting banks would regard themselves as obliged to honour whatever the circumstances.

Finally, we include data on international bonds and notes issued by the five Asian emerging economies.

⁴These data are also available on quarterly basis from 1999

We are also aware that, owing in large part to the growing globalisation and sophistication of banking and financial markets, contractual claims have become a less accurate measure of banks's credit exposures. Off-balance sheet transactions can significantly modify on balance sheet claims. The net foreign asset position of the banks and the high levels of foreign debt in these economies do not necessarily mean that all these exposures were unhedged. However, documenting these require information on the positions taken by the banks and the private sector in derivatives markets, which only recently has been available.

Other indicators of reserve adequacy are ratios of reserves to monetary aggregates, such as M_1 and M_2 , obtained from the International Financial Statistics (IFS) database of the IMF. Money based indicators of reserves provide a measure of the potential for resident-based capital flight from the currency, since it is argued that, an unstable demand for money or the presence of a weak banking system indicates a greater probability of such capital flight.

The data for the components of the EMPI index are obtained from the International Financial Statistics (IFS) of the IMF database. As suggested by Girton and Roper (1977), the measure of the EMPI index consists of a weighted sum of the exchange rate depreciation (measured as unit of domestic currency per US dollar), and US dollar denominated official reserves (minus gold) outflows scaled by base money (of the previous period). The weights chosen that each of the three components has a standard deviation of unity, in order to preclude any of them from dominating the index. As explained above, we also consider another indicator of EMPI which includes an additional component given by interest rates changes (measured by money market rates).

4.2 Empirical Results

As explained above, our test for contagion, is based upon the comparison of the forecasting performance of a model which includes a reserve adequacy factor constructed using data only for country i and of the regional reserve adequacy factor (constructed using data from all countries in the sample except i). In Table 1 and 2 we measure the ability of the two factors in

predicting the index of exchange market pressure given only by exchange rate depreciation and reserve flows scaled by money, and an index of stress on the foreign exchange market augmented by interest rate changes, respectively.

To do this for every vulnerability factor we fit the state space factor model to the appropriate dataset, extract the factor estimate and use the state space model to construct forecasts of the factor. Then, we fit an AR model to the dependent variable, augment the model with the contemporaneous value of the estimated factor and use that to forecast the dependent variable. The lag order of the AR component of the model is obtained using the Akaike information criterion. Note that for forecasting the factor estimates are obtained recursively so as to avoid using future information in the forecasting exercise.

Our forecast evaluation period is the second half of 1997 and the first half of 1998, i.e. the period characterising the Asian crisis. We concentrate on this period and this period only since we are interested in financial crises. Both models are compared with a benchmark given by an AR(1) process⁵ for the dependent variable. The root mean square error is used as the measure of predictive ability. Unfortunately, given the short forecast evaluation period we cannot test whether the performance of the regional factor model is better than that of the country specific factor model. Given the better performance of the regional reserve adequacy factor in forecasting out of sample both indices of exchange market pressure, we conclude that there is evidence of financial contagion across the countries under examination. The two factor models show, in most cases, a predictive performance better than the one corresponding to the benchmark AR(1) process. There is the notable exception of the exchange market pressure index (only the one augmented with interest rate changes) of Thailand for which the AR(1) is the best performing model.

In line with the study of Kamisky and Reinhart (1999), we argue that the evidence for contagion can be explained by the large short-term external borrowing from a common lender country. Throughout the 1990s, among the major international lenders, Japan was heavily exposed country to emerging Asia. Japanese banks, already in fragile conditions after the burst of the 1980s asset bubble and weakened by a stagnant economy in the 1990s, had heavily lent to other Asian economies. Given the very low interest rates in Japan, large scale lending to the fast growing East Asian countries was

⁵The lag order is chosen by the Akaike information criterion

Table 1: Performance of different forecasting models for the EMP index given by exchange rate depreciation and reserve flows scaled by money

	Ind	Mal	Phi	Kor	Tha
$RMSE_i^a$	4.28	4.19	4.36	6.63	7.10
$RMSE_r$	4.06	4.14	4.30	6.45	7.08
$RMSE_1$	4.18	4.33	4.40	6.59	7.22

^a $RMSE_i$ measures the predictive ability of the reserve adequacy factor model for country i , $RMSE_r$ measures the predictive ability of the regional reserve adequacy factor model (including all countries except i), $rmse_1$ measures the predictive ability of an AR(1) model.

stimulated by the higher returns available outside Japan. As of June 1997, Japanese banks held 37% of all claims on counterparts in the five seriously affected countries⁶. Following the onset of the Asian crisis, foreign claims on Asian counterparts shifted significantly. An analysis of both the maturity and sectorial composition of the claims of the Bank for International Settlements (BIS) reporting countries, shows, by the end of 1997, a non renewal of short term credit lines on emerging Asian countries, especially for the corresponding banking sectors. As explained above, pulling out of emerging Asia can be explained by the margin calls on the group of leveraged informed financial investors arising especially in presence of maturity and currency mismatches (the short term claims to the five seriously affected countries in East Asia amounted to roughly 64% of total claims, following a relatively stable trend since 1993).

5 Conclusions

Most of the empirical studies on the predictability of currency crises have been based upon in sample forecasting analysis. There is, however, the no-

⁶European bank lending to emerging Asia was also significant (by June 1997 European banks held 37% of all claims on counterparties in the five seriously affected countries), whereas US bank exposure to Asia was modest on the eve of the crisis (accounting only to 9% of the total claims).

Table 2: Performance of different forecasting models for the EMP index given by exchange rate depreciation, reserve flows scaled by own lag and interest rate changes

	Ind	Mal	Phi	Kor	Tha
$RMSE_i^a$	6.79	3.89	5.46	7.03	7.05
$RMSE_r$	6.76	3.85	5.28	6.72	6.92
$RMSE_1$	6.89	4.29	5.52	6.96	6.76

^a $RMSE_i$ measures the predictive ability of the reserve adequacy factor model for country i , $RMSE_r$ measures the predictive ability of the regional reserve adequacy factor model (including all countries except i), $rmse_1$ measures the predictive ability of an AR(1) model.

table exception of the study of Berg and Patillo (1999). The authors (op. cit.) examine the out of sample prediction performance of both a signalling model and a probit model regarding a measure of a country specific currency pressure during the 1997 Asian crisis period. In this paper we are interested in the predictability of contagious balance of payment crises. Specifically, we compare the performance of country specific and regional indicators of reserve adequacy in predicting out of sample the currency crises involving the five largest economies in emerging Asia during the 1997-98 period. The reserve adequacy indicators were obtained using a Dynamic Factor method. The empirical findings suggest clear evidence of financial contagion.

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**Department of Economics
Queen Mary, University of London
Mile End Road
London E1 4NS
Tel: +44 (0)20 7882 5096 or Fax: +44 (0)20 8983 3580
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