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Three musketeers: A dynamic model of capital inflow (FDI), the real wage rate and the net migration flow with empirical application

Peter Simmons & Yuanyuan Xie

Department of Economics and Related Studies University of York Heslington York, YO10 5DD

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Peter Simmons^{*} Yuanyuan xie[†] The University of York

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Abstract

This paper develops a time continuous dynamic model of a system of piecewise differential equations to study the simultaneous interactions between capital flows (FDI), the real wage rate and the net migration flow allowing for immigration, return migration and immobility. Theoretically, we claim three contributions: this paper is the first one to recognize the inherent regime shifts in migration due to fixed migration costs, the chance of getting a job and two way migration; for non-zero moving cost, there is usually an infinite number of stationary states; the elasticity of labor demand is an important factor in determining local stability and the global dynamics. Empirically, we apply our model with calibrated Cobb-Douglas production functions to estimate the dynamic adjustment speeds for 16 regions of Guangdong (a fast growing Chinese province with the highest internal migration flow in the emerging world) over 1990-2010. The results of our empirical application indicate that regions in Guangdong are heterogeneous but show positive simultaneous interactions between the three endogenous variables. Some policy implications and further research directions are also suggested.

Key words: Dynamic migration; Regime shifts; Local stability; Dynamic adjustment speeds. JEL classification: F22; J61; O10.

1 Introduction

The aim of this paper is to provide an analytical framework to study the simultaneous interactions between capital inflow (FDI), the real wage rate and net migration flow into a region and apply this structural model with numerical calibration to Guangdong, a fast growing Chinese province with the highest net migration in the emerging world (UN, 2011). Except for Federici and Giannetti (2010) who build a dynamic model with these three endogenous variables to study complementarity between FDI and temporary migration in a one way (return) migration setting, the simultaneous interactions with two way migration and immobility have not been studied. The existing migration literature only refers to two dimensional interactions between capital and migration or between the wage rate and migration. In fact migration, wage rates and capital flows are interconnected through the labour and capital markets. In an immigration context, the positive link between immigration and capital inflow (FDI) has been confirmed empirically (Clark and Gertler, 1983; Buch et al., 2006; Foad, 2012; Ivlevs, 2006). In a return migration context, contrary to the "brain drain" effect of emigration on native countries (Docquier and Marfouk, 2005; Borjas, 2005; Kapur and Muhale, 2009; Commander et al., 2003), a positive and complementary dynamic link between FDI and labor mobility has been demonstrated by a group of return migration research scholars (Kugler and Rapoport, 2007; Dustmann and Weiss, 2007; Dustmann and Kirchkamp, 2002; Ma, 2002). A related question is the interaction between

^{*}Corresponding author. peter.simmons@york.ac.uk. +44 1904 433763. Professor of Department Economics and Related Studies, the University of York, UK. YO105DD

[†]Presenting and Corresponding author. Yx518@york.ac.uk. PhD student in Department Economics and Related Studies, the University of York, UK. YO105DD

migration and wages but the findings are mixed: Borjas (2003) argues that immigration has substantial impacts on wages in the host country, but Ottaviano and Peri (2007; 2008) and Amuri et. al. (2010) find small effects.

We develop a time continuous dynamic model of a system of piecewise differential equations. A key migration determinant is the expected income level which depends on the level of wages and the unemployment rate (which determines the chance of finding a job) in different locations. In turn these are determined by the technology, capital and labour endowments and the heterogeneous functioning of the labour market in different locations. But labour migration has a cost. Together these imply that the dynamics of immigration and emigration flows will respond differently to an expected wage gap between two locations, and also there will be combinations of labour, wage and capital endowments under which labour movement does not occur due to the fixed migration cost. We start from a benchmark model in the short run^1 , in which the labour demand is determined by the representative firm's profit maximization process with fixed wages and capital stock, net migration responds to expected labour income differences between host and origin locations. In this context, only migration adjusts and at any time there may be immigration, immobility or return migration. We then extend the time period to the medium run in which the real wage is flexible and adjusts according to the excess demand for labour in the host country but capital is still fixed. Finally we allow capital to adjust dynamically (through FDI), following the gap between the marginal product of capital in the host country and the world interest rate at time t. We compare the equilibria and stability of these three cases. Empirically, we apply a general model (three flexible variables) with calibrated Cobb-Douglas production functions and estimate the dynamic adjustment speeds of wage rates, migration and FDI in 16 regions of Guangdong over 1990-2010. We claim three contributions in the paper. No other study includes these simultaneous interactions which fills a gap in the literature, our paper is the first to recognize the inherent regime shifts due to migration costs, the chance of getting a job and two way migration. We find that the effect of the elasticity of labour demand is an important factor in the local stability condition and the global dynamics. The framework predicts time series properties of real wage rates, migration and capital flows. Generally all may have cycles which will be of varying duration and so not in phase. Migration flows should show relatively flat peaks and troughs whilst real wage rates turn around more quickly. The correlation and cross auto-correlation between the series should vary with the phases of the cycle. The empirical results indicate that regions in Guangdong are heterogeneous but with positive simultaneous interactions between the three endogenous variables. Some policy implications and further research directions are also suggested.

The paper is structured as follows. Section 2 reviews the existing literature and frames this paper's contributions within those literatures. Section 3 presents the model in detail. Section 4 applies the general model with calibrated Cobb-Douglas production, describes the data and the empirical methodology. The results will also be discussed in this part. In the final section, we draw conclusions and some policy implications and further research direction are also suggested.

2 Review of the literature

2.1 Capital (FDI) and immigration

The existing empirical evidence on immigration and FDI concentrates on the empirical relationship between the two. Clark and Gertler (1983) use a time-series framework for 15 U.S. states over 1958-1975 to explore the relationship between immigration and capital. The close and positive similarities in the magnitude and the timing of fluctuations of immigration and capital growth for all states are indicated by their empirical work. More recent empirical work has also confirmed the positive interaction between capital and immigration, Barry (2003) and Groznik (2003) show that immigration tends to lead to capital inflows to Germany. UK

¹Primarily for clarity of exposition, we build up the three dimensional dynamic system in stages.

FDI favors destinations that also attract a large number of immigrants (Clemens and Williamson, 2000). Buch et al. (2006) use Tobit fixed effects panel regressions for 16 German states over 1991-2002 to analyze the relationship between FDI and migration stocks empirically. They find that immigration and FDI are positively related, though the effect is largest for FDI from high-income origins. Complementary to the findings by Buch, Foad (2012) looks at the links between flows at the regional level for the 50 US states. The results in his paper strongly support a positive/complementary relationship between cross-border flows of immigration and FDI in US.

Similar to Foad's (2012) paper, our empirical work studies the sign of the link by also looking at the regional level. A regional level analysis allows us to strip away any variation at national levels such as exchange rates. So FDI flows from the same source country to different regions in a single destination country will be subject to the same exchange rate. This approach helps hold any determinants at the national level constant and any variation in immigration must be due to be regional differences in FDI or vice versa. But the shortcomings of Foad's paper are the measurement of FDI and the time frequency of the immigration data. Due to data limitations, he defines FDI as the number of majority-owned affiliates instead of computing the actual value of FDI. An obvious bias arises if a variable number of small enterprises enter the local market. Another disadvantage of his paper is that the immigration data are only updated every ten years while the FDI data are available on an annual basis. Annual migration flows cannot be explained. To overcome these flaws, our paper estimates the sign of the link by using annual migration data and the reported value of FDI at the regional level. In addition our paper also provides a structural theoretical-framework to guide the empirical application. This predicts that there will be an agglomeration effect: regions with a high initial value of FDI and migration will tend to grow fastest. A region starting out with a high level of FDI or a large number of immigrants attracts more successive FDI and immigrants.

