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Editor's Introduction to Volume 2, Issue 1 of Expert Journal of Economics

Simona VINEREAN*

Sprint Investify

The first issue of the second volume of *Expert Journal of Economics* encompasses various interesting articles that explore economic issues in terms of policy of renewable energy, developing strategies for solving crises with the help of local companies, post inflation targeting monetary policy, and modeling of the dynamic interdependence of three types of capital in various adaptations. Thus, the topics and research methods presented in this issue make meaningful contributions to economics knowledge. Further, I present a short description of each article that is published in *Expert Journal of Economics*, vol. 2, issue 1.

Monadjemi and Lodewijks (2014), in their article entitled *Post Inflation Targeting Monetary Policy: A Study of Britain, Japan and the United States*, examine the theoretical and practical premises of monetary, exchange rate, and inflation targeting in the context of the slow economic recovery after the 2007-2008 recession. The authors provide empirical evidence for three countries (United Kingdom, Japan, and the United States) in terms of their inflation and growth rates, general government expenditure, and their evolution on a Hodrick-Prescott filter before and after the 2007-2008 global financial crisis. Monadjemi and Lodewijks (2014) conclude that central banks aimed for an inflation level that was far too low, and that the inflation target should be increased in order to allow a higher level of liquidity and to decrease the value of real debt when extensive financial deleveraging is occurring. Their paper is very interesting in the analytical approach and in the policy recommendation in relation to inflation targeting, which was was highly effective before the crisis, however, in the current context, a more flexible form of inflation targeting may be required.

Zhang (2014) examines the dynamic interdependence of the three types of capital (wealth, human capital, and renewable resources) that are essential for economic growth. The author proposes different versions of a model that summarizes certain well-known models in economics. By disregarding the resources and keeping human capital at a constant value, the model reflects the one-sector neoclassical growth model by Solow. Also, the model can display structural similarities to the Uzawa-Lucas two-sector model when the resources are again neglected from the overall model. The model considered different ways of improving human capital: learning by producing, learning by education, and learning by consuming. Most importantly, Zhang 92014) provides a valuable research that encompasses various models of the effects of the three types of capital under different adaptations, such as the propensity to receive education, and the propensity to save upon dynamic paths of the system. Also, the significance of the research relies in the equations for the accumulation of human capital, wealth, the change of resources, and division of labor under perfect competition. Moreover, the proposed model simulates the existence of different equilibrium points and motion of the dynamic system regarding the three types of capital.

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Nazal (2014) explores how local private companies can develop their strategies in solving crises. For this main research objective, the author proposes an introspective approach in establishing the ways companies deal with crises and try to avoid taxes because of the difficult financial situation they are facing. Local companies are valuable participants in solving crises. For this aspect to occur, countries should encourage certain practices in relation to their economic policies. In this respect, Nazal (2014) proposes ways to evaluate local private companies' standards in a country's tax environment and credit planning. The researcher suggests that crises' effects could be diminished through the use of three tables, that should pose as as models to evaluate the fair general budget policies, the ability of local private companies to get support, and also to evaluate the sharing between local private companies and government.

In *Achieving the Renewable Energy Target for Jamaica*, Abdulkadri (2014) discusses Jamaica's energy policy in terms of a need for energy diversification in a context that is lacking substantial progress in terms of renewable energy. In this article, the author examines the current and potential context for renewable energy in Jamaica and proposes an energy plan for meeting electricity targets. The empirical analysis of the article involves an interesting linear programming model, which is highly regarded in terms of energy planning. The results of the model concur that a rapid investment in renewable energy is necessary to achieve an optimal energy plan, by focusing on wind power, hydropower, and bagasse power, respectively. Abdulkadri (2014) also emphasizes the need for policy reform and government action to ensure the attainment of the renewable energy target of 20% by 2030, considering the current level of only 8%.

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Zhang, W.B., 2014. Human Capital, Wealth, and Renewable Resources. *Expert Journal of Economics*, 2(1), pp.1-20

Monadjemi, M. and Lodewijks, J., 2014. Post Inflation Targeting Monetary Policy: A Study of Britain, Japan and the United States. *Expert Journal of Economics*, 2(1), pp. 21-29

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Human Capital, Wealth, and Renewable Resources

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This paper studies dynamic interdependence among physical capital, resource and human capital. We integrate the Solow one-sector growth, Uzawa-Lucas two-sector and some neoclassical growth models with renewable resource models. The economic system consists of the households, production sector, resource sector and education sector. We take account of three ways of improving human capital: Arrow's learning by producing (Arrow, 1962), Uzawa's learning by education (Uzawa, 1965), and Zhang's learning by consuming (Zhang, 2007). The model describes a dynamic interdependence among wealth accumulation, human capital accumulation, resource change, and division of labor under perfect competition. We simulate the model to demonstrate existence of equilibrium points and motion of the dynamic system. We also examine effects of changes in the productivity of the resource sector, the utilization efficiency of human capital, the propensity to receive education, and the propensity to save upon dynamic paths of the system.

Keywords*: education; physical capital; renewable resource; human capital; propensities to save and to learn; time distribution among study, work and leisure*

JEL Classification*: O41; I25; Q2;*

1. Introduction

Three kinds of "capital" - physical capital such as machines, human capital such as skills, and renewable resources such as forests - are important for economic growth and development. As human capital, resources and physical capital are scarce resources and play different roles in production and consumption, it is significant to study how these resources are allocated in different activities. Moreover, these stock variables change according to different mechanisms. Physical capital changes due to, for instance, depreciation and wealth accumulation. Savings by households, firms, or nations are essential for physical capital accumulation. Human capital is accumulated through human capital in learning. Education and learning by doing are common sources of human capital accumulation. Stock of renewable resources is also changeable according how fast agents utilize resources and how fast renewable resources grow. This paper studies dynamic interdependence among physical capital, resource and human capital. We integrate the Solow one-sector growth, Uzawa-Lucas two-sector and some neoclassical growth models with renewable resource models. The economic system consists of the households, production sector, resource sector and education sector. We take account of three ways of improving human capital: Arrow's learning by producing (1962), Uzawa's learning by education (Uzawa, 1965), and Zhang's learning by consuming (2007). The model describes a dynamic interdependence among wealth accumulation, human capital accumulation, resource change, and division of labor under perfect competition.

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As far as physical capital and wealth accumulation are concerned, the model in this study is based on the neoclassical growth theory. Most of the models in the neoclassical growth theory are extensions and generalizations of the pioneering works of Solow in 1956. The model has played an important role in the development of economic growth theory by using the neoclassical production function and neoclassical production theory. The Solow model has been extended and generalized in numerous directions (e.g., Uzawa, 1961; Kurz, 1963; Diamond, 1965; Stiglitz, 1967; Drugeon and Venditti, 2001; Erceg *et al*. 2005). An important direction of extending the traditional neoclassical one-sector growth model was carried out by Uzawa (1965), who proposed a formal dynamic growth model with education. But with regards to formal modeling of education and economic growth, the work by Lucas (1988) has recently caused a great interest in the issue among economists. Dynamic interdependence between education and economic growth is currently a main topic in the literature of economic theory and economic empirical studies (e.g., Hanushek and Kimko, 2000; Barro, 2001; Krueger and Lindahl, 2001; Fleisher *et al.* 2011; Li *et al.*, 2012; Castelló-Climent and Hidalgo-Cabrillana, 2012). In the Uzawa-Lucas model and many of their extensions and generalizations, it is implicitly assumes that all skills and human capital is formed due to formal schooling. Common sense tells us that much of the so-called human capital may be accumulated through parents' influences, family and other social environment, and other social and economic activities, not to say learning by producing (and professional training). If these non-school factors are neglected in modelling human capital and economic growth, we may not be able to properly understand the role of formal education in economic development. Chen and Chevalier (2008) point out: "Making and exploiting an investment in human capital requires individuals to sacrifice not only consumption, but also leisure. When estimating the returns to education, existing studies typically weigh the monetary costs of schooling (tuition and forgone wages) against increased wages, neglecting the associated labor/leisure tradeoff." This study will generalize the Uzawa-Lucas two-sector growth model by taking account of leisure activities, learning by producing and learning by consuming.

Natural resources are incorporated into the neoclassical growth theory in the 1970s (e.g., Plourde, 1970, 1971; Stiglitz, 1974; Clark, 1976; Dasgupta and Heal, 1979). In fact, economists were aware of the necessity of modeling resources with dynamic theory long before. For instance, Gordon (1956) emphasized the need for a dynamic approach to fisheries economics as one finds in capital theory in economics: "The conservation problem is essentially one which requires a dynamic formulation… The economic justification of conservation is the same as that of any capital investment – by postponing utilization we hope to increase the quantity available for use at a future date. In the fishing industry we may allow our fish to grow and to reproduce so that the stock at a future date will be greater than it would be if we attempted to catch as much as possible at the present time. … [I]t is necessary to arrive at an optimum which is a catch per unit of time, and one must reach this objective through consideration of the interaction between the rate of catch, the dynamics of fish population, and the economic time-preference schedule of the community or the interest rate on invested capital. His is a very complicated problem and I suspect that we will have to look to the mathematical economists for assistance in clarifying it." As pointed out by Munro and Scott (1985), in the 1950s it was quite difficult to develop workable dynamic models of resources. Solow (1999) also argues for the necessity of taking account of natural resources in the neoclassical growth theory. According to Solow if the resource good is used as one of the inputs in the production, then it is easy to incorporate the use of renewable resources into the neoclassical growth model. Nevertheless, Solow does not show how to incorporate possible consumption of renewable resource into the growth model. There are only a few models of growth and renewable resources which treat the renewable resource as both input of production and a source of utility (see, Beltratti, *et al*., 1994, Ayong Le Kama, 2001). Our model contains the renewable resource as a source of utility and input of production. It should be noted that there are also studies on dynamic interactions among economic growth, renewable resources and elastic labor supply on the basis of the neoclassical growth theory with capital accumulation and renewable resource (e.g., Eliasson and Turnovsky, 2004, Alvarez-Cuadrado and van Long, 2011). Our model differs from these studies not only in that we use an alternative utility function, but also in that we introduce human capital and education sector into the growth theory with capital and resource.

Another important variable in dynamic analysis is time distribution among various activities. The allocation of time has been explicit introduced into economic theory since Becker (1965) published his seminal work in 1965. There is an immense body of empirical and theoretical literature on economic growth with time distribution between home and non-home economic and leisure activities (e.g., Benhabib and Perli, 1994; Ladrón-de-Guevara *et al*. 1997; Jones and Manuelli, 1995; Turnovsky, 1999; Greenwood and Hercowitz, 1991; Rupert *et al*. 1995; Cambell and Ludvigson, 2001). Nevertheless, only a few theoretical economic growth models with renewable resource and human capital explicitly treat work time as an endogenous variable. This paper introduces endogenous time into the neoclassical growth theory with renewable resource. This paper is to integrate two papers by Zhang (2007, 2011). The former paper deals with education

and capital accumulation, while the latter studies dynamic interactions between resource and physical capital. This paper integrates the two models to examine dynamic interactions among human capital, physical capital and renewable resources. Our model is also a synthesis of three main growth models – Solow's one-sector growth model, Arrow's learning by doing model, and the Uzawa-Lucas's growth model with education - in the growth literature. We integrate the main mechanisms of economic growth in these three models in a comprehensive framework. The remainder of the paper is organized as follows. Section 2 defines the economic model with endogenous human capital accumulation, resource dynamics and wealth accumulation. Section 3 shows that the motion of the economic system is described by three differential equations and simulates the model. Section 4 carries out comparative dynamics analysis. Section 5 concludes the study.

2. The Basic Model

The economy has three - production, education and renewable resource - sectors. Most aspects of the production sector are similar to the standard one-sector growth model in the neoclassical growth theory (Burmeister and Dobell, 1970; Barro and Sala-i-Martin, 1995). It is assumed that there is only one (durable) good in the economy under consideration. Households own assets of the economy and distribute their incomes to consume and save. Production sectors or firms use inputs such as labor with varied levels of human capital, different kinds of capital, knowledge and natural resources to produce material goods or services. Exchanges take place in perfectly competitive markets. Factor markets work well; 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, labor, managerial skill and capital ownership. We assume a homogenous and fixed population $\overline{N}$. The labor force is employed the three sectors. We select commodity to serve as numeraire, with all the other prices being measured relative to its price. We assume that wage rate is identical among all professions.

2.1. The production sector

We assume that production is to combine labor force, $N_i(t)$, and physical capital, $K_i(t)$, and renewable resource, $X_i(t)$. We use the conventional production function to describe a relationship between inputs and output. Let $F_i(t)$ stand for output level of the production sector at time t. The production function is specified as follows

$$F_i(t) = A_i K_i^{\alpha_i}(t) N_i^{\beta_i}(t) X_i^{\gamma_i}(t), \quad A_i, \alpha_i, \beta_i, \gamma_i > 0, \quad \alpha_i + \beta_i + \gamma_i = 1, \tag{1}$$

where A_i, α_i, β_i and γ_i are positive parameters. Markets are competitive; thus labor and capital earn their marginal products. The rate of interest, $r(t)$, and wage rate, $w(t)$, the price of the resource, $p_x(t)$, are determined by markets. The marginal conditions are given by

$$r(t) + \delta_k = \frac{\alpha_i F_i(t)}{K_i(t)}, \quad w(t) = \frac{\beta_i F_i(t)}{N_i(t)}, \quad p_x(t) = \frac{\gamma_i F_i(t)}{X_i(t)}, \tag{2}$$

where δ_k is the given depreciation rate of physical capital.

2.2. Resource sector and change of renewable resources

We use $X(t)$ to represent the stock of the resource. We assume that the natural growth rate of the resource is a logistic function of the existing stock (e.g., Brander and Taylor, 1998; Brown, 2000; Hannesson, 2000; Cairns and Tian, 2010, Farmer and Bednar-Friedl, 2011). It should be noted that there are some alternative approaches to renewable resources in the literature (Tornell and Velasco, 1992; Long and Wang, 2009; Fujiwara, 2011). The logistic function is

$$\phi_0 X(t)\left(1 - \frac{X(t)}{\phi}\right),$$

where the variable, ϕ, is the maximum possible size for the resource stock, called the carrying capacity of the resource, and , the variable, ϕ_0, is "uncongested" or "intrinsic" growth rate of the renewable resource. If the stock is equal to ϕ, then the growth rate should equal zero. If the carrying capacity is much larger than the current stock, then the growth rate per unit of the stock is approximately equal to the intrinsic growth rate. In this case, the congestion effect is negligible. It should be noted that according Jinni (2006), the carrying capacity changes as a function of the stock of a renewable resource. Also in Benchekroun (2003), an inversed-V shaped dynamics of resource accumulation is accepted. The resource decreases if its stock is sufficiently large. There are also models which introduce human efforts and other factors to the dynamics of resources (e.g., Long, 1977; Berck, 1981; Levhari and Withagen, 1992; Ayong Le Kama, 2001; Wirl, 2004).

