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Full Length Research Paper

Portfolio balance approach: An empirical testing

Aima Khan* and Zaheer Abbas

Faculty of Management Sciences, International Islamic University Islamabad, Pakistan.

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Exchange rate plays vital role in an economy and thus has gained much attention in the literature. The purpose of the study is to test the portfolio balance approach which proposes that money supply and bonds of a country impact its exchange rate. For this purpose, Augmented Dickey Fuller and Phillips Perron test have been applied on the quarterly data from 2001 to 2010 to test the stationarity of the data. Auto regressive distributed lag model has been used to analyze the data. Results validate the empirical evidence and reveal that long term relationship is found among the variables. Money supply of US, money supply of Pakistan and bonds for US are having an impact on the exchange rate of these countries.

Key words: Portfolio balance approach, exchange rate, money supply, bonds, balance of payments.

INTRODUCTION

Determination and forecasting of exchange rate has been widely investigated by academics and practitioners through different models and theories. It is because exchange rate plays fundamental role in any economy especially in international trade and competitiveness in the global market. Fluctuations in exchange rate create uncertainty which makes decision making and profit anticipation difficult. Therefore, both financing and investing decisions are affected by the exchange rate uncertainty. On the other hand, if exchange rate is stable, it gives a sense of confidence to the investors and financial resources can be efficiently utilized. This, in turn moves investments to capital markets through which economic opportunities can be exploited, which leads to economic growth (Damankeshideh and Shanasaei, 2013).

Determination and forecasting of exchange rate has involved many theories which include mainly purchasing power parity, balance of payments approach (BOP), monetary approach and portfolio balance approach. Before theintroduction of monetary approaches in 1970, trade flows were considered the main determinants of exchange rate. Therefore, BOP approach was important as it captures the impact of current account. However, due to liberalization, markets for financial assets gained more importance and models having the asset approaches are now more successful in explaining the determinants of exchange rate. These approaches include monetary and portfolio approaches.

The portfolio approach is an extension of monetary

*Corresponding author. E-mail: Aimamhkhan@yahoo.com.

model. The monetary approach assumes monetary factors impact the demand and supply of money and determine the equilibrium exchange rate. Wide empirical investigations of this approach include mix results about the theory such as Zettelmeyer (2003) and Rapach and Wohar (2004). Portfolio balance approach towards determining exchange rate widens the monetary approach by including financial assets such as bonds in it. The portfolio balance approach (Mckinnon, 1969) recommends that besides monetary factors, holding of financial assets also influences the exchange rate. Financial assets include local and foreign bonds. This approach is based upon two financial assets, money and bonds (local and foreign). This approach assumes that the relative supply and demand of money and bonds determine the equilibrium exchange rate between two countries.

According to this approach, exchange rate establishes an equilibrium in the investor portfolio (including the money, local and foreign bonds) in such a way that if there is a change in any one of these three assets, investor reestablishes the desired balance in his portfolio. This rebalancing process needs adjustment which influences the demand for the asset and in turn exchange rate. For example, if interest rate on foreign bonds increases, it would increase the demand for the asset, increasing demand for foreign currency and depreciating local currency (Sharan, 2012 (p.98)). Foreign money and bonds are substitutes for local money and bonds. Therefore, if demand for local currency rises, it appreciates the price of local currency. In the same way, increase in demand for local bonds positively affects local currency. When demand for local bonds increases, local currency appreciates. The role of interest rate is ambiguous in this theory as it plays role in the demand of money and assets. There are few focused treatments on portfolio balance approach (Cushman, 2007). This suggests the need to test the model empirically and its validity is yet an unsettled issue and is the centre of discussion in this paper.

The objective of this study is to test the portfolio balance approach on the bilateral exchange rate of Pakistan and US by using their money supplies and bonds. There is no consensus about the model in the literature and is still under evolution. Therefore, there is need to test the validity of the model empirically. As this model might have not been tested in Pakistan before, the validity of the model in Pakistan has been tested in this paper by using auto regressive distributed lag model. This empirical testing would provide the evidence on determinants of exchange rate and thus would have implications for policy makers.

The paper is organized as follows; section 2 describes the literature review, section 3 discusses the data collection, section 4 tells about the methodology, in section 5 results are reported. In last section conclusion and limitations are given.

LITERATURE REVIEW

Monetary approach in exchange rate determination is of very importance and studied extensively in literature. The portfolio balance approach is said to be an extension of monetary approach. Work on monetary models includes Frenkel (1976) who studied the models of exchange rate determination and investigated the monetary view of determination and found favorable results. Applying monetary models on small economies leave many puzzle responses regarding the impact of monetary shocks. To resolve the issue, another model is suggested by Cushman and Zha (1997) and applied on Canada with encouraging results. Research on Australia, New Zealand and Canada reveal interest rate, being monetary policy tool impacts exchange rate directly. Contraction leads to appreciation in exchange rate (Zettelmeyer, 2003). Furlani et al. (2010) found monetary policy of Brazil does not take into account the fluctuations of exchange rate and economy adjusts shocks induced on exchange rate. Imposing the restriction of the long run on monetary models, monetary aggregates are found to be in proportion to the exchange rates of pound, deutsche mark, Italian lira and French franc (Diamandis and Kouretas; 1996). Bilson(1978) revealed the behavior of DM/pound estimated by monetary model is valid. Mussa(1984) tested the Schematic asset price model and revealed the model explained the deviations from PPP caused by overshooting of exchange rate due to monetary disturbance.

Some studies,however, found no or little evidence for the validity of monetary models. Such as,Rapach and Wohar (2004) found no evidence in support of monetary models. Macdonald and Taylor (1992) surveyed the views on exchange rate determination which are monetary and portfolio approach. Sarantis (1994) tested long run monetary model on bilateral exchange rate and found negative results. The balance of payments also gained attention in literature and was tested empirically (Johnson, 1972).