2.2 Capital (FDI) and return migration

Much research in economics is devoted to studying the impacts of immigration on the host economy (Borjas, 1989; 1994), but the beneficial aspects of migration for the sending country have received less attention. Contrary to the "brain drain" effect on native countries (Docquier and Marfouk, 2005; Borjas, 1989; Kapur and Muhale, 2009; Commander et al., 2003), migration can also be subsequently welfare-enhancing for those left behind, especially if capital-rich return migrants engage in entrepreneurial activities (or self-employed activities), undertaking capital investment in their home countries. The capital investment helps to overcome capital constraints and supports the economic development of the migrant's home region (Dustmann and Kirchkamp, 2002). In addition, the role of migrant networks and the relatively high skill level of return migrants ensures that return migrants will be fully employed and this return migration will prompt FDI inflow to the native countries. The link between migration and FDI is supported both from a static standpoint and from a dynamic perspective. The standard static trade models (based on international factor endowment differentials) normally support the negative link argument while Kugler and Rapoport (2006) confirm the positive argument dynamically. To our knowledge, the only relevant theoretical framework is developed by Dustmann and Kirchkamp (2002), who are motivated by the empirical evidence from Turkish migrants (51.10% of Turkish return migrants become self-employed and do capital investment in Turkey, 6.2% choose to be salaried workers and 43.72% choose to retire) and develop a simple theoretical model to study the occupation choices of return migrants and the optimal immigration duration. Our paper extends the empirical literature on the link between FDI and return migration and develops a wider theoretical framework to understand the connections between variations in FDI and return migration.

2.3 Immigration and wage

The findings of the interaction between immigration and the wage rate vary a lot. Brucker and Jahn (2011) apply Layard's (2005) wage-setting approach (the wage rate reacts to the change in labor supply especially migration) to analyze the labor market effects of immigration into Germany and find that the effects are moderate (1% increase in immigration increases the unemployment rate by less than 0.1% and reduces the wage rates by 0.1%). By contrast Borjas (2003) indicates that immigration lowers the wage rate of competing workers: a 10% increase in immigration reduces the wage rate of the natives by 3% - 4%. Especially, a significant negative effect of immigration on the wage rate of less educated natives is emphasized by Borjas (2003). Contrary to Borjas's results, Ottaviano and Peri (2007) find small positive effects on the wages of highly educated and small negative effect on the native average wage rate in the short run but a small positive effect in the long run.

The structural model Brucker and Jahn (2011) used to study the effects only refers to two dimensional interactions (the wage rate and migration). In their structural model, the wage rate is a function of labor and fixed capital. Given the market is competitive and the supply of native labor is inelastic, the wage rate equals the marginal product of labor when firm's labor demand is equal to market labor supply. Similarly, in Borjas's (2003) paper, capital is also assumed to be fixed. This assumption supports the argument "the labor demand is downward sloping" but rules out the possibility that the demand curve can be shifted "when the supplies of other imperfectly substitutable factors change" (Ottaviano and Peri, 2008). By enriching Borajs's methodology and refining previous estimates, Ottaviano and Peri (2008) allow capital to be flexible to estimate the effects of immigration on the wage rate at the national US level. And they find an effect of immigration (a 10% increase in immigration) on the wage rate equal to -3.2% with no capital adjustment but -0.6% with capital adjustment. This result suggests that capital adjustment does matter for the effects of immigration on the wage rate. Our framework is in line with this result but goes further in studying the full interactions between capital, wage rates and migration. In detail, our paper relaxes the fixed capital assumption, puts the three dimensional interactions in a dynamic framework and considers regime shifts (due to a fixed moving cost) between immigration, return migration and immobility in the migration dynamic equation. Moreover, instead of looking at the national level, our empirical work uses an "area approach" (Card and Lewis, 2007) to estimate the dynamic adjustment speeds of capital, migration and the real wage rate. The "area approach" improves the efficiency, corrects for the endogeneity of the migrant's choice of location and eliminates the cross-city effects. For example, cities can have different values for adjustment speeds and attract different types of migrants. A city with a open economy system will have a high value for capital adjustment speeds which attracts high skilled workers while a city with a closed economy system will have a low value attracting low skilled workers. By disaggregating, we will have a better way to explain those local average effects.

3 The dynamic systems

3.1 Model (1): sticky wage and fixed capital stock in the short run and local stability of interior region

We consider a small open economy or region which produces one good requiring labor (E) and capital (K). Labor supply comes from two different sources within the given region i: a fixed native labor force (F_i) and a time-variant stock of net-migrants $(M_i(t))$. Capital stock K_i only accumulates from foreign direct investment (FDI) inflows coming from outside of this given region. Since we are mainly interested in the role of FDI, for the time being domestic investment is neglected. In our study, a representative firm in i has a well behaved production function $G(E_{i,t}, K_{i,t})$ which is strictly concave in inputs². At time t the firm in i decides the amount of inputs based on the profit maximization 3 . In the short run it faces a sticky real wage (w_i) and fixed capital (K_i) inputs, so employment demand E_i is determined as a function of the given w_i, K_i and so is also a constant⁴.

Here we analyse the case in which the migrants move between a developed region i (e.g. the urban area) and a developing or undeveloped area j (e.g. the agricultural area) and labour movements in either direction (immigration and return migration) occur when the net gain of relocation is positive. The net gain of immigration from i to i is determined by the expected income in i (employment rate the real wage rate). the real wage rate in $j(w_j)$ and the moving cost $(T_{i,j})$. Return migration is treated asymmetrically and is determined by just the wage differential allowing for the incidence of moving costs, $w_i + T_{ij} - w_j$. For reasons given below, we assume that only the employed in i can consider return migration and any return migrant is sure to find employment in j. If expected movement in either direction cannot cover the moving cost, then there is immobility: no one moves This gives us a piecewise but continuous differential equation for migration between i and j:

$$M_{i}(t) = \left\{ \begin{array}{c} \delta_{m,i}[\min(1, \frac{E(K_{i}, w_{i},)}{(M_{i}(t) + F_{i}(t))})w_{i} - T_{i,j} - w_{j}], \ if \ \text{positive (a)} \\ \delta_{m,i}^{'}[w_{i} - w_{j} + T_{i,j}], if \ \text{negative (b)} \\ 0, otherwise \ (c) \end{array} \right\}$$
(1)

where the coefficients $\delta_{m,i}, \delta'_{m,i}$ reflect the adjustment speeds of immigration and emigration respectively. The institutional barriers that regulate migration are taken into account by the values of $\delta_{m,i}$ and $\delta_{m,i}$. A high value implies a high level of labor mobility in this given region/country, while high barriers are equivalent to low values of $\delta_{m,i}$ and $\delta_{m,i}$

Part (a) of the equation defines the immigration process in which the gap between the expected real wage $(\min(1, \frac{E(K_i, w_i)}{(M_i(t) + F_i(t))})w_i)$ in i and the forsaken real wage $(w_j(t))$ in the origin location j is high enough to cover the moving cost $(T_{i,i})$. For region i the employment rate (chance of a job) in i is min $[1, E_i/(F_i + M_i)]$ so that at time t if there is excess demand for labour, then there is certainty of employment in i. The "rest of the world" is modelled as region j. We think of j as an undeveloped largely agricultural economy with no clearly functioning labour market but in which it is always possible to gain a subsistence income⁵ w_i . So in j the expected income available is w_i for sure. For example, a migrant working in the farmland in region j is always employed. This idea is consistent with Harris-Todaro's (1969, 1970) rural-urban migration in a two sector setting for developing countries. For the link between region i and j, individuals face a moving cost T_{ij} . The moving cost T_{ij} can be either the cost of travelling the physical distance or the entry cost in i or the exit cost in the "rest of the world" j. For example, the costs of acquiring a Hukou can be the entry or exist cost for migrants in China.

Part (b) of the equation represents the return migration⁶ case in which the wage difference $w_i - w_i$ exceeds the moving cost for those employed individuals in region i. The emigration from i to j continues so long as $w_j - w_i - T_{ij} > 0$. For various reasons, we model the immigration case and the return migration case in an asymmetric way and select the employed workers to be the return migration candidates (w_i instead

GKK * GEE - GEK * GKE > 0.