We use $F_x(t)$ to stand for the harvest rate of the resource. The change rate in the stock is then equal to the natural growth rate minus the harvest rate, that is

$$\dot{X}(t) = \phi_0 X(t)\left(1 - \frac{X(t)}{\phi}\right) - F_x(t). \tag{3}$$

We assume a nationally owned open-access renewable resource. The open-access case was initially examined by Gordon (1954). There are different approaches to growth with renewable resources with different property-rights regimes (e.g., Bulter and Barbier, 2005; Copeland and Taylor, 2009; Alvarez-Guadrado and Von Long, 2011; Tajibaeva, 2012). With open access, harvesting occurs up to the point at which the current return to a representative entrant equals the entrant's cost. We use $N_x(t)$ and $K_x(t)$ to respectively stand for the labor force and capital stocks employed by the resource sector. We assume that harvesting of the resource is carried out according to the following harvesting production function

$$F_x(t) = A_x X^b(t) K_x^{\alpha_x}(t) N_x^{\beta_x}(t), \quad A_x, b \geq 0, \quad \alpha_x, \beta_x > 0, \quad \alpha_x + \beta_x = 1, \tag{4}$$

where A_x, b, α_x and β_x are parameters. It should be noted that the Schaefer harvesting production function which is taken on the following form

$$F_x(t) = A_x X(t) N_x(t),$$

is a special case of (4). The Schaefer production function does not take account of capital (or with capital being fixed, see Schaefer, 1957). The function with fixed capital and technology is widely applied to fishing (see also, Paterson and Wilen, 1977; Milner-Gulland and Leader-Williams, 1992; Bulter and van Kooten, 1999). As machines are important inputs in harvesting, we explicitly take account of capital input.

Harvesting is carried out by competitive profit-maximizing firms under conditions of free entry. The marginal conditions are given as follows

$$r(t) + \delta_k = \frac{\alpha_x p_x(t) F_x(t)}{K_x(t)}, \quad w(t) = \frac{\beta_x p_x(t) F_x(t)}{N_x(t)}. \tag{5}$$

2.3. The education sector and accumulation of human capital

We assume that the education sector is also characterized of perfect competition. Students are supposed to pay the education fee $p_e(t)$ per unity time. The education sector pays teachers and capital with the market rates. Let $N_e(t)$ and $K_e(t)$ stand for respectively the labor force and capital stocks employed by the education sector. The cost of the education sector is given by $w(t)N_e(t) + r(t)K_e(t)$. The total education service is measured by the total (qualified) education time received by the population. The production function of the education sector is assumed to be a function of $K_e(t)$ and $N_e(t)$. We specify the production function of the education sector as follows

$$F_e(t) = A_e K_e^{\alpha_e}(t) N_e^{\beta_e}(t), \quad \alpha_e, \beta_e > 0, \quad \alpha_e + \beta_e = 1, \tag{6}$$

where A_e, α_e and β_e are positive parameters. Empirical studies on education production functions are referred to, for instance, Krueger (1999). For given $p_e(t)$, $H(t)$, $r(t)$, and $w(t)$, the education sector chooses $K_e(t)$ and $N_e(t)$ to maximize profit. The optimal solution is given by

$$r(t) + \delta_k = \frac{\alpha_e\, p_e(t) F_e(t)}{K_e(t)}, \quad w(t) = \frac{\beta_e\, p_e(t) F_e(t)}{N_e(t)}. \tag{7}$$

Following Zhang (2007), we assume that there are three sources of improving human capital, through education, "learning by producing", and "learning by leisure". Arrow (1962) first introduced learning by doing into growth theory; Uzawa (1965) took account of trade-offs between investment in education and capital accumulation, and Zhang (2007) introduced impact of consumption on human capital accumulation (via the so-called creative leisure) into growth theory. We use $H(t)$ to stand for the level of human capital. We propose that human capital dynamics is given by

$$\dot{H}(t) = \frac{\upsilon_e F_e^{a_e}(t)\left(H^m(t) T_e(t) \overline{N}\right)^{b_e}}{H^{\pi_e}(t)\overline{N}} + \frac{\upsilon_i F_i^{a_i}(t)}{H^{\pi_i}(t)\overline{N}} + \frac{\upsilon_x F_x^{a_x}(t)}{H^{\pi_x}(t)\overline{N}} + \frac{\upsilon_h C^{a_h}(t) T_h^{b_h}(t)}{H^{\pi_h}(t)\overline{N}} - \delta_h H(t), \tag{8}$$

where δ_h (> 0) is the depreciation rate of human capital, $\upsilon_e, \upsilon_i, \upsilon_h, a_e, b_e, a_i, a_h$ and b_h are non-negative parameters. The signs of the parameters π_e, π_i, and π_h are not specified as they can be either negative or positive. The above equation is a synthesis and generalization of Arrow's, Uzawa's, and Zhang's ideas about human capital accumulation. The term, $\upsilon_e F_e^{a_e}\left(H^m T_e \overline{N}\right)^{b_e} / H^{\pi_e}\,\overline{N}$, describes the contribution to human capital improvement through education. Human capital tends to increase with an increase in the level of education service, F_e, and in the (qualified) total study time, $H^m T_e \overline{N}$. The population $\overline{N}$ in the denominator measures the contribution in terms of per capita. The term H^{π_e} indicates that as the level of human capital of the population increases, it may be more difficult (in the case of $\pi_e > 0$) or easier, for instance, due to learning externalities as in Choi (2011) (in the case of $\pi_e < 0$) to accumulate more human capital via formal education. We refer the literature on human capital externalities to Rauch (1993) and Liu (2007), and on economies of scale and scope in education to Cohn and Cooper (2004). It should be noted that this unique formation of human capital is important to explore complexity of human capital accumulation, division of time and economic growth. For instance, the formation implies that if a society can enable people to learning through work experiences and through non-higher-education activities, national economic growth can be sustainable if its higher education is not efficient.

We take account of learning by doing effects in human capital accumulation by the term $\upsilon_i F_i^{a_i} / H^{\pi_i}$. This term implies that contribution of the production sector to human capital improvement is positively related to its production scale F_i and is dependent on the level of human capital. The term H^{π_i} takes account of returns to scale effects in human capital accumulation. The case of $\pi_i > (<)\, 0$ implies that as human capital is increased it is more difficult (easier) to further improve the level of human capital. We take account of learning by consuming by the term $\upsilon_c C^{a_h} T_h^{b_h} / H^{\pi_h} N_0$. This term can be interpreted similarly as the term for learning by producing. It should be noted that in the literature on education and economic growth, it is assumed that human capital evolves according to the following equation (see Barro and Sala-i-Martin, 1995)

$$\dot{H}(t) = H^{\eta}(t) G(T_e(t)),$$

where the function G is increasing as the effort rises with $G(0) = 0$. In the case of $\eta < 1$, there is diminishing return to the human capital accumulation. This formation is due to Lucas (1988). As $\dot{H} / H < H^{\eta-1} G(1)$, we

conclude that the growth rate of human capital must eventually tend to zero no matter how much effort is devoted to accumulating human capital. Uzawa's model may be considered a special case of the Lucas model with $\gamma = 0$, $U(c) = c$, and the assumption that the right-hand side of the above equation is linear in the effort. Solow adapts the Uzawa formation to the following form

$$\dot{H}(t) = H(t)\kappa T_e(t).$$

This is a special case of the above equation. The new formation implies that if no effort is devoted to human capital accumulation, then $\dot{H}(0) = 0$ (human capital does not vary as time passes; this results from depreciation of human capital being ignored); if all effort is devoted to human capital accumulation, then $g_H(t) = \kappa$ (human capital grows at its maximum rate; this results from the assumption of potentially unlimited growth of human capital). Between the two extremes, there is no diminishing return to the stock $H(t)$. To achieve a given percentage increase in $H(t)$ requires the same effort. As remarked by Solow (2000), the above formulation is very far from a plausible relationship. If we consider the above equation as a production for new human capital (i.e., $\dot{H}(t)$), and if the inputs are already accumulated human capital and study time, then this production function is homogenous of degree two. It has strong increasing returns to scale and constant returns to $H(t)$ itself. It can be seen that our approach is more general to the traditional formation with regard to education. Moreover, we treat teaching also as a significant factor in human capital accumulation. Efforts in teaching are neglected in Uzawa-Lucas model. Choi (2011) proposes the following human capital accumulation equation

$$\dot{H}(t) = B(t)[u(t)H(t)]^{\phi}\,\bar{H}^{\theta}(t) - \delta_H H(t),$$

where $B(t)$ is productivity of human capital production and $u(t)$ is the fraction of human capital devoted to human capital accumulation. Here $\bar{H}(t)$, is the average human capital stock in the economy. The term, $\bar{H}^{\theta}(t)$, measures learning externalities. As for a homogenous population, $\bar{H}(t)$ is $H(t)$. We see that Choi's learning equation is a special case of (3).

2.4. Consumer behaviors

Consumers make decisions on choice of consumption levels of goods, services, and education (which is services), as well as on how much to save. It should also be remarked that neither Uzawa nor Lucas took account of leisure in their growth models with education. Hahn (1990) takes account of leisure in generalizing the Lucas model, altering model to the case that each member of the population can use his available – nevertheless fixed - time for working, for leisure, or for studying. Like Hahn, this study also introduces leisure into the growth model with leisure, but in an alternative approach to household proposed by Zhang (1993). We denote per capita wealth by $\bar{k}(t)$, where $\bar{k}(t) \equiv K(t)/\bar{N}$. Per capita current income from the interest payment $r(t)\bar{k}(t)$ and the wage payment $w(t)T(t)$ is given by

$$y(t) = r(t)\bar{k}(t) + w(t)H^m(t)T(t).$$

We call $y(t)$ the current income in the sense that it comes from consumers' work and current earnings from ownership of wealth. The total value of wealth that consumers can sell to purchase goods and to save is equal to $p_0(t)\bar{k}(t)$, where $p_0(t)\,(=1)$ is the price of the capital good (which is unity). Here, we assume that selling and buying wealth can be conducted instantaneously without any transaction cost. The per capita disposable income is given by

$$\hat{y}(t) = y(t) + \bar{k}(t) = (1 + r(t))\bar{k}(t) + w(t)H^m(t)T(t). \quad (9)$$

The disposable income is used for saving and consumption. At each point of time, a consumer would distribute the total available budget among saving, $s(t)$, consumption of the commodity, $c(t)$, education, $T_e(t)$, and consumption of the resource good, $c_x(t)$. The budget constraint is given by

$$c(t) + s(t) + p_e(t)T_e(t) + p_x(t)c_x(t) = \hat{y}(t) = (1 + r(t))\bar{k}(t) + w(t)H^m(t)T(t). \tag{10}$$

The total available time is allocated among working, receiving education, and leisure. The consumer is faced with the following time constraint

$$T(t) + T_e(t) + T_h(t) = T_0, \tag{11}$$

where T_0 is the total available time. Substituting (10) into the budget constraint (7) yields

$$\begin{aligned} &c(t) + s(t) + w(t)H^m(t)T_h(t) + \bar{p}(t)T_e(t) + p_x(t)c_x(t) = \bar{y}(t) = (1 + r(t))\bar{k}(t) + w(t)H^m(t), \\ &\bar{p}(t) \equiv p_e(t) + w(t)H^m(t). \end{aligned} \tag{12}$$

At each point of time, consumers have four variables, the consumption level of consumption good $c(t)$, the consumption level of resource $c_x(t)$, the level of saving $s(t)$, the leisure time $T_h(t)$, and the education time $T_e(t)$, to decide. For simplicity of analysis, we specify the utility function as follows

$$U(t) = T_h^{\sigma_0}(t)\, T_e^{\eta_0}(t) c^{\xi_0}(t) s^{\lambda_0}(t) c_x^{\chi_0}(t), \quad \sigma_0, \eta_0, \xi_0, \lambda_0, \chi_0 > 0, \tag{13}$$

where σ_0 is called the propensity to use leisure time, ξ_0 the propensity to consume the good, λ_0 the propensity to own wealth, σ_0 the propensity to use leisure time, and η_0 the propensity to get education, and χ_0 the propensity to consume the resource good. It should be noted that we enter the time that the household spends on education into the utility. In traditional economic growth theory with endogenous human capital, education is mainly modeled by assuming that it positively affects earnings through enhanced productivity. Nevertheless, common sense tells us that one chooses education not only for higher wages, but also for social status, for social network buildings, signaling, or other purposes. In the literature of education and economics, the signaling view of education was initially formally presented by Spence (1973), Arrow (1973), and Stiglitz (1975). This implies that in addition to wages there are many other factors which we should take account of when analyzing decision on education decision. For instance, Lee (2007) holds that signaling explains why American students study more in college than in high school while the opposite is true for East Asian students. Hussey (2012) empirically distinguish human capital augmentation and the signaling value of MBA education using U.S. data. Hussey shows that signaling plays a large role in producing post-graduation earnings. Applying the idea that money burning (such as some advertising activities by firms, e.g., Nelson, 1974; Kihlstrom and Riordian, 1984; Milgrom and Roberts, 1986) may convey credible information, with a model of higher education as money burning activities Ishida (2004) shows: "this money burning activity can actually be welfare-improving under certain conditions. This result indicates that, even when education is simply a way to waste resources, it can still be meaningful and even socially desirable under certain conditions."

For the representative consumer, the wage rate $w(t)$, the rate of interest $r(t)$, the fee of education $p_e(t)$, and the price of resource $p_x(t)$ are given in markets. Maximizing $U(t)$ subject to the budget constraint yields

$$w(t)\,\mathrm{H}^{\mathrm{m}}(t)T_h(t) = \sigma\,\bar{y}(t), \quad \bar{p}(t)T_e(t) = \eta\,\bar{y}(t), \quad c(t) = \xi\,\bar{y}(t), \quad s(t) = \lambda\,\bar{y}(t), \quad p_x(t)c_x(t) = \chi\,\bar{y}(t), \tag{14}$$

where $\sigma \equiv \rho\sigma_0$, $\eta \equiv \rho\eta_0$, $\xi \equiv \rho\xi_0$, $\lambda \equiv \rho\lambda_0$, $\chi \equiv \rho\chi_0$, $\rho \equiv \dfrac{1}{\sigma_0 + \eta_0 + \xi_0 + \lambda_0 + \chi_0}$.

The demand for resource is given by $c_x = \chi \bar{y} / p_x$. The demand decreases in its price and increases in the disposable income. An increase in the propensity to consume the resource good increases the consumption when the other conditions are fixed. As any factor is related to all the other factors over time, it is difficult to see how one factor affects any other variables over time in the dynamic system.