Portfolio equilibrium approach also called asset approach has been studied extensively for the past few decades in literature and has undergone many changes. The validity of the approach has been tested in many ways by testing it empirically for purposes. For example, the impact of foreign and local bonds holdings by UK residents on pound sterling value by using asset market model on bilateral exchange rates reveal pound behavior well (Sarantis; 1987). Zietz (1994) emphasized on the clear graphical representation of the model to make clear evident the forces in the model and provide graphs for every asset of the model. The demand in US for foreign direct assets in the country and abroad using portfolio

model and VRP has been tested by Parachowny (1972). Cushman (2007) employed portfolio balance approach on the Canadian-US exchange rate and also tested it for out of sample forecasting. Under certain assumptions, the model was able to beat random walk models. Portfolio model for expected change in prices was tested by Gupta (1970) and results confirm a structural shift in expectations in the last two decades. Use of portfolio approach for the inter-organizational collaboration in order to make innovation strategies effective has been suggested strongly by Faems et al. (2005).

Many improvements and explanations have been given for the portfolio model which includes study by Dooley and Isard (1983). They used the portfolio model to solve issues regarding the exchange rate which have not been solved. Although exchange markets are inefficient, little evidence for risk premium existence was found and observed changes in exchange rate are mostly un-expected. Driskill (1980) also discusses the new portfolio approach incorporating asset equilibrium to test the model empirically and reveal that exchange rate is not determined in any single market but all markets play role in it. Portfolio approach defines devaluation in a better way (Boyer,1977). Another extension of model was done by Alami (2001), which distinguished the dollarization to currency substitution in portfolio balance approach and stated this division would help identify where to add these deposits in money supply. Some modifications in Branson et al. model such as assumption of small economy, one tradable asset and equilibrium in financial markets are suggested. Applied these assumptions in true spirit, results are better than those of conventional models (Bisignano and Hoover, 1982). Proposal for extending the two asset model to three was put forward by Rinshaw (1967) and further to be applicable, a method for a simple index for investors for three asset model was also given by him.

Combining the portfolio balance approach with monetary models was done by Sinn (1983) who incorporated the portfolio balance approach into IS-LM keynesian model under the flexible exchange rate regime and compared with capital movement hypothesis. The volatility of exchange rates on the basis of fundamentals by using model of exchange rate to test whether they produce the same results has been explored by Gros (1989). Integration of monetary model with portfolio model with adding risk premium also give significant results (Frankel, 1984).

Use of portfolio approach for explaining related variables or phenomena have been in literature. For example, Kouri and Porter (1974) studied capital flows by developing a model for it from portfolio model with fixed exchange rate assumption. Investigation on the two-tier exchange rate system using portfolio balance approach reveals that two-tier exchange market could save an economy from disturbances under certain assumptions in the short run (Marion, 1984). Frankel and Froot (1990) studied the intervention of foreign exchange by separating it into portfolio effect and expectation effect. Estimation resulted in significant results for both effects. The currency substitution has been tested using portfolio model and reveals when local currencies devalue, economic agents prefer foreign currency (Thomas, 1985). McCord and Tole (1977) tried to explain in simple form the quantification of risk being an important part in portfolio balance to provide ease for understanding by investors. Betas for measuring risk are not satisfactory. Martin and Masson (1979) applied portfolio model to open economies including data for many countries. The model suggested that for short run equilibrium, all countries should be creditors in dollar currency bonds as the whole data is used in dollars. Doolery and Isard (1979) studied portfolio balance approach in the perspective that current account imbalance can impact the exchange rate. Appreciation in exchange rate is equal to the observable forward premium and exchange risk premium which is unobservable. Applying the portfolio model to an economy which trade in money assets and commodities reveal if exchange rate is flexible, change in money stock would cause change in exchange rate. Under the fixed exchange rate, if currency depreciates, it would cause an increase in money stock with a proportion (Frenkel and Rodriguez, 1975).

Criticisms include weaknesses in the Mackinnon's model. They include many but important are whether it is a short term or long term model and also assumptions regarding policy impact, interest rates and behavior of firms are criticized and an improved model is suggested (Girton, 1972). Mckinnon's and results by Mathieson have been criticized for not capable of being applied to the large economies. Large countries' money supply could be affected by changes in stock assets and interest rate changes (Enders,1977).

Data Source

Data for the variables used in this study were taken from International monetary fund's website from International financial statistics. Variables used in this paper include money supply for Pakistan's currency, money supply for US currency and bonds of US. Data for bonds of Pakistan were not available. Exchange rate which is dependent variable has been used in indirect form.Data were used quarterly from 2001 to 2010.

METHODOLOGY

Unit root test

Unit root test checks for the stationarity of data, which means that data are having no trend or there is no autocorrelation in the series.

In this paper, Augmented Dickey fuller test (Dickey and Fuller, 1981) and Phillips Perron test(Phillips and Perron, 1988)were employed to test whether series is stationary or not. If the data is stationary at level, regression can be employed to test the long term relationship. If this is not the case, data is tested for stationarity at the first or second difference. If the data is not stationary at one level, Ordinary Least Squares is not appropriate. Then Auto Regressive Distributed lag model might be more appropriate. ADF works as under as follows:

$$\Delta Y_t = \beta_1 . Y_{t-1} + \beta_2 . \Delta Y_{t-1} + \epsilon_t \quad (1)$$

In the above equation, if B_1 is equal to zero, it means the data is stationary and no trend is found in the data.

Auto regressive distributed lag model

As the data in the equation do not become stationary at any one level, auto regressive distributed lag model has been employed as it seems more appropriate for such kind of data. In this model, lagged values of dependent variable are included as regressors due to theoretical basis of the model. Lagged values of explanatory variables are also included in the model.Addition of lagged variables normally corrects any serial correlation in the errors. It is because the error term in the equation includes all the omitted variables that affect the dependent variable. In ARDL, the lagged term carries the effect of omitted variables and thus reduces the possibility of serial correlation in the error term (Box et al., 2014; p.89).

$$y_t = \alpha + \alpha_1 y_{t-1} + \beta_0 x_t + \beta_1 x_{t-1} + u_t \quad (2)$$

$y_t$is the dependent variable and y_{t-1} is its lag value in equation no.2. $X_t$is the explanatory variable and x_{t-1} is its lagged value. $u_t$stands for error term.