 ${}^{3}\pi(P_{i,t},w_{i,t}) = \max_{E_{i,t}t \ge 0} P_{i,t}G(E_{i,t},K_{i,t}) - W_{i,t} * E_{i,t} = \max_{E_{i,t}t \ge 0} G(E_{i,t},K_{i,t}) - w_{i,t} * E_{i,t},$ Where $P_{i,t}$ is the nominal of the maximum equation of the maximum equation $W_{i,t} = \max_{E_{i,t} \in U} P_{i,t}G(E_{i,t},K_{i,t}) - W_{i,t} * E_{i,t}$. price of the output and the real wage rate $w_{i,t}$ equals to $\frac{W_{i,t}}{P_{i,t}}$ ⁴We get a fixed employment demand $E_i^* = E(K_i, w_i)$. Also E^* exists and is unique $If \lim_{E \to +\infty} GE(E_i, K_i) < w_i$ and

 $G_{E|E=0} > w_i$. As the firm will continue to increase the labor demand until (GE) reaches real urban wage rate at equilibrium.

This highlights the importance of asymmetric immigration and emigration possibilities arising from heterogeneous labour market systems in origin and destination.

²The strict concavity assumption leads to the following properties: marginal product of labor GE > 0; marginal product of capital GK > 0; GEE < 0; GKK < 0;

 $^{^{6}}$ The determinants of return migration are coherent with those (high real wage rate in j and the cost of moving) defined by Stark (1996).

of min $(1, \frac{E(K_i, w_i, j)}{(M_i(t) + F_i(t))})w_i)$. Firstly, the unemployed workers⁷ are claimed to be more credit constrained and have no or fewer resources to cover the moving cost (Docquier & Rapoport, 2010). Secondly, the reasons why the return migrants have a sure chance of employment in j is because they are higher skilled, they are capital rich and can establish businesses, they can access efficient social networks to secure employment in j. The empirical importance of networks is confirmed by Dustmann and Kirchkamp (2002) and Kugler and Rapoport, (2006). According to their findings, return migrants face 100% employment probability in j. Another fundamental reason for asymmetry in the immigration and emigration processes is the different impact of moving costs. A move in either direction is only undertaken if the gain from the move covers the costs T_{ij} . But this means that T_{ij} enters with opposite sign in the immigration and return migration processes, thus ensuring that the moving cost wedge creates an interval of wage differentials within which there is immobility. Part (c) of the equation displays this immobility case in which either the moving cost is too high or the employment rate is too low for migrants so that the neither the net gains of immigration or return migration are positive.

Given that the only time dependent variable is $M_i(t)$ and w_i is sticky over time, the conditions for the existence of a stationary population level (immobility) vary with the values of the fixed wage rates, employment demand and moving cost. Let $G(M) = \min[1, E/(M+F)]w_i - w_j - T$ then:

When w_i, K_i are time invariant (Figure 1)

Insert Figure 1 here

Proposition 1 (i) if $w_i < w_j - T_{i,j}$, there is no stationary population distribution but continuous return migration.

Proposition 2 (ii) if $G(0) = \min[1, E/(F)]w_i - w_j - Tij \leq 0$ ($w_i \leq \frac{w_j + Tij}{\min[1, E/(F)]}$), there is a stationary population distribution and continuous immobility.

Proposition 3 (iii) if $G(0) = \min[1, E/(F)]w_i - w_j - Tij > 0$ ($w_i > \frac{w_j + Tij}{\min[1, E/(F)]}$), there is a positive finite M^* such that and $G(M^*) = \min[1, E/(M^* + F)]w_i - w_j - Tij = 0$ ($w_i = \frac{w_j + Tij}{\min[1, E/(M^* + F)]}$), and there are an infinite number of stationary states with immobility when $M_i \ge M_i^*$. For $M_i < M_i^*$ there is immigration into *i*.

Proposition 4 Thus the condition for stationary population distribution is $w_j - T_{i,j} \le w_i \le \frac{w_j + T_{i,j}}{\min[1, E/(F)]}$

If we observed a sample of net migration from this process we should see weakly monotone net migration with no sign reversals. The requirements of a constant real wage and constant capital stock limit the applicability of this special model but it could fit a relatively static centrally planned economy, perhaps such as North Korea or even some relatively under-developed economies of Latin America or sub Saharan Africa.

3.2 Model (2): fixed capital stock but flexible real wage rate in medium run

The urban region *i* has a well structured labour market, so one would expect the real wage rate w_i to adjust according to labour market conditions at least in the medium run. Here we analyse the case in which the real wage rate varies according to the excess demand for labour, migration flows are determined by expected income differences as in model (1) but the capital stock is still fixed. This gives a two dimensional system for the dynamic interaction between net migration and the real wage rate. The employers demand for labour $(E_i(t) = E(K_i, w_i(t)))$ in each time period depends on the real wage rate (w_i) and on the fixed amount of

⁷If instead jobs in *i* were renegotiated each instant then the dynamic determinant of emigration would be $\min(1, \frac{E(K_{i}, w_{i})}{(M_{i}(t) + F_{i})})w_{i} - w_{j} + T_{ij}$. The qualitative properties we find below would not change if we used this formulation.

capital (K_i) and so is time varying. The supply of labour at t is $M_i(t) + F_i$ and so the wage rate adjusts proportionally to $E_i(t) - (M_i(t) + F_i)$. If the labour market clears, the real wage remains constant.

The two dimensional system is

$$w_{i}(t) = \delta_{w,i}[E(K_{i}, w_{i}(t)) - (M_{i}(t) + F_{i})]$$

$$M_{i}(t) = \begin{cases} \delta_{m,i}[\min(1, \frac{E(K_{i}, w_{i}(t))}{(M_{i}(t) + F_{i})})w_{i} - T_{i,j} - w_{j}], if \text{ positive} \\ \delta'_{m,i}[w_{i} - w_{j} + T_{i,j}], if \text{ negative} \\ 0, otherwise \end{cases}$$

$$\end{cases}$$

$$(2)$$

where δ_w (> 0) is the adjustment speed for the real wage rate in *i*.

In the real wage/migration space we define the no-immigration locus by values of w_i, M_i satisfying $\min(1, \frac{E(K_i, w_i)}{(M_i + F_i)})w_i = T_{i,j} + w_j$. And we define the constant real wage rate locus by values of w_i, M_i satisfying $E(K_i, w_i) = M_i + F_i$. Depending on the elasticity of the labor demand, the no-immigration line (line 2) is either upward or downward slope.(figure 2 and 3). The slope of this no-immigration line (line 2) will not affect the location of the three regimes. Region I (immigration) which is located to the right of the high real wage threshold $(w_i > w_j + T_{ij})$ and to the downside of the no-immigration line has positive immigration flow $(M_i(t) > 0)$ with the net gain of relocation from j to i being positive; the region R (return migration) which is located to the left of the low real wage threshold $(w_i < w_j - T_{ij})$ has positive return migration flow $(M_i(t) < 0)$. Apart from those two regions, the remaining areas refer to the immobility region. The immobility region includes the area above the no-immigration line (line 2) and to the left of the high real wage threshold $(w_i > w_j + T_{ij})$ and the area between the high and low real wage thresholds $(w_j - T_{ij} < w_i < w_j + T_{ij})$.

Proposition 5 The no-immigration plane is downward (upward) slope if labor demand is inelastic (elastic).

Proposition 6 In both cases (elastic and inelastic), there is an infinite number of stationary states for migration and the real wage rate lying on a line of the wage-migration plane (S1-S2) satisfying $\frac{(w_j - T_{ij})E(K_i, w_{i,j})}{w_j + T_{ij}} - F_i \leq M_i \leq E(K_i, w_{i,j}) - F_i$ and $E(K_i, w_i) = (M_i + F_i)$.