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

$$\dot{\bar{k}}(t) = s(t) - \bar{k}(t) = \lambda \bar{y}(t) - \bar{k}(t). \tag{15}$$

For the education sector, the demand and supply balances at any point of time

$$T_e(t)\bar{N} = F_e(t). \tag{16}$$

"The research indicates that literacy scores, as a direct measure of human capital, perform better in growth regressions than indicators of schooling. A country able to attain literacy scores 1% higher than the international average will achieve levels of labour productivity and GDP per capita that are 2.5 and 1.5% higher, respectively, than those of other countries." (OECD, Education at a Glance, 2006: 155). This implies that when modeling education and economic growth, it is necessary to take quantity and quality aspects of education. Equation (16) accounts for quantity balance of education. The quality aspect of education is reflected in the term of human capital accumulation associated with education in equation (3).

2.5. Full employment of the production factors

The labor force and capital are allocated among the three sectors. Let $N(t)$ and $K(t)$ stand for respectively the labor supply and total capital stock. The total labor force and the total capital are given by

$$N(t) = H^m(t)T(t)\bar{N}, \quad K(t) = \bar{N}\bar{k}(t), \tag{17}$$

where the parameter, m, measures of the efficiency that the population applies human capital. The conditions of full employment of labor and capital are

$$K_i(t) + K_e(t) + K_x(t) = K(t), \quad N_i(t) + N_e(t) + N_x(t) = N(t). \tag{18}$$

As output of the production sector is equal to the sum of the level of consumption, the depreciation of capital stock and the net savings, we have

$$C(t) + S(t) - K(t) + \delta_k K(t) = F_i(t), \tag{19}$$

where $C(t)$ is the total consumption, $S(t) - K(t) + \delta_k K(t)$ is the sum of saving and depreciation, and

$$C(t) = c(t)\bar{N}, \quad S(t) = s(t)\bar{N}.$$

As the resource output is used up by the production sector and the households, we have

$$c_x(t)\bar{N} + X_i(t) = F_x(t). \tag{20}$$

We completed the model. The model is based on some strict assumptions. Nevertheless, from the structural point of view our model is general in the sense that it synthesizes a few well-known models in economics. For instance, if we neglect resource and assume human capital constant, then the model is the one-sector neoclassical growth model by Solow (1956). If we neglect resources, then the model is structurally similar to the well-known Uzawa-Lucas two-sector model (Uzawa, 1965; Lucas, 1988). As mentioned before, our approach is also based on some growth models in the literature of resource economics.

3. The Dynamics and Its Properties

The dynamic system consists of three differential equations for wealth (or physical capital), human capital and resource stock. As the three differential equations contain other variables, we need to find three differential equations which contain only three variables. The following lemma shows how to obtain the three differential equations which contain only three variables. We also provide a computational procedure for calculating all the variables in the system at any point of time. This section examines dynamics of the model. The following lemma provides the procedure about how to determine the motion of all the variables in the dynamic system. We first introduce a variable

$$z(t) \equiv \frac{r(t) + \delta_k}{w(t)}.$$

3.1. Lemma

The dynamics of the economic system is governed by the following three differential equations with three variables, $z(t)$, $X(t)$, and $H(t)$

$$\begin{aligned} \dot{z}(t) &= \Lambda_z(z(t), X(t), H(t)), \\ \dot{X}(t) &= \Lambda_X(z(t), X(t), H(t)), \\ \dot{H}(t) &= \Lambda_H(z(t), X(t), H(t)), \end{aligned} \tag{21}$$

where Λ_z, Λ_X and Λ_H are $z(t)$, $X(t)$, and $H(t)$ given in the appendix. Moreover, all the other variables are determined as functions of $z(t)$, $X(t)$, and $H(t)$ at any point of time by the following procedure: $x_i(t)$ by (A6) $\rightarrow p_x(t)$ by (A5) $\rightarrow r(t)$ by (A3) $\rightarrow w(t)$ by (A3) $\rightarrow \bar{k}(t)$ by (A20) $\rightarrow K(t) = \bar{k}(t)\bar{N} \rightarrow N(t)$ by (A18) $\rightarrow T(t) = N(t)/H^m(t)\bar{N} \rightarrow T_h(t)$ and $T_e(t)$ by (A16) $\rightarrow p_w(t)$ by the definition $\rightarrow p_e(t)$ by (A16) $\rightarrow K_i(t)$ and $K_e(t)$ by (A13) $\rightarrow K_x(t)$ by (A11) $\rightarrow N_i(t)$, $N_e(t)$, and $N_x(t)$ by (A1) $\rightarrow \bar{y}(t)$ by (A15) $\rightarrow c_x(t)$, $c(t)$, $s(t)$ by (14) $\rightarrow X_i(t) = x_i(t)N_i(t) \rightarrow F_i(t)$ by (1) $\rightarrow F_x(t)$ by (4) $\rightarrow F_e(t)$ by (6) $\rightarrow U(t)$ by (11).

The lemma provides a computational procedure for following the motion of the economic system with initial conditions. As it is difficult to interpret the analytical results, to study properties of the system we simulate the model. In the remainder of this study, we specify the depreciation rates by $\delta_k = 0.05$, $\delta_h = 0.03$, and let $T_0 = 1$. We specify the other parameters as follows

$$\begin{aligned} &\alpha_i = 0.33,\ \gamma_i = 0.08,\ \alpha_e = 0.45,\ \alpha_x = 0.3,\ \phi_0 = 5,\ \phi = 8,\ \lambda_0 = 0.6,\ \xi_0 = 0.08, \\ &\sigma_0 = 0.2,\ \eta_0 = 0.01,\ \chi_0 = 0.01,\ N_0 = 5,\ A_i = 1,\ A_e = 0.9,\ A_x = 0.3,\ b = 0.5, \\ &m = 0.8,\ v_e = 1,\ v_i = 2,\ v_h = 1.2,\ v_x = 1.5,\ a_e = 0.3,\ b_e = 0.4,\ a_i = 0.4, \\ &a_x = 0.1,\ a_h = 0.2,\ b_h = 0.1,\ \pi_e = 0.3,\ \pi_i = 0.7,\ \pi_x = 0.7,\ \pi_h = 0.6. \end{aligned} \tag{22}$$

The propensity to save is 0.6 and the propensities to consume education and resource are 0.01. We specify the values of the parameters, α_i and α_x in the Cobb-Douglas productions approximately 0.3. The propensity to enjoy leisure is 0.2. The total productivities of the production sector, education sector, and resource sector are respectively 1, 0.9 and 0.3. The conditions $\pi_e = 0.2$, $\pi_i = 0.7$ and $\pi_h = 0.1$ mean respectively that the learning by education, learning by producing, and learning by consuming exhibits (weak) increasing effects in human capital. We plot the motion of the system under (22) with the following initial conditions

$$z(0)=0.08,\quad X(0)=7,\quad H(0)=12.$$

The motion of the variables is plotted in Figure 1. In Figure 1, the national output is

$$Y = F_i + p_x F_x + p_e F_e .$$

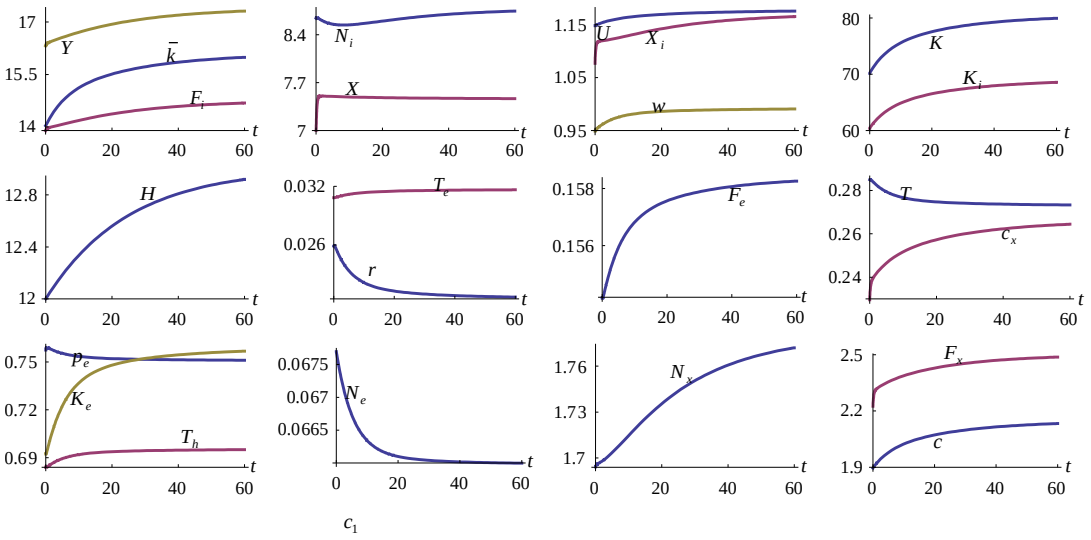

Figure 1. The Motion of the Economic System

As the initial level of human capital is lower than its equilibrium value, human capital rises over time. In association with rises in human capital, the wage rate rises and rate of interest falls over time. The equilibrium values of the variables are listed as follows

$$Y=17.33,\quad K=80.16,\quad H=12.93,\quad N=10.53,\quad X=7.47,\quad F_i=14.70,$$
$$F_x=2.49,\quad F_e=0.16,\quad N_i=8.74,\quad N_x=1.77,\quad N_e=0.066,\quad K_i=68.72,$$
$$K_x=10.68,\quad K_e=0.76,\quad r=0.021,\quad p_e=0.75,\quad p_x=1.01,\quad W=7.69,\quad T=0.27,$$
$$T_h=0.70,\quad T_e=0.032,\quad c=2.14,\quad c_x=0.27,\quad s=16.03,\quad U=1.18.$$

It is straightforward to calculate the three eigenvalues at the equilibrium point as follows

-4.50, -0.18, -0.04.

As the eigenvalues are negative, the equilibrium point is locally stable. Hence, if the system is near the equilibrium, it will approach the equilibrium in the long term. This conclusion is important as it guarantees that we can effectively carry out comparative dynamic analysis.

4. Comparative dynamic analysis

We simulated the motion of the national economy under (22). We now study how the economic system reacts to exogenous changes, for instance, in resource capacity and preference. As the lemma gives a computational procedure to calibrate the motion of all the variables, we can conduct analysis on effects of change in any parameter on transitory processes as well stationary states of all the variables. In the rest of this study we use $\overline{\Delta}x(t)$ to stand for the change rate of the variable, $x(t)$, in percentage due to changes in the parameter value.

4.1. A rise in the carrying capacity of the renewable resource

We first study the case when the carrying capacity of renewable resource is increased as follows: $\phi : 8 \Rightarrow 8.2$. The simulation result is plotted in Figure 2. When he capacity is expanded, from equation (3) we see that the level of renewable resource stock tends to increase. The old development path is disturbed. The level of resource stock is augmented. In association of rises in the stock, both the production sector and households use more resources. The price of resource stock is lowered due to the expansion of supply. The education time and leisure time are initially reduced and work time is initially reduced; in the long term the time distribution is slightly affected. It should be noted that education time is augmented in the long term. The level of human capital is initially increased faster than the total labor force; in the long term the level of human capital is increased less than the total labor force. The total physical stock is also increased in association with rises in the consumption level of goods and the wealth. The education sector's output and its inputs are slightly affected. The other two sectors' output levels and inputs are increased. The utility level and national output are enhanced.

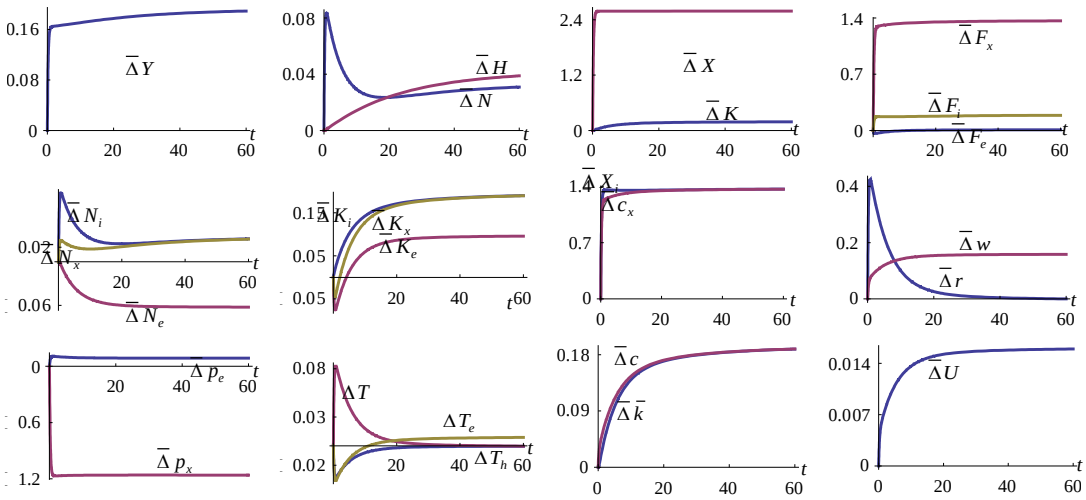

Figure 2. A Rise in the Capacity of Resources

Our simulation shows that if the economic system functions effectively, an economy with richer natural resources should have faster economic growth and better steady state. It should be mentioned that the impact of natural resources on economic as well as human development has caused attention of economists for a long time. Debates about whether natural resources are a blessing or a curse for human development are still a hot topic in the literature of economic development. It is well-known that the in the 1990s Sachs and Warner (1999, 2001) demonstrated a negative relationship between resource dependence and economic growth over the period 1970-1990. Since then, the curse of natural resource hypothesis has been theoretically re-examined and empirically tested in many studies. In a recent comprehensive study on natural resources and economic development, Daniele (2011: 568) concludes: "Natural resources can be a blessing for countries, but the blessing can turn into a curse when rents serve to fund conflicts, to corrupt institutions or are simply wasted. So, the effects that resources produce on people's welfare do not appear to depend on the resources themselves, as much as on the social and institutional ability to manage them. In this respect, the concept of resource curse appears misleading, as it tends to hide the real pathology affecting some nations: poor governance of natural resources." In fact, It has been empirically demonstrated that natural resources may have either an adverse or positive effect on the equilibrium growth rate (for instance, Gylfason, *et al*. 1999, Barbier, 1999, Chen and Lu, 2009).