Thus the model used in this equation becomes,

$$d(E.R) = \alpha + \beta_1 d(E.R)_{t-1} + \beta_2 d(E.R)_{t-2} + \beta_3 (M^p) + \beta_4 (M^{us}) + \beta_5 (USB) + \beta_6 d(M^p)_{t-1} + \beta_7 d(M^p)_{t-2} + \beta_8 d(M^{us})_{t-1} + \beta_9 d(M^{us})_{t-2} + \beta_{10} d(USB)_{t-1} + \beta_{11} d(USB)_{t-2} + \beta_{12} (M^p)_{t-1} + \beta_{14} (M^{US})_{t-1} + \beta_{15} (USB)_{t-1} + \beta_{16} (E.R)_{t-1} \quad (3)$$

In the equation no.3, exchange rate has been denoted by “E.R”. Money supply for Pakistan has been denoted by “M^p” and for US with “M^{us}”. “USB” represents the bonds of US.

Wald test

Wald test is used to approximate the actual value of the parameters based on the sample estimates when the link among the variables can be represented as a statistical model and parameters are to be projected from that sample. Wald test is a test of parametric statistics having variety of uses. It is used to estimate the value of parameters when based on estimates of sample. Here it is used to test the ARDL results by calculating value of F-statistics. For analysis, Pesaran et al. (2001) table has been used for critical values of upper I(1) and lower I(0) bounds.

ANALYSIS OF RESULTS

Unit root test

Unit root test has been applied to test for the stationarity of the data. Results are shown inTable 1.

Results in the table from Augmented Dickey Fuller and Philips Perron test show that exchange rate is not stationary at level and becomes stationary at first difference. Using ADF, exchange rate becomes stationary at first difference with test statistics -3.59 at first difference. Money supply for Pakistan is not stationary at level as test statistics is -0.808 and becomes stationary at first difference with t-statistics of -4.13. Money supply for US is not stationary at level and becomes stationary at first difference with a test statistics of -6.29. The only variable of bonds for US is stationary at level with test statistics of -3.40. Therefore, three variables are stationary at first difference whereas one is stationary at level. The same result is validated by Phillips-Perron test as can be seen from the table as well. As the variables become stationary at different levels, autoregressive distributed lag model has been used to test the long-term relationship.

ARDL RESULTS

Auto regressive distributed lag model has been employed to test the long run relationship between the dependent and independent variables.

Overall, the fitness of the model is good. R-square for the model is 82%. It implies that 82% of the variation in dependent variable is being explained by the independent variable.Adjusted R-square of the model is 69% which means that 69% of the variation in dependent variable is being explained by independent variables after taking into account the degrees of freedom.Wald test has been applied on the estimated coefficient values (Table 2) of the dependent and independent variables with one lag to calculate the F-statistics of the model.

Results of Wald test show that the value of f-statics is 7.306. Value of F-statistics is in the Upper bound values of unrestricted intercept and no trend at 1% significance level (Tables 3 and 4). At 5 and 10% level, F-statistics is greater than the critical values. However, in case of unrestricted intercept and restricted trend, value of F-statistics is greater than critical values at 1%, 5% and 10% levels. It implies the rejection of null hypothesis which means that there is long term relationship between the variables. Therefore, results of auto regressive distributed lag model reveal that long term relationship is found between the dependent and independent variables.

Thus, applying the ARDL model to empirically test the portfolio balance approach in Pakistan and US exchange rate, it is found that the model is better able to explain the exchange rate determinants as assets of the countries also play role in the determination of the exchange rate. It confirms that as implied by the monetary approach, the demand for currency of a country also plays role in the exchange rate determination and along with that bonds of a country also play role in exchange rate determination.

Table 1. Unit root test.

Variables	Augmented Dickey Fuller test statistics		Phillips-Perron test statistics	
	Null hypothesis: Variable has unit root		Null hypothesis: Variable is has unit root	
	Level	1st Difference	Level	1st Difference
Exchange rate	-0.3381	-3.5901	0.21	-3.59
Money Supply of Pakistan	-0.808	-4.13	-0.39	-12.98
Money supply of US	0.69	-6.29	0.46	-5.46
Bonds of US	-3.40	-6.72	-3.39	-9.75
Critical Values	1%	5%	10%	
	-3.61	-2.94	-2.60	

Table 2. ARDL estimation.

Variable Description	Coefficient	T-statistics	P-value
C	0.043115	0.659632	0.5167
DER(-1)	0.063105	0.305929	0.7627
DER(-2)	0.118992	0.638574	0.5300
PAKM2	0.006650	2.355111	0.0283
USM2	0.011472	1.839697	0.0800
BONDUS	-3.07E-15	-2.804852	0.0106
DPAKM2(-1)	0.008459	2.320983	0.0304
DPAKM2(-2)	0.002501	0.742931	0.4658
DUSM2(-1)	-0.005530	-0.688516	0.4987
DUSM2(-2)	-0.008097	-1.682093	0.1074
DBONDUS(-1)	3.87E-16	0.277490	0.7841
DBONDUS(-2)	2.29E-16	0.197321	0.8455
PAKM2(-1)	-0.007574	-2.666590	0.0144
USM2(-1)	-0.011966	-2.143738	0.0439
BONDUS(-1)	-2.45E-16	-0.145903	0.8854
ER(-1)	-0.178482	-3.656289	0.0015
R-squared		0.822973	
Adjusted R-squared		0.696526	
F-statistic		6.508414	

Table 3. Wald test.

Test Statistic	Value	Probability
F-statistic	7.306744	0.0008

Table 4. (Pesaran et al.(2001).