The directions of change vary at different points w_i and M_i (figure 2 and figure 3). When there is excess labor supply, the real wage will be decreasing (the horizontal arrows above the employment line 1 are pointing inward). When there is excess labor demand, the real wage will be increasing (the horizontal arrows below the employment line 1 are pointing outward). At a high real wage in *i* the positive net gain of immigration drives a large number of immigrants to move from *j* to *i* (the vertical arrows below the no-immigration line 2 are pointing upward). Conversely with a relatively low real wage in *i* but the high real wage in *j* and a low moving cost, employed workers in *i* will be motivated to return to *j*. So that there will be a positive return migration flow (the vertical arrows to the left of $(w_i = w_j - T_{ij})$ are pointing downward). However the gains to moving do not cover the migration cost if $|w_i - w_j| < 2T_{ij}$ or above the immigration line where the stock of migrants is so high in *i* that the chance of getting a job there is too low. For all such w_i , M_i combinations there is no incentive to move. Piecing this information together gives cyclical paths, crossing between the regions of immigration, return migration and immobility.

Insert Figure 2 and 3 here

Migration flows have different determinants in the different regions of the w_i, M_i plane. However any dynamic path is continuous where it crosses form one region into another. We also have an infinite number of stationary points so that stability analysis of the equilibria is non-standard. We say that any stationary point

x is locally stable if there is an open set S(x) which has x as a boundary point and such that starting from any point y within S(x) that is not itself a stationary point, the path through y converges to a stationary point. Inspection of Figs shows that any stationary point on the interior of S_1S_2 is locally stable in this sense. The most interesting points are at the ends of S_1S_2 . For these points there is such a set S(x) entirely contained within the immobility region and paths within this set will converge to a stationary point. There is also an open set S around the point S_2 entirely contained within the immigration region. Paths starting here will also tend to converge to a stationary point. Similarly there is an open set around S_1 entirely contained within the return migration region.

To see this we can adapt the usual arguments of local stability analysis by computing eigenvalues of the system subject to different dynamics in small areas around S_1, S_2 We can partition a neighborhood N_1 of the stationary point S_1 and a neighborhood N_2 of the stationary point S_2 into three sub-neighbourhoods, each contained within one of the three regions, for example $SM_1 \cup SM_3 = N_1$ and $SM_2 \cup SM_3 = N_2$. Paths which start in SM_1 follow immigration dynamics, in SM_2 return migration dynamics and in SM_3 immobility but with a varying wage. We can then determine local stability of the stationary point by computing the eigenvalues of each part of the dynamic process at points close to the stationary point. For paths starting close to the stationary point and in the immigration regime SM_1 , the Jacobian matrix becomes

$$\begin{array}{lll} when \ \min(1, \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}) &=& \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)} \\ & immigration \ \rightarrow & \left[\begin{array}{cc} \frac{dE}{dwi} & -1 \\ \frac{(dE/dwi)wi+E}{M+F} & \frac{-E}{(M+F)^2} \end{array} \right] = \left[\begin{array}{cc} G_{EE} & -1 \\ \frac{(\eta+1)E}{M+F} & \frac{-E}{(M+F)^2} \end{array} \right] \\ & \eta & : \ \text{ elasticity of labor demand} \\ \text{or when } \min(1, \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}) &=& 1 \\ & immigration \ \rightarrow & \left[\begin{array}{cc} \frac{dE}{dwi} & -1 \\ 1 & 0 \end{array} \right] \end{array}$$

Proposition 7 when $\min(1, \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}) = \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}$, the system of immigration is locally stable if $|\eta| < 1$. when $\min(1, \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}) = 1$, the system of immigration is locally stable.

For the return migration SM_2 and immobility SM_3 cases we can also compute the eigenvalues from the Jacobian of the relevant dynamic process and find that the systems are assured to be locally stable with two negative eigenvalues and to be weakly local stable with one negative real roots and one zero root respectively. The relevant Jacobian matrices are

$$return migration \rightarrow \begin{bmatrix} G_{EE} & -1 \\ 1 & 0 \end{bmatrix}$$
$$immobility \rightarrow \begin{bmatrix} G_{EE} & -1 \\ 0 & 0 \end{bmatrix}$$

Proposition 8 Given that the return migration system (SM_2) and immobility (SM_3) case are locally stable, so the equilibrium at S_2 is locally stable. Thus, If $|\eta| < 1$, then the immigration system (SM_1) is locally stable. Then equilibrium at S_1 is locally stable.

When the moving cost is zero $(T_{ij} = 0)$ the local stability analysis is easier to visualize and formalize (Figure 4 and figure 5). Due to the zero moving cost, the immobility region $(w_j - T_{ij} \le w_i \le w_j + T_{ij})$ converges to a single line $(w_j = w_i)$. But as a result of the bounded employment probability and the moving cost, the dynamic process of migration still differs between the immigration region, return migration and immobility regions. There is a unique stationary point (w_i^*, M_i^*) at the intersection of these three regions. We apply the same half neighborhood methodology to study the local stability for (w_i^*, M_i^*) . Except for the change in the functional form of the dynamic system⁸ and the change in the partition of the neighborhood N of the stationary point $(SM_1 \cup SM_2 \cup SM_3 = N)$, the relevant Jacobian matrices stay the same and the local stability conditions are unchanged. (If $|\eta| < 1$, the equilibrium (w_i^*, M_i^*) is locally stable).

Insert Figure 4 and 5 here

We have an infinite number of stationary points of a dynamic system in the plane whose continuous solution paths can exhibit non-differentiabilities. Existing results on global stability rely on the construction of a Lyapunov function although in general there is no simple way of doing this. However if the space (M, w, K) is compact then any solution path must have a limit and then from the Poincare-Bendixson classification, these limits must be either stationary points, limit cycles or periodic orbits. M, w, K are all bounded below by zero, and population size and finiteness of resources can be taken to bound M, K above. So we can expect a weak form of global stability in that eventually all paths either approach one of the stationary points, or a limit cycle, or one or more of the variables becomes zero⁹. (Figure 6)

Insert Figure 6 here

Time series data from this process will have a richer structure than in the case with a fixed real wage (Figure 7). Net migration should show pronged peaks and troughs arising from immobility due to the moving cost. These will not carry over into the real wage series. With a long data series net migration and the real wage rate should be positively correlated overall but for shorter periods they may move in opposite directions with the real wage tending to lead the net migration series. Both series will tend to be cyclical but within short time intervals the cross auto-correlation between them can change sign.

Insert Figure 7 here

3.3 General framework (model (3)): flexible capital and real wage rate

Finally, we relax the assumption of a fixed capital input. FDI flows respond to the differential between the return in i (the marginal product of capital) and the world real interest rate r. Each of the three variables adjusts to its own partial equilibrium level with $\delta_{x,i} > 0$ (x = w, M, K) the adjustment speed for location i. The dynamic system becomes,

$$M_{i}(t) = \begin{cases} \delta_{m,i}[\min(1, \frac{E(K_{i}(t), w_{i}, (t))}{(M_{i}(t) + F_{i})})w_{i} - T_{i,j} - w_{j}], if \text{ positive (IM)} \\ \delta'_{m,i}[w_{i}(t) - w_{j} + T_{i,j}], if \text{ negative (RM)} \\ 0, \text{otherwise} \end{cases} \end{cases}$$

$$w_{i}(t) = \delta_{w,i}[E(K_{i}(t), w_{i}(t)) - (M_{i}(t) + F_{i})]$$

$$K_{i}(t) = \delta_{k,i}(MPK_{i}(t) - r)$$

$$M_{i}(t) = \begin{cases} \delta_{m,i}[\min(1, \frac{E(K_{i}, w_{i}(t))}{(M_{i}(t) + F_{i})})w_{i}(t) - w_{j}], if \text{ positive}} \\ \delta'_{m,i}[wi(t) - w_{j}], if \text{ negative}} \\ 0, otherwise \end{cases} \end{cases}$$

$$w_{i}(t) = \delta_{w,i}[E(K_{i}, w_{i}(t)) - (M_{i}(t) + F_{i})]$$

$$w_{i}(t) = \delta_{w,i}[E(K_{i}, w_{i}(t)) - (M_{i}(t) + F_{i})]$$

⁹The Inada conditions on the production function will generally ensure M remains positive if F is very small. Similarly the real wage will be bounded above by a finite limiting value of the marginal product of labour.

where $MPK_i(t)$ is the marginal product of capital of region *i* and *r* is the world interest rate at time; $K_i(t)$ is the capital (FDI) inflow.