4.2. An enhancement in efficiency of the education sector

We now increase the total productivity of the education sector as follows: $A_e : 0.8 \Rightarrow 0.92$. When A_e is increased, by $T_e\, N_0 = F_e$ the education time is increased initially. In the association of rise in the productivity, the price of education tends to fall and the education sector employs less labor and capital inputs. The households spend more time on education and less time on work and leisure. The three sectors' output levels are all increased. The national output and wealth initially fall slightly and increases but very small in the long term. The total labor is reduced and the level of human capital and the wage rate are increased. The rate of interest falls and the utility level is enhanced.

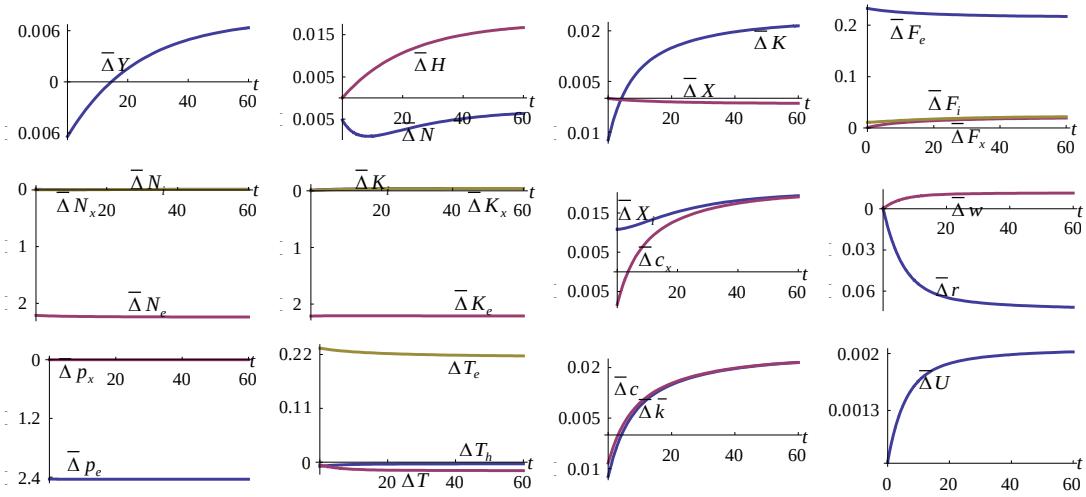

Figure 3. An Enhancement in Efficiency of the Education Sector

4.3. Human capital being more effectively utilized

We now study what will happen to the economic system if workers more effectively utilize human capital as follows: $m: 0.8 \Rightarrow 0.82$. The total labor is increased. The increase in the total labor is mostly absorbed by the production and resource sectors. The output levels and capital inputs of the production and resource sectors are increased. The output level and two inputs of the education sector are slightly affected. The economy has lower level of the resource, even though the resource input and consumption levels are increased. The rate of interest is initially increased and reduced in the long term. The wage rate is reduced. The education price is initially slightly increased, but reduced in the long term. The price of the resource is increased. The households spend more time on education and less time on leisure. The work time is slightly affected. The national output and utility level are enhanced.

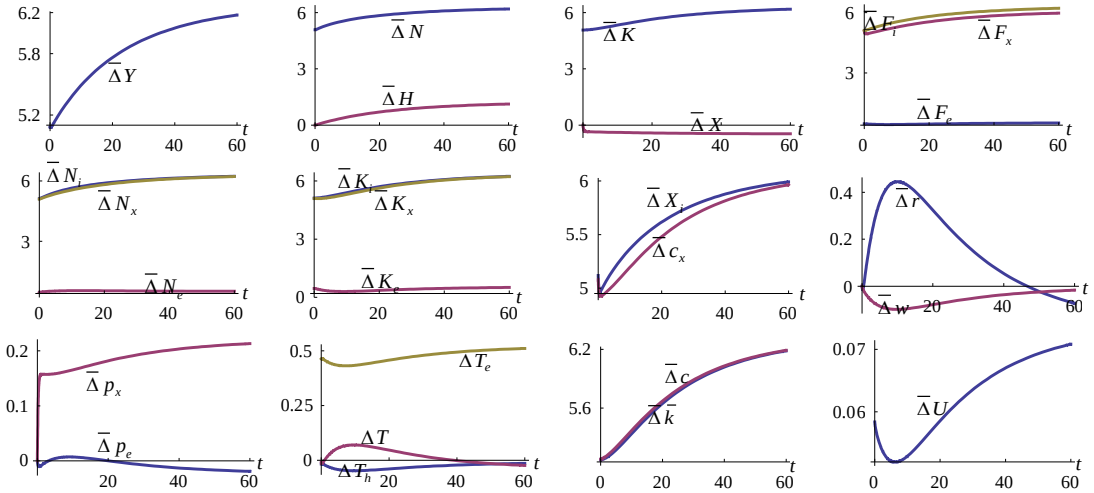

Figure 4. Human Capital Being More Effectively Utilized

4.4. The propensity to receive education being strengthened

We increase the propensity to receive education as follows: $\eta_0 : 0.01 \Rightarrow 0.012$. The simulation result is plotted in Figure 5. As the preference for education is strengthened, the education time is increased. Both leisure time and work time are reduced. The level of human capital is increased. The total labor supply is initially reduced and increased in the long term. The fall in the total labor is due to the reduction the work time. Correspondingly, the national output falls initially and rises in the long term. The rise in the demand for education drives up the price of education. The output level and capital and labor inputs of the education sector are increased. The total wealth is slightly changed. The stock of renewable resource is reduced first and then increased. The price of resources is reduced. The consumption and input levels of the resources are initially reduced and enhanced in the long term. The output levels and input levels of the production and resource sectors are slightly reduced. The rate of interest and utility level are increased.

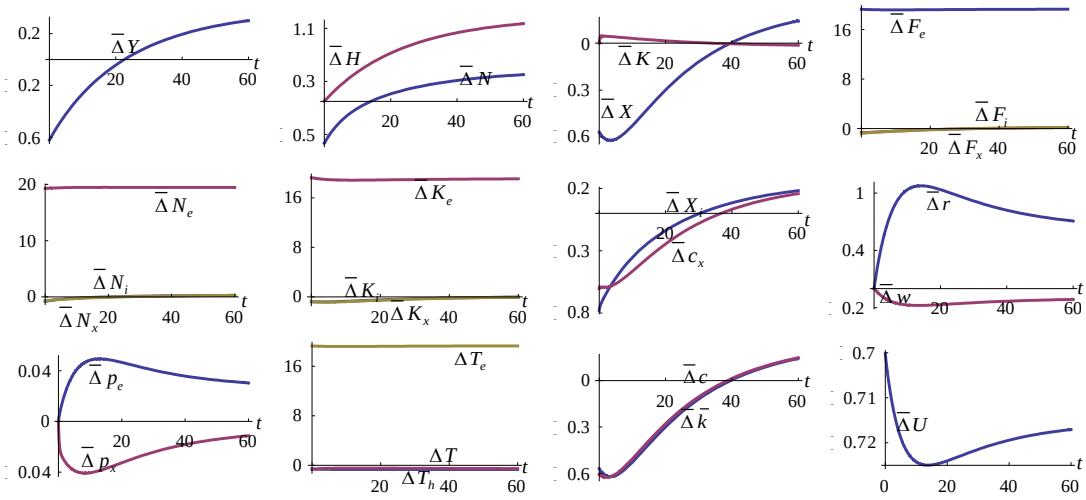

Figure 5. The Propensity to Receive Education Being Strengthened

4.5. The propensity to save being augmented

We increase the propensity to save as follows: $\lambda_0 : 0.6 \Rightarrow 0.62$. The simulation result is plotted in Figure 6. As the propensity to save is increased, the national wealth is increased. The increase in the total wealth enables the three sectors employs more capital inputs in the long term. The rise in the total physical wealth is association with a slight fall in the stock of the renewable resource. The price of the resource is increased, while the price of education is reduced. The rate of interest is reduced, while the wage rate is increased. The households work longer hours and have less leisure time and education time. The consumption level of resource by the households is initially reduced, and increased in the long term. The output levels of the production and resource sectors are increased, while the output level of the education sector is slightly reduced in association with falling in the price of education.

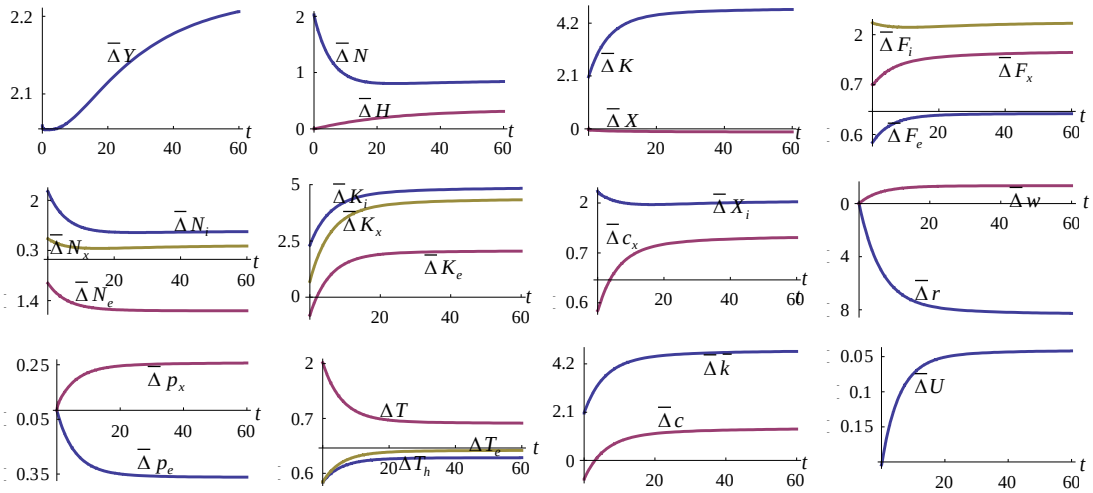

Figure 6. The Propensity to Save Being Augmented

5. Concluding Remarks

The main concern of this paper is dynamic interdependence among physical capital, resource and human capital. We modelled the dynamics of the three variables in an economic system with production, resource and education sectors. We took account of three ways of improving human capital: learning by producing, learning by education, and learning by consuming. The model describes a dynamic interdependence among wealth accumulation, human capital accumulation, resource change, and division of labor under perfect competition. We simulated the model to demonstrate existence of equilibrium points and motion of the dynamic system. We also examined effects of changes in the productivity of the resource sector, the utilization efficiency of human capital, the propensity to receive education, and the propensity to save upon dynamic paths of the

system. We may extend the model in some directions. For instance, we may introduce some kind of government intervention in education into the model. Ownership of resources is a complicated issue. Another interesting extension is to examine how human capital and education may interact with population dynamics.

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7. Appendix: Proving Lemma 1

The appendix shows that the dynamics can be expressed by three dimensional differential equations. From (2), (5) and (7), we obtain

$$z \equiv \frac{r+\delta_k}{w} = \frac{\tilde{\alpha}_i N_i}{K_i} = \frac{\tilde{\alpha}_e N_e}{K_e} = \frac{\tilde{\alpha}_x N_x}{K_x}, \tag{A1}$$

where we omit time index and $\tilde{\alpha}_j \equiv \frac{\alpha_j}{\beta_j}$, $j = i, e, x$.

By (1), we have

$$f_i(z, x_i) \equiv \frac{F_i}{N_i} = A_i x_i^{\gamma_i} \left(\frac{\tilde{\alpha}_i}{z}\right)^{\alpha_i}, \tag{A2}$$

where we also use (A1) and $x_i \equiv X_i / N_i$. By (2), (A1) and (A2), we have

$$r + \delta_k = \frac{\alpha_i z f_i}{\tilde{\alpha}_i}, \quad w = \beta_i f_i, \quad p_x = \frac{\gamma_i f_i}{x_i}. \tag{A3}$$

We can express w, r and p_x as functions of z and x_i. From (5) and (A1), we solve

$$r + \delta_k = \frac{\alpha_x p_x A_x X^b z^{\beta_x}}{\tilde{\alpha}_x^{\beta_x}}, \quad w = \frac{\beta_x p_x A_x X^b \tilde{\alpha}_x^{\alpha_x}}{z^{\alpha_x}}. \tag{A4}$$

From (A2) and the marginal conditions for labor in (A3) and (A4), we have

$$p_x = \frac{\beta_0 x_i^{\gamma_i} z^{\alpha_x - \alpha_i}}{X^b}, \tag{A5}$$

where $\beta_0 \equiv \frac{\beta_i A_i \tilde{\alpha}_i^{\alpha_i}}{\beta_x A_x \tilde{\alpha}_x^{\alpha_x}}$.

From (A5) and (A3), we solve

$$x_i = \frac{\gamma_i \beta_x A_x \tilde{\alpha}_x^{\alpha_x}}{\beta_i} \frac{X^b}{z^{\alpha_x}}. \tag{A6}$$

From the above analyses, we express w, f_i, r, p_x and x_i as functions of z and X. From (6) and (7), we have

$$p_e = \frac{w z^{\alpha_e}}{\beta_e A_e \tilde{\alpha}_e^{\alpha_e}}. \tag{A7}$$

where we also use (A1). Hence, we can express p_e and $\bar{p}$ as functions of z, X, and H.

From (20), (2) and $p_x c_x = \chi \bar{y}$ in (14), we get $\chi \bar{N} \bar{y} + \gamma_i F_i = p_x F_x$.

From $T_e = \eta \bar{y} / \bar{p}$ in (14) and (16), we have $\bar{y} = \frac{\bar{p} F_e}{\bar{N} \eta}$.

Insert this equation in $\chi \bar{N} \bar{y} + \gamma_i F_i = p_x F_x$

$$\frac{\chi \bar{p} F_e}{\eta} + \gamma_i F_i = p_x F_x. \tag{A8}$$

From (2), (5) and (7), we have

$$r + \delta_k = \frac{\alpha_i F_i}{K_i} = \frac{\alpha_x p_x F_x}{K_x} = \frac{\alpha_e p_e F_e}{K_e}. \tag{A9}$$

Substituting (A9) into (A8) yields

$$K_x = \bar{p}_e K_e + \bar{\gamma}_i K_i, \tag{A10}$$

where $\bar{p}_e(z, X, H) \equiv \frac{\alpha_x \chi \bar{p}}{\eta \alpha_e p_e}$, $\bar{\gamma}_i \equiv \frac{\alpha_x \gamma_i}{\alpha_i}$,

Insert (A1) in $N_i + N_e + N_x = N$

$$\frac{K_i}{\tilde{\alpha}_i} + \frac{K_e}{\tilde{\alpha}_e} + \frac{K_x}{\tilde{\alpha}_x} = \frac{N}{z}. \tag{A11}$$

Insert (A10) in $K_i + K_e + K_x = K$ and (A11)

$$\begin{aligned} \varepsilon_{1i} K_i + \varepsilon_{1e} K_e &= \frac{N}{z}, \\ \varepsilon_{2i} K_i + \varepsilon_{2e} K_e &= K, \end{aligned} \tag{A12}$$

where $\varepsilon_{1i} \equiv \frac{1}{\tilde{\alpha}_i} + \frac{\bar{\gamma}_i}{\tilde{\alpha}_x}$, $\varepsilon_{1e}(z, X, H) \equiv \frac{1}{\tilde{\alpha}_e} + \frac{\bar{p}_e}{\tilde{\alpha}_x}$, $\varepsilon_{2i} \equiv 1 + \bar{\gamma}_i$, $\varepsilon_{2e}(z, X, H) \equiv 1 + \bar{p}_e$.