	Case III(unrestricted intercept and no trend)		Case IV(unrestricted intercept and restricted trend)	
	I(0)	I(1)	I(0)	I(1)
Critical values at 1%	6.84	7.84	6.10	6.73
Critical values at 5%	4.94	5.73	4.68	5.15
Critical values at 10%	4.04	4.78	4.05	4.49

The model is being well explained as explanatory variables are being able to explain the explained variable more than 80%. Therefore, assets of a country should also be considered while trying to forecast the exchange rate. It is because change in the demand and holding of bonds would also affect the exchange rate and if this factor is ignored the exchange rate forecasting might not be correct. Thus, the results of the model provide empirical validity of the portfolio balance approach.The results are consistent with many other studies confirming the portfolio balance approach (Frankel, 1984; Sarantis, 1987).

Conclusion

The paper has investigated the portfolio balance approach empirically to test its validity. The portfolio balance approach is an extension of the monetary models and considers the impact of bonds which are part of portfolio investments in capital accounts of balance of payments on exchange rates. The model has been tested in the literature but there is no consensus on its empirical evidence. Moreover, there is lack of empirical evidence in case of Pakistan. Therefore, using the data for money supply of US and Pakistan and bonds for US the model has been tested. Data for bonds for Pakistan was not available. Data has been used quarterly from 2001 to 2010. Augmented Dickey Fuller test and Phillips Perron test revealed exchange rate, money supply for Pakistan and money supply for US were stationary at first difference and bonds for US were stationary at level. As the variables were not found stationary at one level, auto regressive lag distributed model has been used. Wald test has been used to find the F-statistics value by imposing restrictions on the coefficients estimated by the model. The results reveal that long term relationship is found between the dependent and independent variables. It implies that money supply of Pakistan, money supply of US and bonds of US are impacting the exchange rate of Pakistan and US.Therefore, to keep exchange rate stable for the benefit of the economy, these variables should be controlled.

The results of the model have implications for the academicians, practitioners and policy makers. For policy makers, it is important to know which factors affect the exchange rate in order to maintain exchange rate stability. Moreover, they are especially important for the businesses dealing multi-nationally because exchange rate movements influence their decisions such as hedging, financing and borrowing etc.

LIMITATIONS AND SUGGESTIONS

Every study has certain limitations. The study has tested the portfolio balance approach only using data for the one country. The theory needs to be tested on more countries to test the validity of the model. As exchange rate is playing very important role in the economy, identification of factors impacting it is important for policy making and other purposes. Moreover, this identification can be taken into account in trying to keep exchange rate stable by controlling the variables impacting the exchange rate.

Conflict of Interests

The authors have not declared any conflict of interests.

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Full Length Research Paper

Population growth and gender time distribution in a small-open growth model

Wei-Bin Zhang

Ritsumeikan Asia Pacific University, 1-1 Jumonjibaru, Beppu, Japan.

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This study proposes an endogenous population economic growth model with gender time distribution between work, children fostering and leisure. It deals with nonlinear dynamic interdependence between the birth rate, the mortality rate, the population, wealth accumulation, and time distribution. We model the production side and wealth accumulation on the basis of the Solow model. The population dynamics is influenced by the Haavelmo population model and the Barro-Becker fertility choice model. The different growth mechanisms are integrated in a compact framework by applying the utility function proposed by Zhang. We simulate the model to demonstrate existence of equilibrium points and motion of the dynamic system and examine the effects of changes in the effects of changes in the propensity to have children, woman's propensity to pursue leisure activities, and woman's human capital.

Key words: Endogenous population, small-open economy, propensity to have children; birth and mortality rate, gender time distribution.

INTRODUCTION

The purpose of this study is to examine dynamic interdependence between endogenous population growth, wealth accumulation, and gender time distribution among work, children fostering and leisure activities. The model is a synthesis of some well-known approaches in economic growth theory and population dynamics. We deal with dynamic interactions between wealth and population dynamics for a small-open economy.

The economic aspects of this paper are strongly influenced by the neoclassical growth theory (Solow, 1956). We follow the Solow model in modeling economic production and wealth accumulation. We deviate from the Solow model in modeling behavior of households. We analyze household behavior by the approach proposed by Zhang (1993). Since Malthus published his *An Essay on the Principle of Population* in 1798, economists have made great efforts in revealing dynamic complexity of population change. Modern economies have experiences un-precedented population dynamics (such as aging and declining fertility rates in developed economies). This research treats birth rate and mortality rate as endogenous variables. Barro and Becker (1989) examine an interaction between endogenous fertility and economic growth in an overlapping generation model.

E-mail: wbz1@apu.ac.jp

Acemoglu and Johnson (2007) try to analyze the impact of life expectancy on economic growth. Aging become a great concern in many modern economies. Given the population structure, aging is closely related to mortality rate. Lancia and Prarolo (2012) propose a model of the longevity of life and economic development. Our study is strongly influenced by the literature of the neoclassical growth theory and the literature of population growth and economic developed. A unique contribution of this paper is to model population growth in the framework of the Solow growth model with endogenous wealth accumulation and gender time distribution. The physical capital accumulation is built on the Solow growth model. The birth rate and mortality rate dynamics are influenced by the Haavelmo population model and the Barro-Becker fertility choice model. We synthesize these dynamic mechanisms in a compact framework, applying an alternative utility function proposed by Zhang (1993). The model is actually a synthesis of Zhang's two models. Zhang (2012) develops a growth model of a small-open economy. Zhang (2014) develops a growth model with endogenous population without considering gender issues. The paper is organized as follows. Section 2 introduces the basic model with wealth accumulation and human capital accumulation with government subsidy on education. Section 3 simulates the model. Section 4 carries out comparative dynamic analysis with regard to some parameters. Section 5 concludes the study.