Since capital is subject to diminishing returns, capital flows continue until the marginal product of capital (MPK_i) is equal to the world interest (r). The marginal product of capital is determined by the technology and labor. In particular the impact of one input on the demand for the other depends on the substitute/complementarity relation between them. If capital and labor are complements, an increase in the capital stock leads to an increase in labor demand. This increase in labor demand shifts the demand curve upward at any real wage, so that more jobs will be created. In turn this raises the probability of employment and attracts more immigrants from j to i. But at the same time, the real wage rate is determined by the labor supply. If the number of immigrants is far higher than the number of job vacancies, there will be excess labor supply which leads to the real wage rate falling. If labor and capital are substitutes, an increase in the capital stock will lead to an decrease in labor demand shifting the demand curve downward, so that more jobs will be destroyed and the employment rate will fall. Then the employed workers in i will be pushed to return to j. If the number of return migrants is very high and over-reacts, then the real wage rate may rise because of inadequate labor supply.

Similar to the w/M space, in the w, K and M space, the definitions for the no-immigration locus and constant real wage rate locus stay the same as in model (2). In addition, here we define the capital locus by values of w, K and M and r satisfying $MPK_i = r$. Also the regions for immigration, return migration and immobility are very similar to those in the two dimensional system, except that each of the three regimes are partitioned into two parts by the capital locus. Within the two elements of each partition there are different signs for capital inflows. The parts located to the right part of the capital locus (with the high real wage rate) have positive capital inflows. While the parts located to the left part of the capital locus (with the low real wage rate) have negative capital inflows.

The dynamic paths in the 3 dimensional space for labor market and migration process are consistent with those in the 2 dimensional space. For example, the real wage is increasing (decreasing) when there is excess labor demand (supply) and there is a positive (negative) immigration flow when the net gain is positive (negative). In addition, the marginal capital product of capital is a decreasing function of the real wage rate. Capital inflows (outflows) to (from) region i when w_i is relatively low (high). Immigration takes off at a high wage rate and a low initial stock of migrants. Especially, in a region with a high employment probability and high real wage rate, the immigration flow will not stop until job creation (driven by capital) and the associated rise in the chance of employment can no longer compensate the relative real wage rate loss (i.e. the net gain of relocation becomes zero). However, a backward region with growing but low initial values for w_i and K_i will not attract immigration but will push people to leave from i to j, despite its growing state. In addition, the labor market in a region with growing wage and capital stock but a high moving cost or a low employment probability will be in an equilibrium state of immobility.

Proposition 9 The no-immigration plane is downward (upward) sloping if labor demand is inelastic (elastic). Stationary states exist when the capital plane ($MPK_i(t) = r$) intersects with the employment plane $(E(K_i(t), w_i, (t)) = (M_i(t) + F_i(t)))$ within the immobility regions ($M_i(t) = 0$) (see two examples: figure a and figure b^{10}).

Proposition 10 If stationary states exist, there will be an infinite number lying on a line defined by $\frac{(w_j - T_{ij}) * E(K_{i,i}, w_{i,i})}{w_j + T_{ij}} - F_i \leq M_i \leq E(K_{i,i}, w_{i,i}) - F_i; E(K_{i,i}, w_{i,i}(t)) = (M_i(t) + F_i(t))$ and $MPK_i = r$ in the three dimensional space.

¹⁰Figure a : Stationary states exist as the capital plane (black) interects with the employment plane (green) within the middle immobility region (wj-Tij $\leq wi \leq wj + Tij$). Figure b : Stationary states exist as the capital plane (black) interects with the employment plane (blue) within the upper immobility region (wi $\geq wj + Tij$).

As in the propositions presented above, if there are stationary points, there are an infinite number of stationary states lying on a line (S1-S2) in the labor-force plane. The stationary point S_1 is the intersection point of the immigration set and immobility set and the stationary point S_2 is the intersection point of the return migration set and the immobility set. However if the intersection of the employment and capital loci have no points in common with the immobility region, then there are no stationary points.

The solution paths are still continuous in this model but again can display kinks where the dynamic regime changes. The configuration of migration regimes is similar to the fixed capital case, but the flexibility of capital adds adjustment possibilities between both migration and capital and between the real wage rate and capital. The latter is always stable for a fixed migration stock. Overall similar phases of a dynamic cycle in migration and the wage rate appear but in addition there is a cycle in capital, and of course these cycles are inter-related (Figure 8, 9 and figure 10).

Insert Figure 8, 9 and 10 here

Again we use half-neighbourhood methodology to study the local stability of S_1 and S_2 . We can partition a neighborhood N_1 of the stationary point S_1 and a neighborhood N_2 of the stationary point S_2 into three sub-neighbourhoods, each contained within one of the three regions, for example $SM_1 \cup SM_3 = N_1$ and $SM_2 \cup SM_3 = N_2$. Paths which start in SM_1 follow immigration dynamics, in SM_2 return migration dynamics and in SM_3 immobility but with varying wage and capital stock. We can then determine local stability of the stationary point by computing the eigenvalues of each part of the dynamic process at points close to the stationary point. For paths starting close to the stationary point and in the immigration regime SM_1 , the Jacobian matrix becomes

$$when \min(1, \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}) = \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}$$

$$immigration \rightarrow \begin{bmatrix} G_{KK} - \frac{(G_{KE})^2}{G_{EE}} & \frac{G_{KE}}{G_{EE}} & 0 \\ \frac{-G_{KE}}{G_{EE}} & \frac{1}{G_{EE}} & -1 \\ -\frac{-G_{KE}}{G_{EE}} & \frac{1}{G_{EE}} & -1 \\ \frac{-G_{KE}}{G_{EE}} & \frac{1}{G_{EE}} & -1 \\ \eta \text{ is the elasticity of labor demand} \end{bmatrix}$$

when
$$\min(1, \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}) = 1$$

 $immigration \rightarrow \begin{bmatrix} G_{KK} - \frac{(G_{KE})^2}{G_{EE}} & \frac{G_{KE}}{G_{EE}} & 0\\ \frac{-G_{KE}}{G_{EE}} & \frac{1}{G_{EE}} & -1\\ 0 & 1 & 0 \end{bmatrix}$

Proposition 11 when $\min(1, \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}) = \frac{E(K_i, w_i(t))}{(M_i(t) + F_i)}$, if $\eta > \frac{wi}{G_{EE}(M+F)} - 1$, the immigration system is locally stable.

As soon as the real wage rate in region j passes the threshold $(w_j = w_i + Tij)$ and w_j is higher than w_i then the employed workers in i are intending to move back to j and the Jacobian matrix becomes,

$$return migration \rightarrow \begin{bmatrix} G_{KK} - \frac{(G_{KE})^2}{G_{EE}} & \frac{G_{KE}}{G_{EE}} & 0\\ \frac{-G_{KE}}{G_{EE}} & \frac{1}{G_{EE}} & -1\\ 0 & 1 & 0 \end{bmatrix}$$

The relevant Jacobian matrix for immobility becomes,

or

$$immobility \rightarrow \begin{bmatrix} G_{KK} - \frac{(G_{KE})^2}{G_{EE}} & \frac{G_{KE}}{G_{EE}} & 0\\ \frac{-G_{KE}}{G_{EE}} & \frac{1}{G_{EE}} & -1\\ 0 & 0 & 0 \end{bmatrix}$$

Proposition 12 The return migration (SM_2) and immobility systems (SM_3) are locally stable, so that S_2 is locally stable.