Solve (A12) with K_i and K_e as variables

$$K_i = \left(\frac{\varepsilon_{2e} N}{z} - \varepsilon_{1e} \bar{k} \bar{N} \right) \varepsilon, \quad K_e = \left(\varepsilon_{1i} \bar{k} \bar{N} - \frac{\varepsilon_{2i} N}{z} \right) \varepsilon, \tag{A13}$$

where we use $K = \bar{k} \bar{N}$ and $\varepsilon(z, X, H) \equiv \frac{1}{\varepsilon_{1i} \varepsilon_{2e} - \varepsilon_{2i} \varepsilon_{1e}}$.

By (A13) and (A10), we solve the capital distribution, K_i, K_e and K_x, as functions of z, X, N, H, and $\bar{k}$. By (A1), we solve the labor distribution, N_i, N_e and N_x, as functions of z, X, N, H, and $\bar{k}$.

From (2), (5) and (7), we have

$$F_i = \frac{w N_i}{\beta_i}, \quad X_i = \frac{\gamma_i F_i}{p_x}, \quad F_x = \frac{w N_x}{\beta_x p_x}, \quad F_e = \frac{w N_e}{\beta_x p_e}. \tag{A14}$$

We express F_i, X_i, F_x, and F_e as functions of z, X, N, and $\bar{k}$. From (7) and $\bar{y} = \bar{p} F_e / \bar{N} \eta$, we have

$$\bar{y} = p_w N_e, \tag{A15}$$

where $p_w(z, X, H) \equiv \dfrac{\bar{p} w}{\beta_e \bar{N} \eta p_e}$.

From (A15) and $p_x c_x = \chi \bar{y}$ in (14), we express $\bar{y}$ and c_x as functions of z, X, N, H, and $\bar{k}$. From $w H^m T_h = \sigma \bar{y}$, $\bar{p} T_e = \eta \bar{y}$, and the definition of $\bar{y}$, we have

$$\begin{aligned} T_h &= \left(\frac{1+r}{H^m w} \right) \sigma \bar{k} + \sigma T_0, \\ T_e &= \frac{(1+r)\eta \bar{k}}{\bar{p}} + \frac{T_0 \eta H^m w}{\bar{p}}. \end{aligned} \tag{A16}$$

From $T + T_e + T_h = T_0$ and (A16), we have

$$T = h_1 - h_2 \bar{k}, \tag{A17}$$

where $h_1(z, X, H) \equiv T_0 - \sigma T_0 - \dfrac{T_0 \eta H^m w}{\bar{p}}$, $h_2(z, X, H) \equiv \left(\dfrac{\sigma}{H^m w} + \dfrac{\eta}{\bar{p}} \right)(1+r)$.

From $N = H^m T \bar{N}$, and (A17), we have

$$N = (h_1 - h_2 \bar{k}) \bar{N} H^m. \tag{A18}$$

From (19) and $K = \bar{k} \bar{N}$, we have

$$(\xi + \lambda) \bar{y} - \delta \bar{k} = \frac{w N_i}{\beta_i \bar{N}}, \tag{A19}$$

where we also use (14) and (A14). Substituting the definition of $\bar{y}$ and $N_i = z K_i / \tilde{\alpha}_i$ into (A19) yields

$$\left[\tilde{\xi} (1+r) - \delta \right] \bar{k} + \tilde{\xi} T_0 H^m w = \frac{\tilde{\varepsilon}_2 N}{z} - \tilde{\varepsilon}_1 \bar{k} \bar{N},$$

where we also use (A13) and $\tilde{\xi} \equiv \xi + \lambda$, $\tilde{\varepsilon}_j(z, X, H) \equiv \dfrac{\varepsilon \varepsilon_{je} z w}{\beta_i \tilde{\alpha}_i \bar{N}}$, $j = 1, 2$.

Insert (A18) into the above equation

$$\bar{k} = \Psi(z, X, H) \equiv H^m \left[\frac{\tilde{\varepsilon}_2 h_1 \bar{N}}{z} - \tilde{\xi} T_0 w \right] \left[\tilde{\xi} (1+r) + \tilde{\varepsilon}_1 \bar{N} + \frac{\tilde{\varepsilon}_2 h_2 \bar{N} H^m}{z} - \delta \right]^{-1}. \tag{A20}$$

From (A20), we solve $\bar{k}$ as a function of z, X and H.

It is straightforward to check that all the variables can be expressed as functions of z, X and H at any point of time by the following procedure: x_i by (A6) $\rightarrow p_x$ by (A5) $\rightarrow r$ by (A3) $\rightarrow w$ by (A3) $\rightarrow \bar{k}$ by (A20) $\rightarrow K = \bar{k}\,\bar{N} \rightarrow N$ by (A18) $\rightarrow T = N/H^m\bar{N} \rightarrow T_h$ and T_e by (A16) $\rightarrow p_w$ by the definition $\rightarrow p_e$ by (A16) $\rightarrow K_i$ and K_e by (A13) $\rightarrow K_x$ by (A11) $\rightarrow N_i$, N_e, and N_x by (A1) $\rightarrow \bar{y}$ by (A15) $\rightarrow c_x, c, s$ by (14) $\rightarrow X_i = x_i N_i \rightarrow F_i$ by (1) $\rightarrow F_x$ by (4) $\rightarrow F_e$ by (6) $\rightarrow U$ by (11).

We note that the right-hand sides of (3) and (8) are functions of z, X and H. Hence, we have

$$\begin{aligned} \dot{X}(t) &= \Lambda_X(z, X, H), \\ \dot{H}(t) &= \Lambda_H(z, X, H), \end{aligned} \tag{A21}$$

where we do explicitly express Λ_X and Λ_H as it straightforward but their expressions are tedious.

Taking derivatives of (A20) with respect to t yields

$$\dot{\bar{k}} = \frac{\partial \Psi}{\partial z}\dot{z} + \Lambda_X \frac{\partial \Psi}{\partial X} + \Lambda_H \frac{\partial \Psi}{\partial H}, \tag{A22}$$

where we also use (A21). From (15), we have

$$\dot{\bar{k}} = \lambda \bar{y}(z, X, H) - \bar{k}. \tag{A23}$$

From (A22) and (A23), we solve

$$\dot{z} = \Lambda_z(z, X, H) \equiv \left(\lambda \bar{y} - \Psi - \Lambda_X \frac{\partial \Psi}{\partial X} - \Lambda_H \frac{\partial \Psi}{\partial H}\right)\left(\frac{\partial \Psi}{\partial z}\right)^{-1}. \tag{A24}$$

We thus proved the lemma.

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Post Inflation Targeting Monetary Policy: A Study of Britain, Japan and the United States

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There is now considerable disquiet about the appropriate monetary strategy that central banks should follow in the aftermath of the global financial crisis. Several influential commentators have called for the abandonment of inflation targeting. Empirical research examining three major economies demonstrates that inflation targeting was effective prior to the crisis and a more flexible form of targeting may still be appropriate after the crisis.

***Keywords**: Inflation targeting, monetary policy, comparative study*

***JEL Classification**: E52, E58, E65*

1. Introduction

In the January 31, 2013 issue of Financial Times, Charles Goodhart argued that the recovery from the Great Recession (GR) of 2007-2008 has been slow and disappointing. There are indications that central banks of major industrial countries are using different monetary policy strategy. For example, suggestion that Bank of England is moving towards targeting nominal income, Bank of Japan emphasising employment growth and the Federal Reserve setting a limit for unemployment are all indications of central banks direction monetary policy towards output and employment. Taking Goodhart's suggestion further, it is imperative to see how different types of targeting evolved prior to the GR.

Inflation targeting as a strategy for conducting monetary policy became popular among the industrial and developing countries during the decade of 1990s. The strategy for conducting monetary policy in the 1970s, 1980s and the 1990 respectively changed from money supply targeting, inflation control and central bank independence and inflation targeting. It is interesting to note that the change in the strategy occurred at the same time for the countries that followed the above monetary policy strategies.

Oechsle (2013) argues that "Krugmanite" is a strategy under which the central bank has the mandate to target some growth rate of nominal GDP. The central bank attempts to maintain the actual growth rate of nominal GDP within the target through the use of monetary instruments. Under this strategy, if because of some unexpected negative shocks, the target is missed, the central bank uses its instrument to maintain a higher future rate of growth.

The purpose of this paper is to examine the extent to which real sector targeting has replaced other forms of targeting in three major industrial countries. In Sections 2-4 the concept of targeting and different

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forms of targeting are examined. Theoretical discussions and empirical results are presented in Section 5, and summary and concluding results are offered in Section 6.

2. Monetary Targeting

In conducting monetary policy some variables such as inflation, rate of growth output and unemployment rate are called final targets and some such as money supply, interest rate and exchange rate are called intermediate targets. The central bank attempts to influence the final targets by setting the intermediate targets.

For a successful targeting, an intermediate target must meet the following conditions:

i. The relationship between intermediate and final targets must be stable. If this condition is not met, changes in the intermediate target may not influence the final target or it may change the final target in an undesirable direction.
ii. Data on the intermediate target must be available prior to the data on the final target. This condition allows the central bank to forecast the future changes in the final target by observing the behaviour of the intermediate target.
iii. The intermediate target must be under the control of the central bank.

Monetary targeting was exercised during the 1970s for controlling inflation in Britain, United States, Canada, Australia and New Zealand. This procedure relied on Friedman Schwartz (1963) where the authors showed a long run close relationship between money and prices in the United States.

Monetary targeting adds to the credibility of the central bank and prevents inflationary consequences of a discretionary policy based on the choice between growth and inflation. Moreover, the existence of a target creates transparency in implementation of monetary policy and allows the privates sector to anticipate the direction of monetary policy.

The central bank cannot control both money and interest rate simultaneously. If money is controlled interest rate is left free and vice versa. Poole (1970) proposed conditions for choosing money or interest rate as an intermediate target. Poole assumed that the objective of the central bank is to minimize the deviation of output from its desired level.

Monetary targeting is preferable if the economy is subject to a real sector shock such as changes in consumption, investment or exports. Interest rate targeting is preferable if the source of instability is from the financial sector.

Monadjemi and Kearney (1990) showed that in the 1970s in the United States, United Kingdom, Canada, Germany and Australia monetary targeting was successful in reducing inflation. During the 1980s, financial innovations and financial deregulations caused a considerable instability in the velocity of money. Fluctuations in the velocity of money introduced several problems in conducting monetary targeting. For example, financial deregulations led to a significant expansion of bank deposits and the supply of money (money supply include bank deposits). An increase in the supply of money without a corresponding rise in nominal GDP led to a fall in velocity of money. Most of the above-mentioned countries suspended monetary targeting in the 1980s.

3. Exchange Rate Targeting

During the 1980s, several countries conducted monetary policy by targeting the exchange rate. Stability of the exchange rate is important particularly for countries that international trade comprises a large proportion of their aggregate economic activity.

In 1979, in the context of the European Monetary System (EMS), eight European countries decided to limit fluctuations of their exchange rates within ± 2.5 percent relative to the German Mark. EMS was successful in keeping the inflation rates of the member countries in line with the rate of inflation in Germany, which was the lowest in Europe. EMS actively continued operation until 1992 when a significant depreciation of the British Pound and an increasing limit of fluctuations to ± 15 percent automatically caused the breakdown of the system. Eventually the European Monetary Union and the single currency were introduced in 1999 and the European Central Bank (ECB) was assigned the task of managing euro's liquidity.

In the commodity producing countries, the exchange rate is highly correlated with the commodity prices. In these countries exchange rate targeting may cause problems that are similar to the Argentine (2001), Mexico, (1994) and Britain (1992). In these cases eventually the central bank floated the exchange rate.

4. Inflation Targeting

During the 1990s, some countries such as Australia, Brazil, Britain, Canada, Chilli, Norway, South Africa, Korea, and New Zealand commenced conducting monetary policy base on inflation targeting. In this procedure, the central bank attempts to conduct monetary policy such that the expected rate of inflation remains within a specified range. Countries that exercised inflation targeting were successful in keeping their rate of inflation within the targeted range.

The preference of price stability against growth and employment was demonstrated in Rogoff (1985). Rogoff argued that the society is better-off if the objective function of the central bank is different than the objective function of the society. In other words the monetary authorities must be conservative with an objective function that assigns higher weight to price stability than employment. Decisions made by a conservative central bank must be independent of the expansionary policies of the government. Alesina and Summers (1993) showed that over a decade, Germany and Switzerland with most independent central banks experienced lowest possible rate of inflation.

Preference of price stability over employment follows separate articles by Friedman (1968) and Phelps (1968). Both studies showed that an expansionary monetary policy increases employment in the short run but in the long run employment returns to the natural rate and inflation remains at a higher level. In other words, in the long run an expansionary monetary policy increases inflation without affecting unemployment. Kyland and Prescott (1977) society's welfare is improved if in conducting monetary policy the central bank follows a rule rather than discretion. The authors showed that conducting monetary policy based on a rule generates no inflation whereas a discretionary monetary policy produces positive inflation. Rogoff (1985) argues that in the absence of productivity shocks, inflation targeting is the best strategy because it has no trade-off between inflation and unemployment.

In Argentine one unit of local currency was set to one US dollar. This procedure reduced inflation but created banking crises. In 1994 Mexico attempted to limit fluctuations of peso against the US dollar. However, political turmoil and the loss of foreign exchange reserves forced the government to devalue the peso. In 1992 Britain was forced to leave the EMS fixed exchange rate system when Bank of England experienced heavy losses.

Inflation targeting is not suitable in the presence of a supply shock. In this case control of inflation is associated with a large drop in output and employment.

In inflation targeting by publicly announcing targets and monetary policy strategy the central bank becomes more transparent and responsible. Mishkin and Posen (1997) argued that those countries that implement inflation targeting must have developed financial markets, macroeconomic stability, an independent monetary policy and a credible monetary policy. Moreover, the central bank must not be committed to maintain the exchange rate.

The logic behind the inflation targeting is based on the long run policy ineffectiveness of monetary policy. In the long run monetary policy affects prices but not output.