The basic model

Like in the Solow model, we consider a one-sector economy. It has a single commodity for consumption and investment. There is a single internationally tradable good, called industrial good, in the world economy and the price of the industrial good is unity fixed in global markets. Capital depreciates at a constant exponential rate, δ_k, which is independent of the manner of use. We assume that the economy is too small to affect the world rate of interest, r^*. All the markets are perfectly competitive. Factors are inelastically supplied and the available factors are fully utilized at every moment. Saving is undertaken only by households. All earnings of firms are distributed in the form of payments to factors of production. Households own assets of the economy and distribute their incomes to consumption, child bearing, and wealth accumulation. The population of each gender is homogeneous. We assume that each family consists of husband, wife and children. All the families are identical. We use subscripts $q=1$ and $q=2$ to stand for man and woman respectively. We use $N(t)$ to stand for the population of each gender. Let $T_q(t)$ and $\bar{T}_q(t)$ stand for work time and time spent on taking care of children of gender q and $\bar{N}(t)$ for the flow of labor services used in time t for production. We have $\bar{N}(t)$

$$\bar{N}(t)=\left[h_1 T_1(t)+h_2 T_2(t)\right]N(t), \tag{1}$$

where h_q is the level of human capital of gender q.

The economic production

Let $K(t)$ stand for the capital stock used by the economy at time t. We use $F(t)$ to represent the output level. The production function is

$$F(t)=AK^{\alpha}(t)\bar{N}^{\beta}(t),\ \ \alpha,\beta>0,\ \ \alpha+\beta=1, \tag{2}$$

where $A,\alpha,$ and β are parameters. Markets are competitive; thus labor and capital earn their marginal products, and firms earn zero profits. Let the wage rate per unit of time be denoted by $w(t)$. The marginal conditions are

$$r^*+\delta_k=\frac{\alpha F(t)}{K(t)},\ \ w(t)=\frac{\beta F(t)}{\bar{N}(t)},\ \ w_q(t)=h_q\, w(t). \tag{3}$$

From (2) and (3), we solve

$$\frac{K(t)}{\bar{N}(t)}=\bar{\delta},\ \ w=\beta\bar{\delta}^{\alpha},\ \ w_q=h_q w,\ \ \bar{\delta}\equiv\left(\frac{\alpha A}{r^*+\delta_k}\right)^{1/\beta}. \tag{4}$$

Consumer behaviors

We now use an alternative approach to household proposed by Zhang (1993). To describe behavior of consumers, we denote per family wealth by $\bar{k}(t)$. Per family current income from the interest payment and the wage payments is

$$y(t)=r^*\bar{k}(t)+wh_1T_1(t)+wh_2T_2(t). \tag{5}$$

The disposable income per family is given by

$$\hat{y}(t)=y(t)+\bar{k}(t)=\left(1+r^*\right)\bar{k}(t)+wh_1T_1(t)+wh_2T_2(t). \tag{6}$$

Let $n(t)$ and $p_b(t)$ stand for the birth rate and the cost of birth at time. Following Zhang (2014), we assume that children will have the same level of wealth as that of the parent. In addition to the time spent on children, the cost of the parent is given by

$$p_b(t) = n(t)\bar{k}(t). \tag{7}$$

The relation between fertility rate and the parent's time on raising children is

$$\bar{T}_q(t) = \theta_q\, n(t),\ \ \theta_q \geq 0. \tag{8}$$

The household distributes the total available budget between saving, $s(t)$, consumption of goods, $c(t)$, and bearing children, $p_b(t)$. The budget constraint is

$$p(t)c(t) + s(t) + \bar{k}(t)n(t) = \hat{y}(t). \tag{9}$$

We consider that except work and child caring, parents also have their leisure. We denote the leisure time of gender q by $\tilde{T}_q(t)$. The time constraint is

$$T_q(t) + \bar{T}_q(t) + \tilde{T}_q(t) = T_0, \tag{10}$$

where T_0 is the available time for leisure, work and children caring. Insert (10) and (8) in (9)

$$c(t) + s(t) + \tilde{w}(t)n(t) + h_1\, w(t)\tilde{T}_1(t) + h_2\, w(t)\tilde{T}_2(t) = \bar{y}(t), \tag{11}$$

where

$$\tilde{w}(t) \equiv \bar{k}(t) + \bar{\theta},\ \ \bar{y}(t) \equiv \left(1 + r^*\right)\bar{k}(t) + \bar{w},\ \ \bar{\theta} \equiv h_1\theta_1 w + h_2\theta_2 w,\ \ \bar{w} \equiv \left(wh_1 + wh_2\right)T_0.$$

We assume that the utility is dependent on $c(t),\ s(t),$ $\tilde{T}_q(t),$ and $n(t)$ as

$$U(t) = c^{\xi_0}(t)s^{\lambda_0}(t)\tilde{T}_1^{\sigma_{01}}(t)\tilde{T}_2^{\sigma_{02}}(t)n^{\upsilon_0}(t),$$

where ξ_0 is called the propensity to consume, λ_0 the propensity to own wealth, σ_{0q} the gender $q's$ propensity to use leisure time, and υ_0 the propensity to have children. The first-order condition of maximizing $U(t)$ subject to (11) yields

$$c(t) = \xi\,\bar{y}(t),\ \ s(t) = \lambda\,\bar{y}(t),\ \ \tilde{T}_q(t) = \sigma_q\,\bar{y}(t),\ \ n(t) = \frac{\upsilon\,\bar{y}(t)}{\tilde{w}(t)}, \tag{12}$$

where

$$\xi \equiv \rho\xi_0,\ \ \lambda \equiv \rho\lambda_0,\ \ \sigma_q \equiv \frac{\rho\sigma_{q0}}{wh_q},\ \ \upsilon \equiv \rho\upsilon_0,\ \ \rho \equiv \frac{1}{\xi_0 + \lambda_0 + \sigma_{10} + \sigma_{20} + \upsilon_0}.$$

According to the definitions, the population change follows

$$\dot{N}(t) = \left(n(t) - d(t)\right)N(t), \tag{13}$$

where $n(t)$ and $d(t)$ are respectively the birth rate and mortality rate. In this study we assume that the mortality rate is negatively related to the disposable income as follows

$$d(t) = \frac{\bar{\upsilon}\, N^{b_0}(t)}{\bar{y}^{a_0}(t)}, \tag{14}$$

where $\bar{\upsilon} > 0$ is the mortality rate parameter and $a_0 \geq 0.$

It should be noted that in the literature of population and economic growth economists identify many factors for explaining population dynamics. These factors include, for instance, changes in gender gap in wages (Galor and Weil, 1996), labor market frictions (Adsera, 2005), and age structure (Hock and Weil, 2012). Barro and Becker (1989) propose an endogenous fertility in an overlapping generation model with exogenous economic growth. Recently Bosi and Seegmuller (2012) extend the model by taking account of the heterogeneity of households in terms of capital endowments, mortality, and costs per surviving child. The model is built on the quantity-quality trade-off of having children, summarized by the adjustment of the average rearing cost of a surviving child. They show that a rise in mortality increases the time cost per surviving child and enhances economic growth, while reducing demographic growth. We may make our model more robust in explaining complexity of population dynamics by extending and generalizing our model on the basis of these studies in the future.