Proposition 13 The immobility system (SM_3) is locally stable. Then if $\eta > \frac{wi}{G_{EE}(M+F)} - 1$, the immigration system (SM_1) is locally stable. Then S_1 is locally asymptotically stable equilibrium and unique.

Proposition 14 The local stability condition for S_1 is more relaxed in the three dimensional system $\left(\frac{wi}{G_{EE}(M+F)}-1<-1\right)$ than in the two dimensional system.

If $T_{ij} = 0$, can the migrants be more mobile? The answer is no. The zero moving cost makes the immobility region shrink but cannot eliminate it entirely. Because the employment probability is bounded above by unity, even though the moving cost is zero, the system still contains immobility. If *i* has a high real wage due to high levels of capital but also a high stock of migrants then the expected income difference $\frac{E(K_i(t), w_i, (t))}{(M_i(t) + F_i)})w_i(t) - w_j$ can be negative although $w_i(t) > w_j$. The excess labor supply stemming from the existing high migrant stock leads to such a low employment probability that further immigrants are deterred. In general, the function form¹¹ of the system is changed because of the zero cost and with $T_{ij} = 0$ again the set of stationary points shrinks to at most one point. Assuming it exists, its local stability can be analyzed by the "half neighborhood" approach we used above. The stationary point (w_i^*, M_i^*, K_i^*) is at the intersection of the immigration, return migration and immobility regions. If $\eta > \frac{wi}{G_{EE}(M+F)} - 1$, the stationary point (w_i^*, M_i^*, K_i^*) is locally stable.

The remarks on global stability and patterns in the two variable model (with capital fixed) also apply here to the model with flexible capital. Global patterns can be characterized in broad terms but ensuring global stability is likely to require additional assumptions.

With capital and real wage flexibility, the time series (figure 11^{12}) of net migration remains cyclical with extended peaks and troughs. In periods of zero migration capital stock and the real wage rate converge towards a stationary equilibrium conditional on the fixed net migration level. During this convergence, wand K may move in the same or opposite directions. Again over long horizons and also over particular short horizons such as immigration periods, capital and the wage rate will tend to show positive correlation but in periods of zero migration, the correlation between the two could be of either sign. Capital and the wage rate will again tend to lead net migration.

Insert Figure 11 here

11

$$M_{i}(t) = \begin{cases} \delta_{m,i}[\min(1, \frac{E(K_{i}(t), w_{i}(t))}{(M_{i}(t) + F_{i})})w_{i}(t) - w_{j}], if \text{ positive} \\ \delta'_{m,i}[w_{i}(t) - w_{j}], if \text{ negative} \\ 0, otherwise \end{cases}$$

$$w_{i}(t) = \delta_{w,i}[E(K_{i}(t), w_{i}(t)) - (M_{i}(t) + F_{i})]$$

$$K_{i}(t) = \delta_{k,i}(MPK_{i}(t) - r)$$

 12 Figure 11 portrays the generic cyclical pattern of the variables (from the upper middle immobility region into the return migration region, crossing into immigration region and back to the middle immobility region) in the three dimensional space. And the continued generic cyclical pattern is also captured by figure 11 after the vertical dashed-line.

4 Empirical application for Guangdong

Since the open door policy in China and dramatic reforms later in 1978, Guangdong has been singled out as a province for regional development and has experienced the highest volume of cross province net migration (Chinese Population Census, 1990; 1995; 2000; 2005; 2010) within China and in the emerging world (UN, 2011). Especially, the Guangdong SEZs (special economic zones¹³), ETDs (Economic and Technology Development Zones) and COAs (Coastal Open Areas)¹⁴ with favorable government industrial development incentives¹⁵ have attracted a large number of Chinese workers from outside of Guangdong. In addition, rapid industrialization has been facilitated by high FDI (foreign direct investment), especially that arising from the geographical and social proximity to Hong Kong Subsequently, industrial and trade areas have flourished especially around the Pearl River, triggering further high levels of rural-urban immigration from outside of Guangdong. Our aims are:(1) to estimate the dynamic adjustment speeds of the capital flow, the real wage¹⁶ and the net migration flow; (2) to investigate whether different Guangdong cities share homogenous adjustment speeds; (3) to study the simultaneous interactions between FDI, the real wage and net migration flows; (4) to test whether the capital market in Guandong was negatively influenced by the 1997 Asian financial crisis.

4.1 City Characteristics and Data Description

Our empirical estimation covers 21 years (1990-2010) for 16 city areas in Guangdong. For the first 10 years predictions of real wages, net migration and FDI based on a mixture of calibration and estimation will be compared with the sample panel data and for the next 11 years the predicted data projects the dynamic path out of sample. The sample data comes from the Guangdong Statistical Yearbooks for the period 1990-1999 for 16 city areas¹⁷ (Figure 12: Map of Guangdong). From the descriptive statistics, the capital city 1 (Guandong) and the SEZ city 2 (Shenzhen) are the most developed areas within Guangdong province. Especially as a result of the closeness of city 2 to Hongkong, city 2 attracts the highest FDI from Hongkong (Guangdong Statistical Yearbook 1990-1999). The cities within Guangdong cluster into economic groups. The cities centered in the middle are more advanced economy areas (eg, city 2: a financial center; city 10, 12,11 and 13: manufacturing sectors; city 1 and 3: ETDS, COAs). The northern cities are mountainous areas and have concentrations of heavy industry. The landscape of the southern cities is lowland but those cities mainly produce agricultural goods.

Insert Figure 12 here

In our sample data (1990-1999), the net migration (M) data only covers qianyi renkou not the floating

 $^{^{13}}$ The SEZs were chosen as a result of convenient communication and transportation capabilities from and to overseas countries, especially Macao and Hongkong (Ateno, 1979).

¹⁴The special economic zone "can be defined as an area where enterprises are treated more preferentially than in other areas in relation to such matters as the tax rate and the scope of operations in order to attract foreign capital and advanced technology for modernisation" (Ateno, 1979). The ETDZs are Guangzhou1, Shenzhen2, Zhuhai 3and Foshan13. One of COA is located in Guangdong: Pearl River Delta regions.

 $^{^{15}}$ Foreign investment enterprises enjoy 15% income tax in SEZs and ETDZs, 24% in COAs. If the COAs are classified as productive and run for over 10 years, foreign investment enterprises can apply for free taxation for the first and second years and pay tax at half of the normal rate such as 7.5% for the next three years.

¹⁶ The majority of the regional migrants (inter-province migrants) are rural-urban migrant workers in Guangdong (Fan, 1999), so in our calibration we measure the nominal wage income in region i by the urban wage income of different cities in Guangdong $(w_{i,t})$ and the real wage income in region j is replaced by the national real rural income.

¹⁷Guangdong is divided into a maximum of 21 city areas but one of these, Jieyang (city 20) was only established in 1992 taking over some parts of Shantou (city 4). Moreover some parts of Chaozhou (city19) were formerly part of Shantou (city4) before 1992. We merge these 3 city areas into a single unit (city 22). In addition Yunfu (city21) formerly was part of Zhaoqing (city17) before 1994, so we merge Yunfu and Zhaoqing into a single unit (city 23). For the sake of the consistency of geographical units over our sample time period, these two merged units are dropped out of our sample. This leaves 16 city areas.

population in China¹⁸. The qianyi renkou movement (migration) is a spatial movement between previous residence and current destination leading to a change in hukou status and is often identified with permanent migration. The employment (*E*) data covers the three chief workplace organizations of each city - SOEs (state owned enterprises), UCEs (urban collective owned enterprises) and other units¹⁹. The average wage ($w_{i,t}$) of the urban collective owned enterprises of each city is taken as proxy variable²⁰ for the city market wage. This $w_{i,t}$ is then deflated by city level CPI to get the real wage ($\frac{W_{i,t}}{CPI_{i,t}}$). National average rural income ("the rest of the world" in our theory) is deflated by the national CPI ($\frac{W_{j,t}}{CPI_{j,t}} = w_{j,t}$). Due to the geographical closeness and ethnic ties between Guangdong and Hong Kong, the majority of FDI in Guangdong flows from Hong Kong. So the world interest rate (r_{world}) is replaced by the Hong Kong annual rate of return (rHK)²¹ in HangSeng stock market. Capital stock *K* is derived from an initial capital stock, capital flows and a city common depreciation rate ²². The depreciation rate θ for each city is obtained from the Guangdong Statistical Yearbooks for the period 1990-1999.