The importance of maintaining an inflation target varies among different countries. At the top of the list is New Zealand where the governor of the central bank's job depends on the maintenance of the inflation targets. Inflation targeting is not sensitive to the terms of trade shocks because generally prices of food, energy and interest rate on mortgages are excluded from the consumer price index. Prices of these items are very volatile and cause changes in the aggregate supply curve.

Those economists who are against the inflation targeting such as Debelle and Fischer (1994) and Posen (1995) argue that in Germany and Switzerland inflation targeting was successful enforced at the cost of high unemployment. Recently most of the macroeconomists and central bankers believe that maintaining a low inflation target leads to macroeconomic stability in the long run. Supporters of inflation targeting are not in favour of zero inflation. They argue that since nominal wages are rigid downward, having a positive inflation is the only way to reduce real wages and create employment. Moreover, maintenance of a very low inflation target may lead to the dander of deflation. Bernanke and Mishkin (1997) argue that similar situation existed in Japan in the late 1990s.

Svensson (1999) identifies three features for inflation targeting:

i. Existence of a clear numerical target for inflation,
ii. Forecasts of inflation as a framework for conduction monetary policy,
iii. High level of transparency and responsibility.

McCallum (1996) examined the success of inflation targeting in Canada, Britain, Sweden and New Zealand that conducted monetary policy in the context of inflation targeting in 199o to 1993. All of these

countries used consumer price index, excluding food and energy prices, as a measure of price level. McCallum argues that inflation targeting is preferable to the discretionary policy because in the latter method more attention is paid to the benefits of an expansionary policy than the costs of the policy.

McCallum showed that high rates of inflation that existed in the above mentioned countries in the 1970s and the 1980s, declined to 2 to 4 percent in the 1990s.

Among the developed and developing countries respectively New Zealand and Chilli were the first countries that commenced inflation targeting. Bosede (2004) showed that before the implementation of inflation targeting the average rate of inflation in the developed and the developing countries were 3.72 and 13.11 percent respectively. 12 months after the implementation both rates declined to 2.71 and 8.3 percent respectively.

5. Real Sector Targeting: Empirical Evidence

The choice between inflation targeting and real sector targeting is similar to the choice between fixing the price and letting the quantity be determined in the market or setting the quantity and letting the price to be freely determined. The authorities cannot set the price and quantity together at the same time. Historically, real sector targeting rather than inflation targeting became important when the economy was far away from the potential output and inflation is not a serious problem. Notable examples of real sector targeting are during the Great Depression of 1930s and the GR of 2007-2008.

Figures 1 and 2 show quarterly data on inflation and growth of real GDP for Japan, United Kingdom and United States, 1990- 2013.

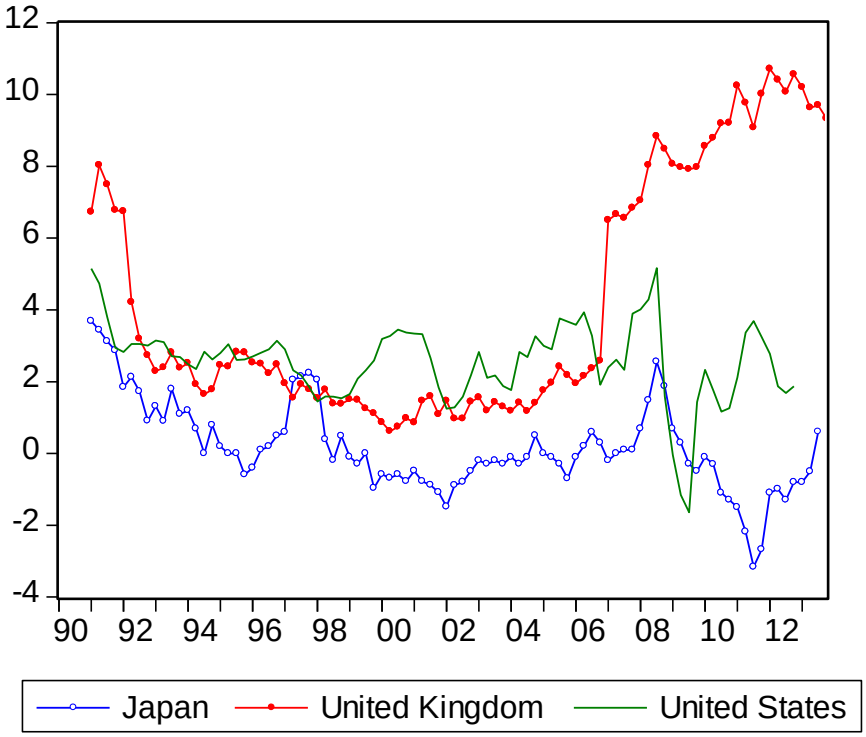

Figure 1. *Inflation Rates: Japan, United Kingdom, and United States*

Source: All of the series in this study including CPI, growth rates, government expenditure and nominal GDP for Japan, UK and US were collected from the OECD website under quarterly national income account.

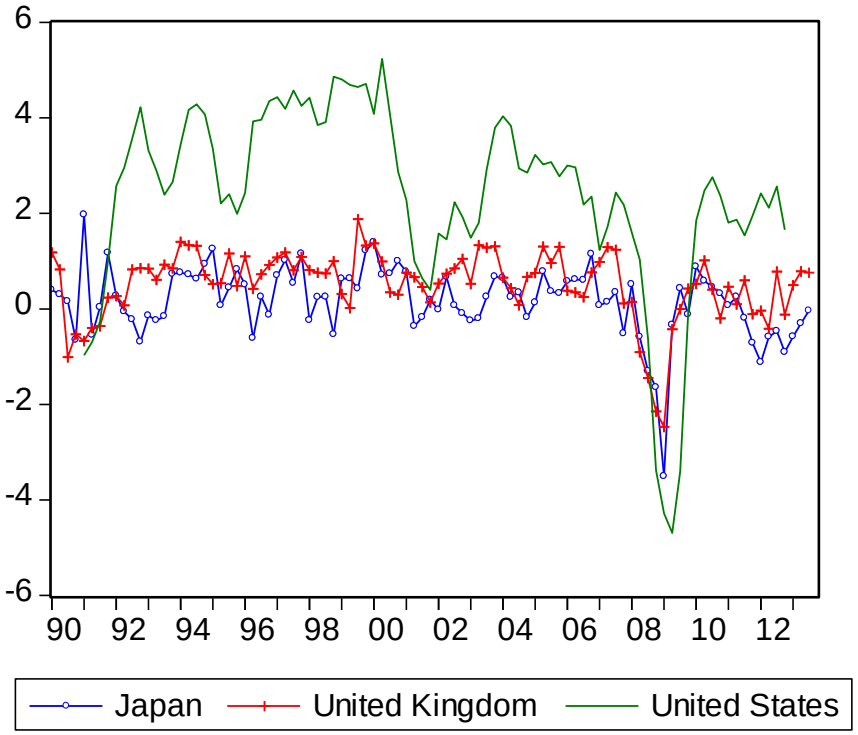

Figure 2. *Growth Rates: Japan, United Kingdom, and United States*

Figure 1 indicates stability of the inflation rates in three countries over roughly about 14 years (1992 to 2006). This period coincides with the period of inflation targeting in all of the three countries. However, the prolong period of tranquil inflation stability did not continue as inflation rates behaved erotically after 2006.

Figure 2 also shows a prolong period of about 17 to 18 years growth for three countries prior to the GR of 2007-2008. All of the three countries experienced a dramatic fall in their growth rates in 2008. Subsequently the fall of growth rates were reversed as governments' macroeconomic policies and rescue packages attempted to restore output and employment. The primary emphasis was placed on growth rather than inflation.

Further information regarding volatility of inflation and growth rates in three selected countries prior and after 2007 are reported in Tables 1and 2.

Table 1. *Standard Deviations of Inflation Rates*

Country	1992-2006	2007-2012
Japan	0.91	1.34
UK	0.93	1.33
USA	0.66	1.60

Table 2. *Standard Deviations of Growth Rates*

Country	1992-2006	2007-2012
Japan	0.49	0.93
UK	0.40	0.96
USA	1.12	2.31

Both tables show more volatile inflation and growth in the latter sub-period. Stability of the inflation rates during the earlier period is indicative of the inflation targeting which was less emphasised as output and employment significantly dropped during the GR in most of the affected countries.

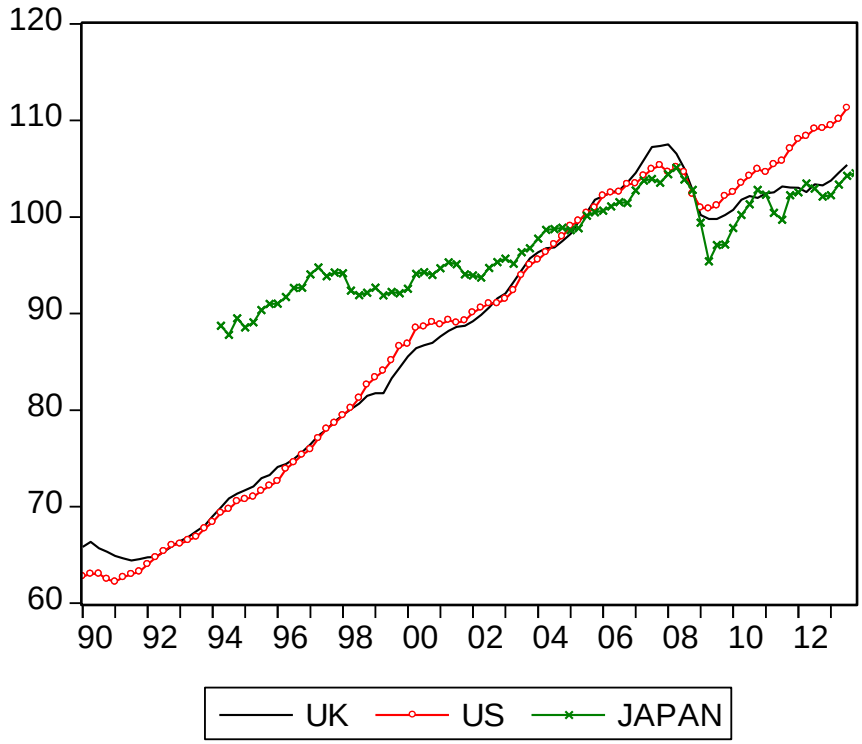

Figure 3. *General Government Expenditure: Japan, UK and USA*

Figure 3 shows that government expenditure in three countries rose steadily until beginning of the financial crises and then after a sharp fall started to rise again indicating fiscal authorities intention to compensate for the decline in output and employment. Figure 3 also suggests that falling government expenditure around 2007 may have contributed to the recession in three selected counties. Monadjemi (2011) argues that rising oil prices coupled with falling government expenditure contributed to the recession in the United States in 2008.

Further evidence on inflation targeting is provided using Hodrick-Prescott (1997) (HP) filter. HP method divides a time series into growth and cyclical components. Using a statistical filter, the growth component can be removed, leaving the cyclical component as deviations around a smooth trend line. Assume Y is a time series on real GDP or CPI.

$$Y = y_c \ + y_g$$

where $y_c \ and \ y_g$ respectively are cyclical and growth components of Y. Assuming that inflation targeting was in effect 1990 – 2006, the cyclical component of CPI is not expected to deviate substantially from the trend line. However, with the abolition of inflation targeting after 2006, price level is uncontrolled and is expected to deviate from the trend line.

Applications of HP method for US, UK and Japan are presented in Figures 4 to 9.