Insert (12) and (14) in (13)

$$\dot{N}(t) = \left(\frac{\upsilon\,\bar{y}(t)}{\tilde{w}(t)} - \frac{\bar{\upsilon}\, N^{b_0}(t)}{\bar{y}^{a_0}(t)}\right)N(t). \tag{15}$$

We now find dynamics of wealth accumulation. According to the definition of $s(t),$ the change in the household's wealth is given by

$$\dot{\bar{k}}(t) = s(t) - \bar{k}(t) = \lambda\bar{y}(t) - \bar{k}(t). \tag{16}$$

The national saving is the sum of the households' saving. We have

$$S(t) + C(t) + n(t)\bar{k}(t)N(t) - K(t) + \delta_k\, K(t) = F(t), \tag{17}$$

Where $S(t) = s(t)N(t),\ C(t) = c(t)N(t),$ and $K(t) = \bar{k}(t)N(t).$ We built the model.

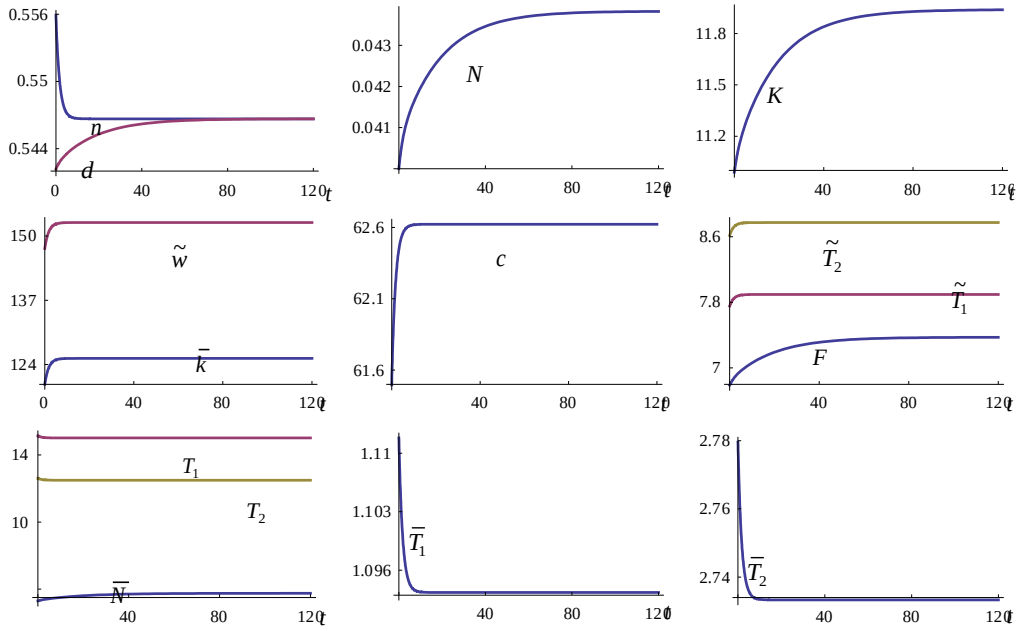

Figure 1. The motion of the economic system

The dynamics and its properties

The dynamics are expressed by differential equations with $\bar{k}(t)$ and $N(t)$ as the variables.

Lemma: All the variables are determined as functions of $\bar{k}(t)$ and $N(t)$ at any point of time by the following procedure: $\bar{y}(t) = (1 + r^*)\bar{k}(t) + \bar{w} \to c(t)$, $s(t)$, $\tilde{T}_q(t)$, and $n(t)$ by (12) $\to \bar{T}_q(t)$ by (8) $\to T_q(t)$ by (10) $\to \bar{N}(t)$ by (1) $\to K(t)$ by (4) $\to F(t)$ by (2). The motion of $\bar{k}(t)$ and $N(t)$ is given by the following two differential equations

$$\dot{\bar{k}}(t) = \lambda\bar{y}(t) - \bar{k}(t),$$
$$\dot{N}(t) = \tilde{\Omega}(\bar{k}(t), N(t)) \equiv \left(\frac{\upsilon\,\bar{y}(t)}{\tilde{w}(t)} - \frac{\bar{\upsilon}\,N^{b_0}(t)}{\bar{y}^{a_0}(t)}\right)N(t). \qquad (18)$$

The expressions are complicated. It is difficult to explicitly interpret economic implications of the two equations. For illustration, we simulate the model to illustrate behavior of the system. In the remainder of this study, we specify the depreciation rate by $\delta_k = 0.05$, and let $T_0 = 24$. We specify the other parameters as follows

$$\alpha = 0.34,\ a = 0.05,\ b = 0.05,\ \lambda_0 = 0.6,\ \xi_0 = 0.3,\ \nu_0 = 0.4,\ \sigma_{10} = 0.16,\ \sigma_{10} = 0.16,$$
$$A = 1,\ a_0 = 0.2,\ b_0 = 0.2,\ h_1 = 5,\ h_2 = 4.5,\ \theta_1 = 2,\ \theta_2 = 5,\ \bar{\upsilon} = 1. \qquad (19)$$

We specify the initial conditions: $\bar{k}(0) = 120$ and $N(0) = 0.04$.