The scatter diagrams (figure 13) obtained from our sample data over 1990-1999 explain the interactions between the real wage, the capital stock and the number of net migrants by city. The immigrants have a strong propensity to migrate towards the Pearl River cities especially the capital (Guangzhou (1)) and the one SEZ (Shenzhen (2)), where the real wage and capital stock are high. The employed workers in city 12 have a relatively strong propensity to leave, where the real wage rate and capital stock are low. The other regions, in general, indicate positive correlations between w_i , immigration M_i and K_i . In particular regions (the Pearl River delta cities) with a high level of capital stock and a high real wage normally have a high net immigration. Conversely the labor intensive and low urban real wage cities (the northern mountainous and the southern agricultural regions) have a small number of net migrants and a low real wage rate and low level of capital stock. So roughly, the regions in Guangdong are heterogenous between clusters but are homogenous within the same cluster (e.g. city 1 and 2 form one cluster).

Insert Figure 13 here

The time series plots of the sample data (Figures 15a-17c) show continuous growth of capital stock in most cities but at varying rates, however cities 9, 15 and 16 show initial growth but then a downturn in the later years of the sample. Although the sample is short the real wage indicates a cyclical pattern in at least half of the cities. In some cities (6, 9, 10 and 14) the net migration is positive but small and relatively flat indicating that they may be in a phase of immobility, but the other cities show positive growing immigration. Overall though the sample period reflects a relatively short window of immigration. In terms of our theoretical framework, the data only cover part of the dynamics between the three variables.

For the production technology, we use a calibrated Cobb-Douglas $G(K, E) = AK^{\alpha}E^{\beta}$ with A = 1, $\alpha = 0.4705, \beta = 0.5295$. Wu (2000) finds that the total factor productivity in Guangdong typically ranges from 0.9996 to 1.0605 from 1979 to 1997. Thus, A = 1 should be an appropriate value for Guangdong. Also

¹⁸ The floating population (liudong renkou) is a unique concept in China and measures the stock of past migrants who have retained their original hukou status. Liudong renkou is often identified with temporary migration. The qianyi renkou is a measure of flow and is defined as "individuals five years old or older who have moved from one county to another within the past year and (a) whose hukou has changed to the place of residence at the previous year or (b) who had left their hukou location for more than one year" (Fan , 2008).

¹⁹The other units includes units funded by entrepreneurs from Hongkong, Macau and Taiwan, foreign funded units, joint ventures, shareholding units and others (Statistical Yearbook, 1999).

 $^{^{20}}$ This method coincides with Lee (1999), who uses the average wage of the UCEs as proxy variables for market wages to estimate correlation between market wages and firm employment in SOEs in China.

 $^{{}^{21}(\}mathbf{r}_{world})_t = rHK_t = rr - \frac{(P_t - P_{t-1})}{P_{t-1}}$. Where rHK_t is annual return in Hong Kong stock market; $\frac{(P_t - P_{t-1})}{P_{t-1}}$ is inflation

rate for Hong Kong and is taken from world bank (http://www.worldbank.org/); rr is calculated by author and is take from HangSengIndex (http://uk.finance.yahoo.com/q/hp?s=%5EHSI).

 $^{^{22}}K_{t+1} = (1 - \theta)K_t + FDI_t$, where θ is the depreciation rate.

his empirical estimation suggests that $\alpha = 0.4705, \beta = 0.5295$. No other studies on Guangdong cities are available, so we apply city-invariant values α and β for all cities. In terms of the theoretical framework, a Cobb-Douglas always has an elastic labour demand and so we should expect to predict the corresponding cyclical patterns of the relevant theoretical phase diagrams and time series plots.

4.2 Empirical estimation of adjustment speeds

Given the values of two exogenous variables rHK(t) and $w_j(t)$ over the period 1990-2010, it is now possible to calculate the dynamic path for capital stock $(K_i(t+1))$, real urban wage $(w_i(t+1))$ and the net migration stock $(M_i(t+1))$. The dynamic system starts from historically given actual values²³. The estimated dynamic system is a extension of the model (3) of equation (3),

$$K_{i}(t+1) = (1-\theta_{i})K_{i}(t) + K_{i}(t)$$
(4)

$$w_{i}(t+1) = w_{i}(t) + w_{i}(t)$$
(5)

$$M_{i}(t+1) = M_{i}(t) + M_{i}(t)$$
(7)

$$i = 1..16; t = 0..20$$

where $K_i(t) w_i(t) M_i(t)$ are defined in the general model (model (3)); $K_i(t+1) w_i(t+1)$ and $M_i(t+1)$ are the capital stock, the real wage and the net migration stock at time t+1 for city *i*; the index *i* stands for the 16 cities within Guangdong province.

The three adjustment speeds for each city are estimated by the method of moments (Sims, 2010; Ruge-Murcia, 2007), to match the means of the sample data to the predicted means of the model. Formally, let m^* be a $k \times 1$ vector of data moments. Let $m(\Theta)$ be the vector of those same moments from the model evaluated at a given set of adjustment speeds such as $\Theta = [\delta_1, \delta_2, \delta_3]$. Let W be a $k \times k$ matrix, for simplicity we choose an identity matrix. The GMM estimate of the model's parameters (adjustment speeds) is

$$\Theta^* = \arg\min(m(\Theta) - m^*)'W(m(\Theta) - m^*)$$

The adjustment speeds for K, M and w effectively minimize the sum of squares of deviations between the model data and the first moment over 1990-1999. Given the estimated adjustment speeds, predictions of K, w and M come from the model for the sample period 1990-1999 and the projection period 2000-2010.

Figures 14a - 14c show that the adjustment speeds for capital and the net migration are consistent with the scatter diagrams (figure 13), suggesting that city 1 and 2 can be clustered with rapid adjustments. The remaining cities are very different from these two cities and have low adjustment speeds. However, figure 14c shows that the adjustment speeds for the real wage rate in Guangdong are rather dispersed. Roughly, the advanced regions with high FDI (cities 1&2) still have high values for the adjustment rate of w_i , manufacturing centers (city 3 and 13) have moderate values while the less developed regions share low values. An exception is cities 5 and 16 which have a low initial level of w_i but have high adjustment speeds for the real wage rate.

Insert Figures 14a-14c here

For the dynamic adjustment speeds for capital (figures 15a-15c), the dynamic adjustment speed of capital (0.95) is very high and is close to 1 in the capital intensive regions (city 1 and 2). A one unit increase in

 $^{{}^{23}}K_{i,1} = (1-\theta)K_{i,0} + FDI_{i,0} = 0 + K_{i,0}; (\frac{w}{P})_{i,1} = (\frac{w}{P})_{i,0} + (\frac{w}{P})_{i,0}; T_{i,j,t} = 0.5wr_t; M_{i,1} = M_{i,0} + M_{i,o}.M_{i,0} = 0.$ For simplicity, $F_{i,t}$ is set equal to $2.8E_{i,t}$.

the capital return gap $(\alpha A K_{i,t}^{\alpha-1}(E_{i,t})^{\beta} - rHK_t)$ leads to 9.5 billion yuan FDI inflows into Guangzhou and Shenzhen. In the moderately developed regions, the adjustment speed of FDI varies between 0.09 and 0.2. In manufacturing centers, the sensitivity of FDI inflow to the capital return gap $(\alpha A K_{i,t}^{\alpha-1}(E_{i,t})^{\beta} - rHK_t)$ is moderate. The value of 0.2 is low but far bigger than that of the less developed regions, where FDI adjusts at a very slow speed (0.01 and 0.003). Particularly the values of the capital adjustment speed in Heyuan(6) and Yangjiang (14) are 0.003 so that capital only reacts marginally to a change in the capital return gap. So the adjustment speeds are heterogenous in Guangdong but are homogenous within the same cluster of cities. In the next 11 years the estimated model predicts that FDI will continuously flow from Hong Kong to Guangdong.