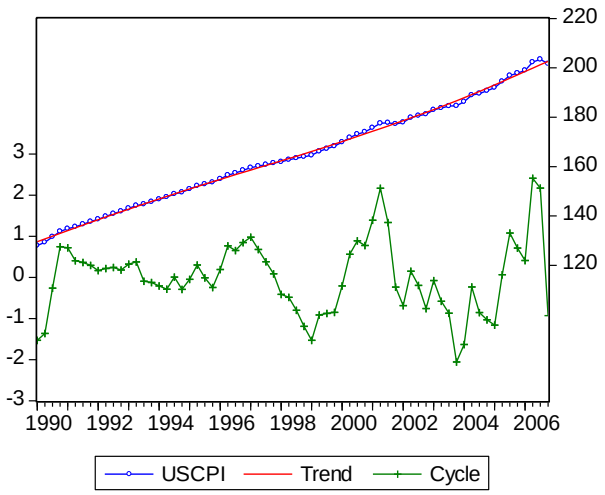

***Figure 4**. Hodrick-Prescott Filter US CPI 1990-2006*

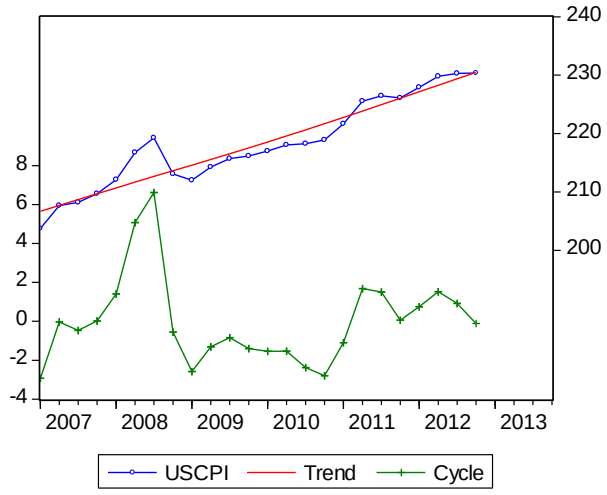

***Figure 5**. Hodrick-Prescott Filter US CPI 2007-2013*

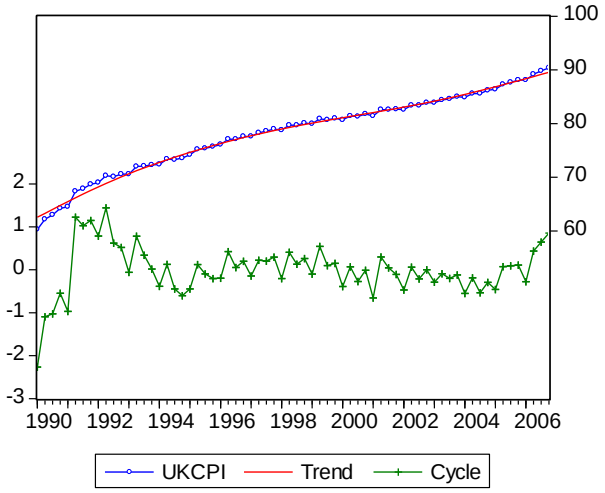

***Figure 6**. Hodrick-Prescott Filter UK CPI 1990-2006*

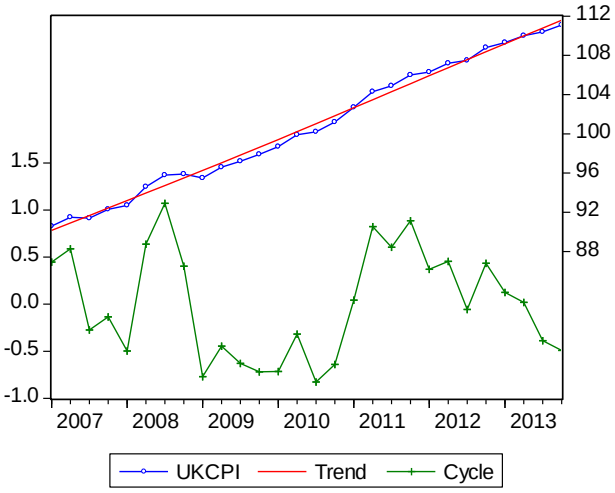

***Figure 7**. Hodrick-Prescott Filter UK CPI 2007-2013*

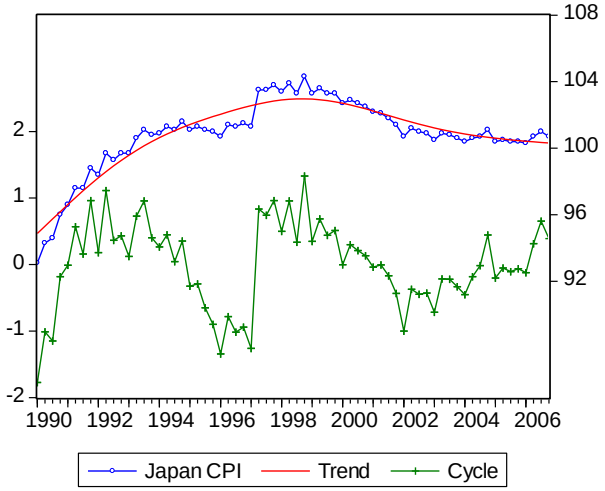

***Figure 8**. Hodrick-Prescott Filter Japan CPI 1990-2006*

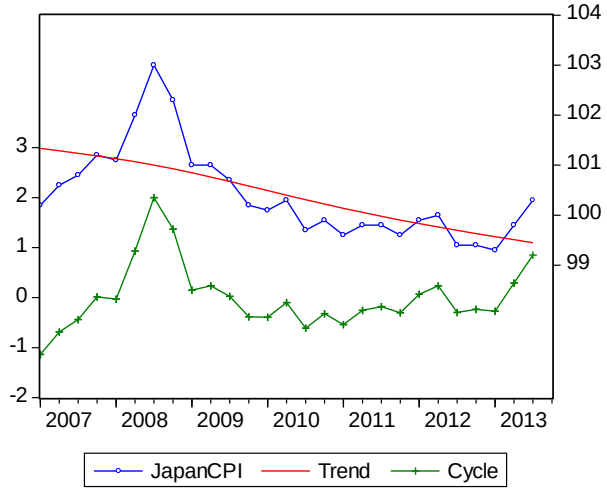

***Figure 9**. Hodrick-Prescott Filter Japan CPI 2007-2013*

All of the figures indicate that prices moved much more closely along the trend lines in 1990 – 2006 than they did in the latter period after 2006. In cases of UK and US in the earlier period, CPIs moved almost completely on the trend lines. These figures provide further evidence on the stability of the prices in three countries enforced by the existence of inflation targeting prior to the GR.

6. Conclusions

Macroeconomic Policy is under review after the harrowing experiences with the global financial crisis and its lingering effects, especially in Europe. The International Monetary Fund, for example, is sponsoring several conferences on 'Rethinking Macro Policy'. There is considerable divergence of views about what the appropriate monetary targets should be after the crisis. A pivotal statement in this respect is the paper by Blanchard et al (2010). This study looks at "what we thought we knew" about the benefits of having just one target of inflation and how "we were wrong" and that "what we have learned from the crisis" is that central banks aimed for too low a level of inflation. The target should be raised to provide liquidity more broadly and to reduce the value of real debt when extensive financial deleveraging is occurring. Coming from an institution such as the International Monetary Fund, which had been a champion of inflation targeting in the past, really does indicate how much central bank behaviour has been transformed.

Michael Woodford (2012, 2013) suggests caution before we discard the conventional wisdom. Our empirical results support this proposition. Inflation targeting has provided stability for medium-run inflation expectations before the crisis and has prevented a deflationary spiral, during and after the crisis. What the profession has learned is that inflation stabilization, in itself, does not guarantee macroeconomic stability. A more flexible form of inflation targeting is called for. For example, a central bank may target nominal GDP in such a way that it hits an inflation target over a medium-run rather than in the short-run. Official interest rates might be lowered even if inflation targets are not being met at that point in time as long as nominal GDP is below or is trending below a nominal GDP target. Similarly, interest rates may be raised even if inflation targets are being met if there are indications of excessive debt accumulations, property bubbles and fear of financial crises. Monetary policy needs to be cognisant of not only inflation and real activity forecasts but also the spectre of financial crises.

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Evaluate Local Private Companies Developing Strategy to Solve Crises

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This study concentrated on local private companies' evaluation to solve crises. It explains the factors that have an effect on these companies' success by developing strategies, establishing general budget supporting up their conditions, fair dealing with tax and clear corporate responsibility duties. The companies that get government support may reach their aims of solving the crises or may develop trickeries to get unfair profits besides government support which increases depression. The researcher suggests the use of three tables which will be presented in this study, as models to evaluate the fair general budget policies, the ability of local private companies to get support, and also to evaluate the sharing between companies and government. These tables are important and need to be monitored and can provide direction for companies to a condition which is to cover citizens' need locally, at appropriate prices, at a suitable time and place. On another hand, a figure displayed in this research can be used to watch a company's reaction in crises.

***Keywords**: Evaluation, Crises, General budget, Tax, and Local private companies*

***JEL Classification**: H32*

1. Introduction

Economic crises lead to depression as result of companies' losses. Companies lose capital or expert human resources or their possibility to use land. These aspects come as results to events such as war, earth quick, diseases, and immigration. Some losses come because of market ignorance as using trickery without enough controlling from the government.

Economic crises may lead to depression as result of not using resources in an appropriate manner. Countries could face using capital, such as cash and may experience inflation. They tend to use liquidity of money to function rather than to produce services and products. This case will imply increasing the cash level to buy limited supply of products. On one hand, it leads to increased product price because the buyer has cash to buy in spite of increasing its price; on other hand, increasing liquidity shows companies the possibility to delay credit by getting another credit.

This case means that the country cannot depend on pushing liquidity to supply local companies in order to reduce depression. Nicolas and Serene (2011) promoted an idea about the inflation rate that affected money as means of payment and as a store of value, and as a reason that inflation improves trade if it directs cash liquidity to real investments.

The government tries to solve the problem by encouraging production to reduce tax. Some countries buy companies that do not perform very well and make the necessary management and financial restructuring

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while some countries try to bring in international companies to help them solve the problem as a result to their experience and international power. Some international companies' investors are actually countries. Every way of implementing a solution has a negative effect by decreasing the size of the local private investments and by increasing the general budget government expenses to develop solutions because, if not, the government will be blamed if the solution will not succeed to escape a deficit. Some experts' advice is to develop financing and investment tools by local companies in order to share in solving crises. The ignorance of companies managing and fast dealing with technology to increase speculations of these tools expect more than to use them in direct investment. It leads to more loses because the developing tools were directed to transfer risk. Loses will be transferred to speculators.

The effect of crises can be seen in financial markets. It shows the decrease of companies' shares market prices, number of companies, and daily dealing. It may lead to the loss of the financial market as standard to evaluate the development of the country. It can reduce country credit classification and standard to sell bonds in international markets and it can increase credit cost. However, solving the problem will lead to increased human resource value, assets value and land value.

1.1. The problem

There is need to study the decision problem of government solving crises by supporting private local companies as expected to use the developing strategy to increase country resources' value and tax return in the future. This decision needs limits to success or it will lead to increased general budget deficit as loosing expenses and time. The main problem is to avoid negative effects and increase positive effects. The questions are:

a. What are the limits to direct local private companies in developing the strategy needed to solve crises?
b. What are the tools to evaluate local private companies in developing a success strategy in crises?
c. Is there a possibility to find a model to show local private companies' evaluation to solve crises in order to control reaching the resources' value and keeping citizens satisfied?
d. Are there limits to share government with local private companies?

1.2. The Importance

This research helps governments to distribute local private companies' responsibility to help solution aims. It directs local companies to developing a strategy to achieve their aims. It gives a model to control this sharing practically. It gives a model to watch assets' value, human resources' value, land value and to keep citizen satisfied as a result to cover the needs with a suitable cost in a suitable place within a suitable timeframe.

1.3. The Objectives

This research aims to find the following:

a. To find effects of general budget on success sharing with private local companies to solve crises.
b. To find negative effects of private local companies in developing a strategy.
c. To find positive effects of private local companies in developing a strategy.
d. To find government and local private companies' sharing limits.

1.4. Literature Review

Mashaqbah (2003) aimed to analyze general budget to correct economic policy. He found that reducing the current expenses, setting the price on essential products produced by local company, and increasing tax did not succeeded to the necessary restructuring using production elements sensibly. Khor (2005) explained how Malaysia government controlled Southeast and East Asia economics crises of 1997-1998 that depended on fixed exchange system after people lost their faith in free market system which meant to curb speculations in order to obtain economic growth as result of financial direct investments.

Bonini et al. (2010) found that corporate social responsibility contributes positively to long term shareholder value and helps their companies to build strong reputation. Ziesemer (2011) explained the standard of success tools types is to finance and invest up at a suitable time with suitable cost so there must be financing tools, investment tools, and saving tools to make money. Heinze et al. (2014) explained the important thing to evaluate companies in crises is their past reputation, not to be depended on independent investigation. Because there is the possibility of an ally. Seal and Ball (2011) concentrated on general budget management affected by strategy and structural changing in the public sector and time of needs in long term, short term and medium term, suggesting a dynamic dialectic of control framework. Nazal (2014) explained the effect of tax types on the company, general budget, and citizens. The result was negative because a third world country cannot

depend on economic equilibrium as self-sufficient therefore it leads to transfer citizen middle income type to limit their income type.

2. Developing Strategy

Developing a strategy gives the idea about developing or improving products to get advantages, as increasing quality to be similar to competitors' products, solving client problems, providing unique benefits to clients or establishing standards better than those of competitors (Slotegraf and Atuahene-Gima, 2011, p. 106). Also it gives the idea about developing ways of investing or financing. It shows its managing ability to transfer risk, avoid risk and accept risk with the possibility of controlling it. For instance, a company's debts are delayed and has risk of default or has weak grantee. The company can sell with discount to another company. It transfers risk to the buyer and gets cash currently with a suitable part of loss as result to the discount or it can sell as bonds in financial market.

There is a strong statistical relationship between financial development and economic development. This often is presented as evidence that financial development causes economic development by promoting investment and making the allocation of resources more efficient (Amaral and Quintin, 2010, p. 804). This evidence means certain standards so if the developing strategy works against promoting investments and making the allocation of resources more efficient it will cause negative effects on solving crises.

Negative effects come as result to face government rules which reduce companies' profit. For instance, by increasing taxes, this policy will reduce company profit so it faces this increasing in an indirect way. It reduces asset ownership by using leasing and it depends of financing by loans to increase costs. This aspects make capital easy to transfer to another country. Companies may experiences loses by export products with loss to other country. It can make a commercial company to sell products and make profit by avoiding tax. Some countries try to support this company to keep the level of employment up by giving grants or providing energy at low price than that on the market but practically this supports the increasing of budget expenses.

3. Affections Between General Budget and local Companies Developing Strategy

General budget shows government expenses and returns. Expenses or returns are divided into current and capitalized items. The level of the expenses gives an idea about government expenses to support companies as sharing in employee insurance to reduce their cost or give company products, machines and energy with low prices than those on the market, also show sharing in company capital; however, the returns show local companies taxes and a way for the government to get returns. Reducing tax is an economic tool used to encourage local companies to increase capital, but also to reduce tax just for international companies who will face competition and the possibility of local company to experience loss. Encouraging means less costs, therefore international companies are able to sell products with low prices and good quality. This reduces local companies' sales and can lead to losses.

General budget can be financed by deficit. It means that the expenses are more than the returns so it needs to get loans. If deficit increases for years this means country delay problems and investing in that country may not be suitable to cover general budget returns. It increases a problem. Countries may refuse to give it a loan or to import products to cover the country's needs by credit. The general budget can be financed by surplus as a result to increasing returns than expenses. This surplus must be managed in a suitable way or there will be a case of inflation. This outcome can be protected by the companies' ability to use the resources in an appropriate manner. Government can finance companies in order to reach a self-sufficient level and get in growth mode. Growth can be accelerated by covering international needs or sharing in international investing which reduces local company cost and reduces the country's unemployment.

Government expenses used to support local companies can lead to three cases:

a. Local companies use their developing strategy to increase investment value, human resource value and land value which means the government's future returns will be increased and will be able to cover the current deficit.
b. Local companies use their developing strategy but it does not bring the success they anticipated. They need more support. Companies face crises but need more time. This means the government should increase their support for local companies or look for international companies as a way to reduce government expenses, but local companies will face more competition and reduce their returns. Trust is the rule. If country a lost trust in local companies, the government will choose the second route regardless of current international companies' risk especially if it faces a bad credit classification.

c. Local companies get in a loss despite the government's support. It may come as a result to a company's trickery or its weakness of managing crises. They will be losing land value, human resources value and assets value. Government has to encourage international companies regardless of its bad affection as monopolized products to increase prices.

Any of these cases will revalue a country's economic growth and citizens' need satisfaction.

4. Private Companies - Ways to Face Tax

Citizens need to relate to their investing value whether in direct investment or in shares. Investing in a company means any tax will reduce shareholders' profit. Taking taxes in crises cases means the reduction citizen wealth. Tax is types as sales tax, customs tax and tax on profit. Losing citizen wealth means to transfer from the middle income people to the inferior limit of the income type and to increase government problems. One of the worst case secrets of selling some company assets as an authorized manager and he gives shareholders part of its value as distributed profit to buy tax. A manager who does trickery will take commission and part of the asset value while shareholder losses his investing after tax in spite of losing.

Private companies face tax by many ways. Every action has an effect on government planning. Companies have to increase resources' value but practically it can do so in many cases (Figure 1).