We plot the simulation result in Figure 1. The population grows from its low initial condition. The mortality rate and the labor force are augmented. The opportunity cost of children fostering and man's and woman's time of children fostering are increased.

The equilibrium values of the variables are as follows

$$N = 0.044,\ K = 11.94,\ \bar{N} = 5.75,\ F = 7.38,\ n = d = 0.55,\ w_1 = 4.23,\ w_2 = 3.81,$$
$$\tilde{w} = 152.74,\ \bar{k} = 125.24,\ T_1 = 15.01,\ T_2 = 12.49,\ \tilde{T}_1 = 7.9,\ \tilde{T}_2 = 8.8,\ \bar{T}_1 = 1.09,$$
$$\bar{T}_2 = 2.73,\ c = 62.62.$$

We calculate the two eigenvalues: -0.57 and -0.06.

COMPARATIVE DYNAMIC ANALYSIS

We use a variable $\bar{\Delta}x_j(t)$ to stand for the change rate of the variable, $x_j(t)$, in percentage due to changes in the parameter value.

A rise in the propensity to have children

First, we assume: $\upsilon_0 : 0.4 \Rightarrow 0.42$. The simulation results are plotted in Figure 2. In order to examine how each variable is affected over time, we should follow the motion of the entire system as each variable is related to the others in the dynamic system. As shown in Figure 1, the birth rate is increased, which also results in a rise in the population. The

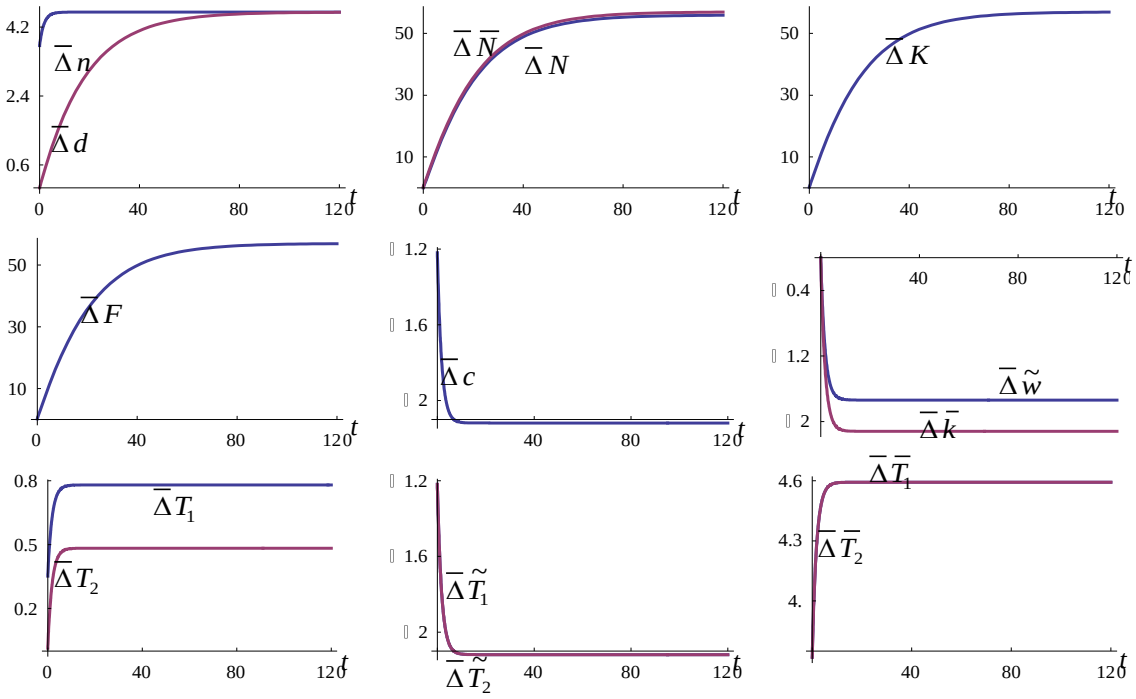

Figure 2. A rise in the propensity to have children

mortality rate is increased. The capital, total labor input and output level are all enhanced. The values of these variables are increased in association with population growth. Both the opportunity cost of children $\tilde{w}$ and the wealth per household are reduced.

A rise in woman's propensity to pursue leisure activities

We have: $\sigma_{02}: 0.16 \Rightarrow 0.17$. The simulation results are plotted in Figure 3. An immediate consequence of the preference change is that the wife spends more time on leisure and the husband has less leisure hours. The husband works more and the wife works less. Both the husband and wife reduce their time of children fostering. The consumption level, opportunity cost of children fostering and wealth are reduced. In association with the net impact of falling opportunity cost and reduction in the relative propensity to have children, the birth rate falls and the mortality rate rises. The population, total labor, wealth and output are all reduced.

Woman's human capital being improved

We now consider: $h_2: 4.5 \Rightarrow 4.7$. The results are plotted in Figure 4. The woman's wage rate rises. As the mother earns more per unit time, she works more. The opportunity cost of child fostering is increased in association with the mother's wage rising. The birth rate falls. The parents spend less time on children caring. The mother works more and the father works less. The father has more leisure time and the mother less. The family consumes more and has more wealth. The mortality rate falls in association with improved living conditions. The net impact of falling birth and mortality rates reduces the population in the long term. The capital, total labor input and output are increased.