Insert Figures 15a-15c here

For the dynamic adjustment speeds for net migration (figures 16a-16c), the capital Guangzhou(1) and the ETDZ (Shenzhen(2)) cities have relatively fast migration adjustment speeds (0.08 and 0.04 respectively) The SEZ cities (Zhuhai(3) and Foshan(13)) have moderate sensitivity to the net gain $\left(\frac{E_{i,t}}{M_{i,t}+F_{i,t}}\left(\frac{w}{P}\right)_{i,t}-T_{i,j,t}-(wr)_t\right)$. Region (Huizhou(8)) shows its potential attraction for rural migrants from outside of Guangdong. The remaining regions are not very sensitive to the wage gap and migration adjusts at slow speeds. An overall low adjustment speed for migration reflects institutional features such as barriers to internal labor movement in China. Recognizing the special Hukou system in China, permanent rural migration means a change of a resident's household registration record from rural to urban areas during migration and this change is restricted by government.

Insert Figures 16a-16c here

The real urban wage in less developed regions shows more or less the same sensitivity (average adjustment speed 0.015) to the change in employment vacancies $(E_{i,t} - (M_{i,t} + F_{i,t}))$, except that capital city (1:Guangzhou), the financial center (city 2) and the manufacturing cities (3, 13) are more sensitive to the change. Compared with the adjustment speeds for capital, the generally low value of the adjustment speed (figures 17a-17c) is a perfect reflection of sticky wage rates in China²⁴. Real wages in the chief three employing organizations are not flexible and the sensitivity to the change in employment vacancies is generally low. The predictions show that this low sensitivity will continue in the next 11 years but the real wage will be growing slowly.

Insert Figures 17a-17c here

In general, we can see that the values of migration adjustment speeds are relatively high in cities for which FDI inflows and the real wage rate occur at a fast speed. This is in line with our hypothesis that FDI has a positive effect on migration and represents an incentive for migration. The increase in the accumulation of capital positively influences wage rates and migration. In our empirical analysis, the scatter diagrams suggest positive correlation between capital flow, the real wage rate and migration flow. The estimation of adjustment speeds indicates the positive interaction between those three endogenous variables. Also the findings of our calibration reveal a complementarity relation between FDI, the real wage and internal labor mobility in Guangdong, but relatively low adjustment speeds for w and M. In this context policies directed towards increasing capital accumulation and relaxing the institutional barriers (or government intervention) have a twofold effect: the adjustment speeds of migration and the real urban wage will be increased. Moreover, the urban real wage and labor absorption capacity will be increased as well.

 $^{^{24}}$ This argument is consistent with Ning's (2008) empirical findings. He uses the panel data of 31 province in China over 1993-2005 to analysis the level of flexibility of wage in China and he finds that the eastern costal areas' (e.g. Guangdong) wage is sticky.

The projections both within and out of sample clearly reflect the fact that the data primarily cover a period of immigration and hence in terms of the phase diagrams we are in a relatively high real wage zone with a relatively low initial stock of migrants. So generally the projections are of further capital growth and immigration. It would be interesting to repeat the empirical analysis for longer samples experiencing emigration and/or immobility.

5 Conclusion

The simultaneous interactions between three endogenous variables (FDI, real wage and net migration) which we developed in the theoretical sections are well captured by the empirical evidence. For our theoretical framework, we start from a benchmark model in the short run, in which the employment is determined by a fixed real wage rate and fixed capital input in the representative firm's profit maximization process. Net migration is then determined by the expected income gap between regions. Based on that, we extend the time period to the medium run in which the real wage is flexible, and adjusts according to the partial equilibrium of labor demand and labor supply in the host country i. Finally, we allow the capital (FDI) to adjust dynamically following the time path of the marginal product of capital in country *i* and the world interest rate at time t. Our migration theory not only includes the determinants of one way migration (immigration) found in the existing literature, but also considers two way migration (immigration and return migration) and labour immobility arising from the migration cost. Importantly, our paper is the first to recognize that the moving cost causes inherent regime shifts between immigration, return migration and immobility in the dynamic migration process. The non-smoothness and non-differentiable properties of solution paths mean that we extend the standard methods of local stability analysis to take accounts of these special features. This approach should have wider applicability than the present context; in particular any market with a similar switching cost should exhibit that same possibility of immobility and regime shift, thus necessitating the local stability methods used here. The elasticity of labor demand plays an important role in immigrants' extensive margin decisions, in the global dynamics and in the local stability conditions. The stationary states for the three dimensional system exist when the capital plane intersects with the employment plane within the immobility region. When they do exist, there is an infinite number of stationary states lying in the immobility region and along the intersection of the equilibria in the labour and capital markets..

For our empirical work, the scatter diagram (Figure 13) indicates potentially positive simultaneous interactions between the three endogenous variables. Regions with high levels of capital stock and high real urban wage rates (the Pearl River delta cities especially city 1 and 2) normally have a high number of net migrants. While the labor intensive and low urban real wage rate cities (the northern mountain and the southern agricultural regions) have a small number of net migrants. So the regions in Guangdong are heterogenous but are homogenous within the same cluster. Also the dynamic adjustment speeds in different variables are positively related. The places with high capital flow adjustment speeds have high values for migration adjustment and relatively fast real wage adjustment. The backward places with slow capital adjustment speeds normally show low values for the adjustment speeds of the migration and real wage. Compared with the adjustment speeds for capital, the overall relatively small value for the real wage and the migration adjustment speeds in Guangdong can be explained by institutional barriers such as the hukou system and the government interventions. These suggest that Guangdong is still in the transitional process to a market system and moving barriers especially the hukou system constrains labour mobility. Also we find that the capital market in Guangdong has not been negatively affected by the 1997 Asian financial crisis. This result is consistent with current results supported by the research on the impact of FDI in China (Pan, 2003).

The novelties of our theoretical and empirical work suggest some further studies. For example, the heterogeneity of migrants can be considered in our model. Within the conceptual framework of the Roy

model and self-selection matching, the high skilled and productive individuals tend to relocate themselves in regions which match the earnings with their skill level. One research question is will the high educated workers move to the place/region with high adjustment speeds of capital and real wage? Will the low educated or low skilled migrants choose to move to the backward regions or to return to their origins? Will the adjustment speeds for different skilled migrants be different? All these questions need to be answered by the further research. Also in the 2002 China household income project data set, 65 per cent of the migrants go to the urban sector to set up their own business and become self-employed and most of them borrow funds from the family for the start up costs of a business. But there is no theoretical framework on "selfemployment and migration", the only empirical work we know of is in Giulietti et. al. (2011). So theoretical research on this topic will be promising. There are also interactions between migration and human capital accumulation, Sjaastad (1962), which gives a fuller context to the costs and returns of migration.

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7 Appendix



Figure 1



Figure 2



Figure 3



Figure 4









Figure 7







Figure 11



Figure a





Figure 12 Map of Guangdong

Figure 13



Figure 14a

Figure 14b

City 3:Zhuhai ******************************

5

5

year

× varK • K(0.13)

year

× varK • K(0,2)

City 8:Huizhou

10 15 20

10 15 20



Figure 14c

Figure 15a Adjustment speeds for capital inflow(FDI)



Figure 15b Adjustment speeds for capital inflow(FDI)



Figure 16a Adjustment speeds for the net migration flow



Figure 16c Adjustment speeds for the net migration flow





NM: real value; M:calibrated value; M(adjustment speeds)

Figure 16b Adjustment speeds for the net migration flow



Figure 17a Adjustment speeds for the real wage



Figure 17b Adjustment speeds for the real wage Figure 17c Adjustment speeds for the real wage