Concluding remarks

This paper introduced endogenous population growth model into the Solow one sector growth model. The study proposed a dynamic interdependence between the birth rate, the mortality rate, the population, wealth accumulation, and time distribution between work, leisure and children caring. We emphasized the role of human capital, technological and preference changes on the birth and mortality rates and time distribution. The model is influenced by many traditional ideas about growth and population change. We took account of gender differences in human capital, the propensity to use leisure time, and children caring efficiency. We simulated the model to show the motion of the economic growth and population change and identified the existence of equilibrium points. We also examined the effects of changes in the propensity to

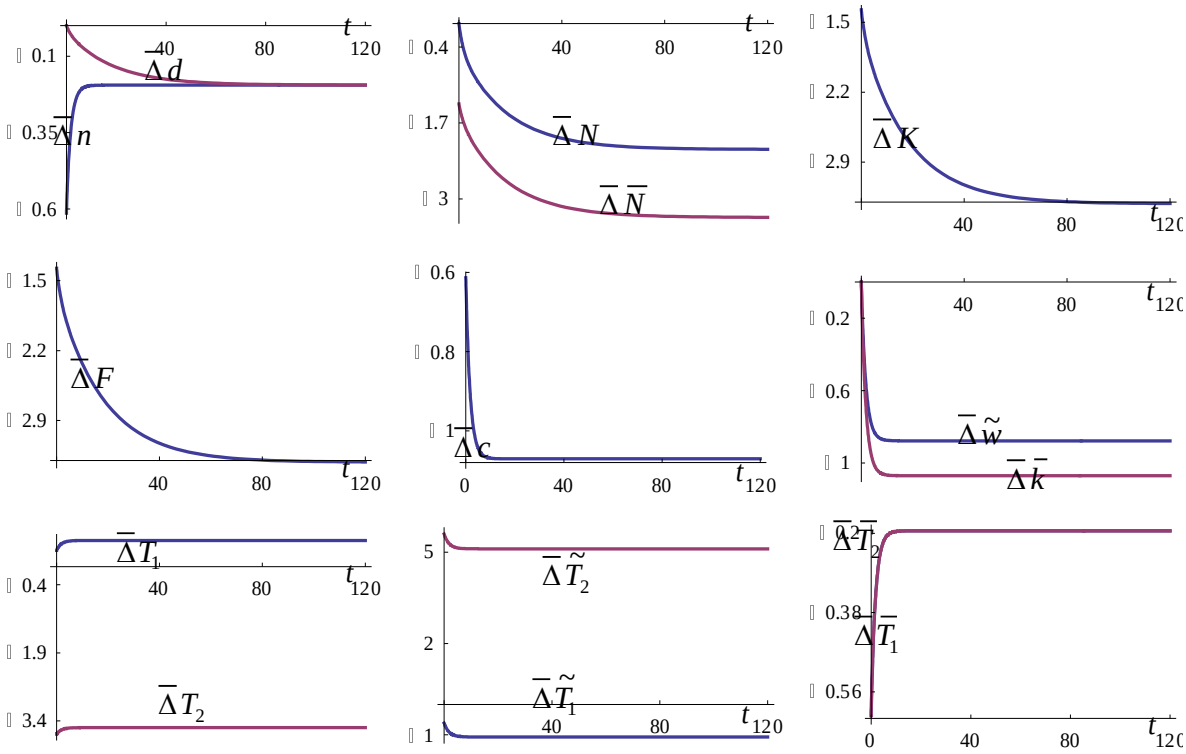

Figure 3. A rise in woman's propensity to pursuing leisure activities.

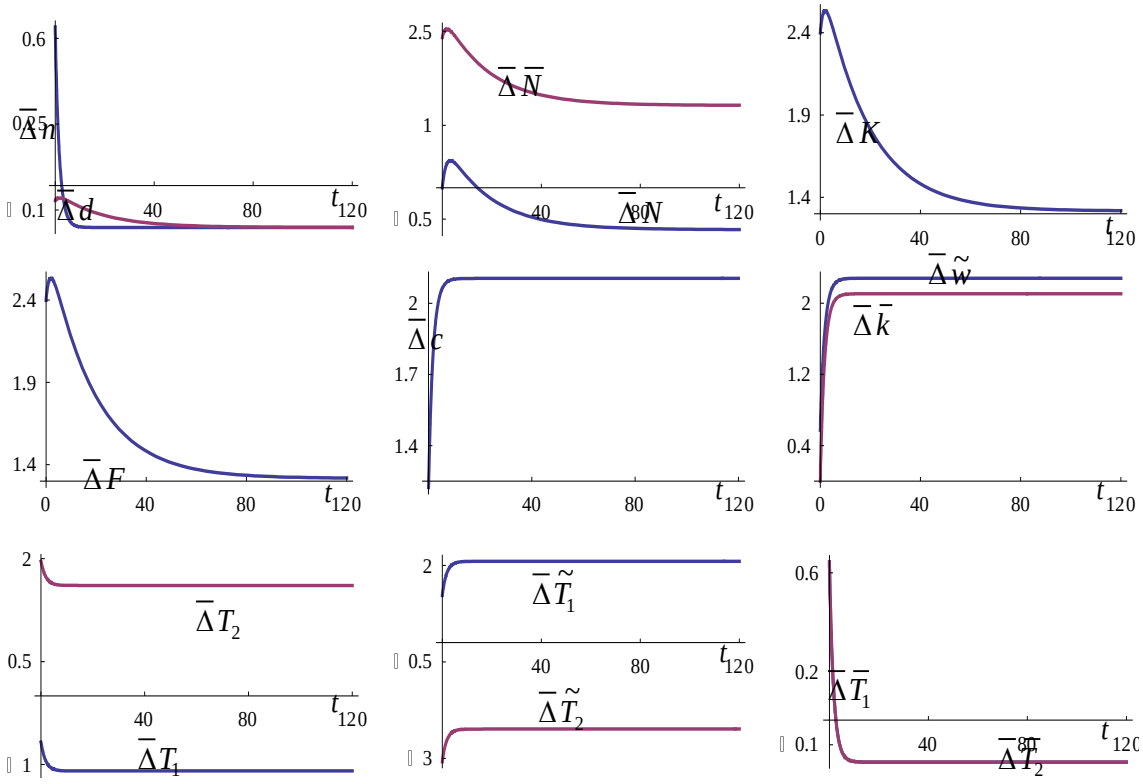

Figure 4. A rise in the mother's human capital.

have children, woman's propensity to use leisure, and woman's human capital.

Conflict of Interests

The author has not declared any conflict of interests.

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