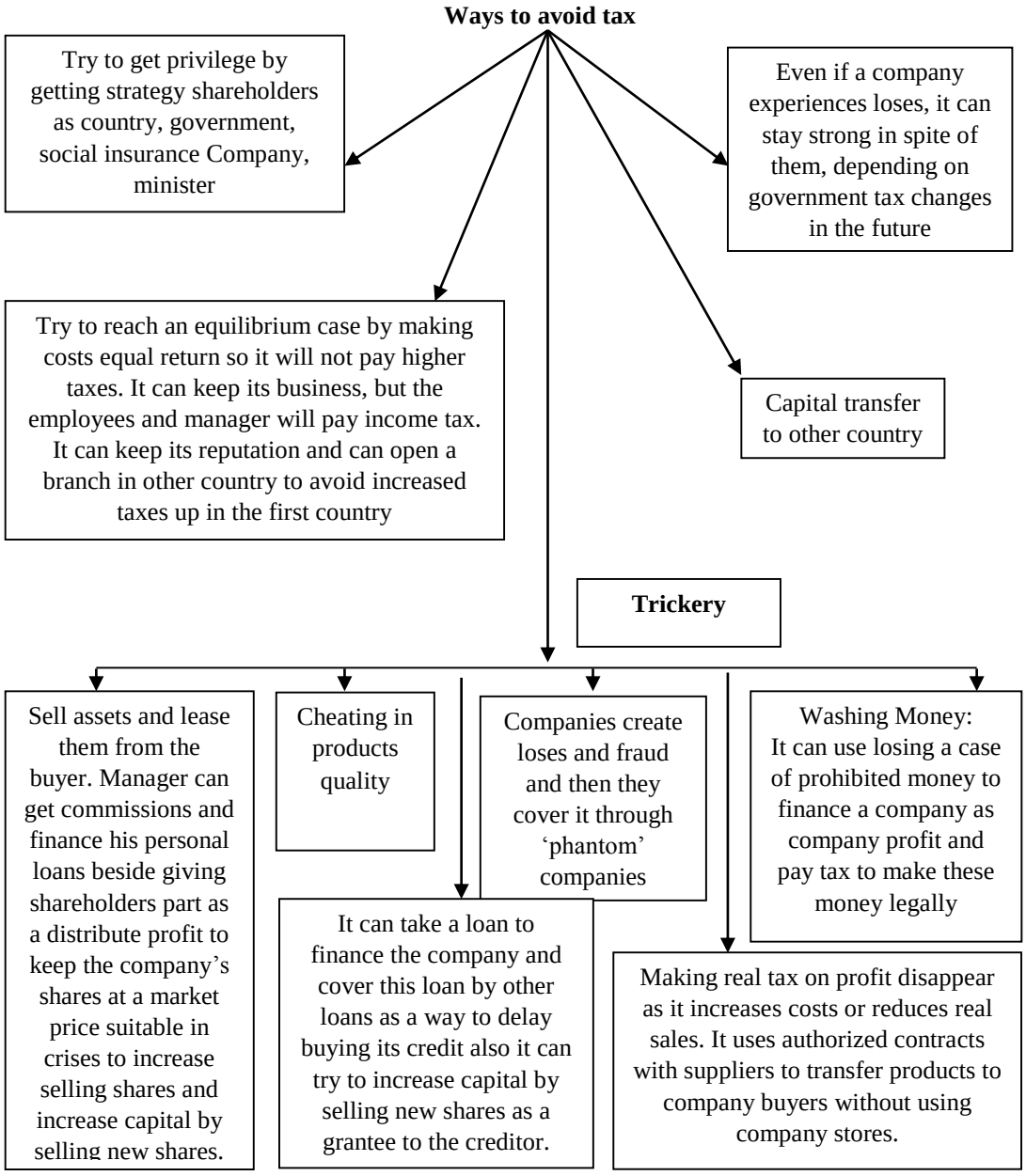

Figure 1. *Company ways to deal with tax*

5. Model of a revaluation of how private companies search for crises solutions

There is a need to control and watch companies while developing their strategy to solve crises. This model must show general budget expenses, return, monetary policy and financial policy. As result to managing general budget there is a flexibility to make adjustments and can be supported by monetary and financial policy.

Table 1. *Evaluate local private companies' standards in the country's tax environment country and credit planning*

Country Planning		**Evaluate local private companies' standards:**
To pull money (as in inflation) - Increase Tax - Reduce credit size	**To push money (as in depression)** - Reduce Tax - Increase credit size	Did the companies added these values in the policy environment of country planning?
It must increase these value standards	**It must increase these value standards**	**Citizens needs of value:** - Products - Savings - Investing
		Companies' value: - Human resources - Assets value - Reduce liabilities - Establish fair prices
		Public welfare value: - Increase advantages for users - Maintain public ownership
		Financial market value: - Increasing daily dealings - Developing safety tools - Increase market segmentation to meet needs - Increase company number to manage risks
		General Budget success managing value - Reducing Expenses - Increasing Returns
		Country resources' value - Increase land value - Increase capital value - Increase workers' value
		International dealing value: - Keep or increase international relationships - Increase international Investing - Increase international savings

These aspects mean that companies must get involved in increasing these value standards. As a result to these standards there will be a way to evaluate local private companies as a way to solve crises and discuss if they deserve to get support or not. See table 2.

Table 2. *Evaluating the success of local private companies to solve crises*

No	**Success factors up for evaluation**	**Degree of success**
1	Covering citizen needs to reduce effect of monopolizing products in international markets and reducing import	
2	Covering international needs to increase export, increase reserves of foreign currency and make good relationships with countries as promoting products with high quality	
3	Increasing human resource experiences to increase their value by training and teaching	
4	Reducing other companies' costs as insurance companies, suppliers or technical players	
5	Promoting good resources for tax	
6	Having the experience to use liquidity in suitable investments therefore a government can help a country to apply pushing money policy	
7	Reducing unemployment	

8	Increasing other companies' ability to share in crises solution	
9	Increasing financial market value as a result to develop financial tools and investment tools with suitable safety and can have a good reputation to sell and buy shares which come as a result to increase its assets' value and profit after tax value.	
10	Increasing public ownership advantages and support its maintenance	
Total		

This table (Table2) shows a company value to get support to contribute in crises solving beside the control of unsuccessful companies to apply this table practically in order to serve support. To use this table there needs to be full disclosure. This can be done if companies apply human resource accounting and methodology. It relates to a company's success of retaining valuable human resources because the employees are ones who understand their work's advantages and disadvantages so they can give information and details fairly (Fariborz and Raiashekar, 2011).

6. Standards to Achieve Success by Government and Private Companies Contributions in Production

Some countries aim to reach a self-sufficient level by increasing employment, local investing, and local savings besides avoiding international negative changes so a country can study the effect of its support and can compare with its choice of international companies. Bad expectations will increase the support to local companies rather than to international companies. The next table (Table 3) explains effects of different possibilities to cover citizens' needs by sharing government, international companies and local companies.

Table 3. *Effects of a country's management of covering citizens' needs on its economic risk*

Ways of covering citizen needs	Effects on a country's economic situation	Needs of success	A country's job	Risk
Only by local companies	The economic situation becomes affected major by local factors as in self-sufficient case	Experiences and resources at a suitable cost	Direct and control on production to meet citizen needs up to quality standards and safety	There are limits by fair country directing and controlling
Only by international companies	The economic situation becomes affected by international factors as in consumer countries	Negotiations can limit international risks by conditions such as using local workers and giving local managers more experience	Direct and control on production to meet citizen needs up to quality standards and safety. It may have to contribute to establishing the managing of international companies	There is the possibility to transfer capital, workers and lands as a result to covering international sales rather than local needs and monopolizing of products to get power in the country
By local companies and international companies	Increasing the effects of factors to international changes	Balance between international companies aims, local companies aims and country aims	Direct and control on production to meet citizen needs up to quality standards and safety. It may have to contribute to establishing the managing of international companies	International companies can transfer capital and monopolize products to get power in country and there is possible to lose local companies competition ability and investing
By government investing, local companies and international companies	The government will have an effect on the economic situation as an investor or stakeholder with companies	Balance between international companies aims, local companies aims and country aims and there must be a limit of the rules and to fairly reduce the factors that change government policies	It becomes an investor, director and controller of production to meet citizen needs up to quality standards and safety. It may have to contribute to establishing the managing of international companies	Missing the balance as a result to the weakness experienced or rating will lead to the loss of investing and experiencing international problems as a result to face international companies expecting certain rights

7. Conclusion

As a result of this study, companies can get government support and may reach aims of solving crises or make unfair activities (trickeries) to get unfair profit beside government support which increases depression. It is important to evaluate local private companies to help government in solving crises up to their limits or it will increase general budget deficit as a result of the support of these companies. There are certain limits: the necessary experience in developing the strategy, the necessary general budget to support the conditions, fair dealing with tax, and clear company responsibilities and duties.

8. Recommendation

As a result of this study, there is a need to evaluate companies' contribution in solving crises. The researcher suggests the use of three tables which will be presented in this study, as models to evaluate the fair general budget policies, the ability of local private companies to get support, and also to evaluate the sharing between companies and government. These tables are important and need to be monitored and can provide direction for companies to a condition which is to cover citizens' need locally, at appropriate prices, at a suitable time and place. On another hand, a figure displayed in this research can be used to watch a company's reaction in crises.

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Achieving the Renewable Energy Target for Jamaica

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The high cost of energy in Jamaica, one of the highest in the Caribbean region, is usually cited as a hindrance to industrial development and efficiency, especially in the manufacturing sector. High energy cost is also considered to be a national energy security issue and the government is taking steps to ensure adequate supply of energy at affordable prices. In the current National Development Plan, the government has set a target for renewable energy sources to supply 20% of the country's energy need by the year 2030. Using a linear programing model of energy planning, we examine how realistically this target could be achieved. Our findings indicate that the 20% renewable energy target is technically achievable with the optimal plan showing a mixture of wind power, hydropower and bagasse power but no solar power. However, when the timeline for investment in new generating capacities that will ensure the attainment of the target is considered, it becomes highly improbable that the target will be met. This study fills the gap that exists in evidence-based analysis of energy policy in Jamaica.

Keywords: *energy planning; energy policy; renewable energy; linear programming; evidence-based policy analysis; Jamaica*

JEL Classification*: C60; O21*

1. Introduction

Energy issues have dominated national discuss in Jamaica in recent times. Since the Government of Jamaica (GOJ) announced a plan in 2004 to introduce liquefied natural gas (LNG) into the country's energy mix as a way to diversify energy sources and reduce the price of energy, there has been a lot of excitement on energy-related issues in the island. With a population of about 2.7 million people, Jamaica is the largest English-speaking country in the Caribbean. The economy has been on the decline with negative growth in GDP for most of the last decade. Between 2008 and 2012, GDP value added declined, ranging from a low of 0.5% in 2012 to a high of 3.4% in 2009. The only growth (1.4%) recorded in that interval occurred in 2011. During this period, the manufacturing and construction sectors, both energy-intensive, recorded greater declines in GDP value added than the economy as a whole (BOJ, 2013). The potential for the manufacturing sector to drive economic growth and provide employment opportunities has always been sounded by the Jamaica Manufacturer's Association (JMA). Given that imports of manufactured goods constitute about 10% of all goods imported to the country compared to just 1% of exported goods (BOJ, 2013), the argument for import-substitution sounds tenable. However, JMA and other stakeholders have consistently cited high energy prices as a detrimental factor to industrialization in Jamaica. For example, industrial rate for electricity in

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Jamaica is US$0.31 per kWh compared to US$0.06 in Trinidad and Tobago (Makhijani et al., 2013), its major regional trading partner.

The energy issue has been paramount on the agenda of the GOJ and a number of initiatives have been floated and policy measures taken to tackle it. The government adopted a national energy policy in 2009 with the vision to attain "a modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies with long-term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework" (Ministry of Energy and Mining, 2009, p. 1). The national energy policy also feeds into the broader national development plan, Vision 2030 Jamaica, with the vision to make Jamaica, by the year 2030, "the place of choice to live, work, raise families, and do business" (Planning Institute of Jamaica, 2009, p. 1). Both the Vision 2030 Jamaica and the national energy policy have set specific goals for renewable energy (RE) sources to form an increasing share of the country's energy mix, reaching 20% by 2030. Although the government remains committed to this goal as outlined in policy statements, it remains uncertain if the targets will be achieved by the deadlines.

Lack of substantial progress towards energy diversification has called to question the reliability of the targets for renewables set by the government. In this paper, focusing on the electricity sub-sector, we examine the progress made so far in incorporating RE sources in the generation of electricity in Jamaica vis-à-vis the required progress that is needed if the targets are to be met. Using a linear programming model, we developed an energy plan that specifies the amount of electricity generation required to meet expected future demands, disaggregated by source. Our model suggests that a rather rapid investment in RE sources is necessary if the targets are to be met. Based on the optimal least-cost plan, only wind, hydro and bagasse power are the recommended RE sources that should be considered over the next 16 years. The results have implications for policy. Although Jamaica has abundant solar energy potential, based on current costs and already installed fossil-fuel generating capacity, solar power is not an economic investment for the country. Therefore, if the targets for renewable energy are to be achieved in the electricity sub-sector, greater emphasis should be placed on wind power and bagasse power as energy sources.

In the next section, an overview of the energy sector in Jamaica is presented. This is followed by the methodology section in which the linear programming (LP) model used to generate the optimal energy plan for Jamaica is presented and a description of the data and sources of data is provided. The results are then presented followed by a discussion of the findings. The paper concludes with implications for policy.

2. The Energy Sector in Jamaica

Petroleum is the major source of energy in Jamaica, accounting for 90% of the country's energy needs (Ministry of Mining, 2009). Electricity generation constitute the largest share of petroleum consumption (31% in 2010) and oil accounted for 95.3% of 4214 GWh of electricity generated in 2009 (Makhijani et al., 2013). The Petroleum Corporation of Jamaica, an executive agency of GOJ, has the sole authority for oil importation. In 2011, the government spent more on oil importation (US$2.2 billion) than the country's total export receipts (US$1.65 billion) (Makhijani et al., 2013). For a country experiencing a stagnant economy, such a mismatch erodes foreign reserves and further aggravates the domestic economic situation. Understandably, energy security and affordability are key goals of Jamaica's national energy policy and the introduction of renewable energy is seen as a critical factor in achieving these goals. To that end, the GOJ has set targets to increase the share of RE sources from 5% in 2008 to 12.5%, 15% and 20% by 2015, 2020 and 2030, respectively.

Diversification initiatives in the energy sector have mainly been focused on the electricity sub-sector, except for the introduction of ethanol fuel (E-10), in the earlier years, in the road transportation sub-sector. The energy mix diversification drive has been slow and hampered by many factors, including regulatory, financial and technical issues. The Jamaica Public Service Company Limited (JPSCo) is the dominant player in electricity generation in the country and has an exclusive right to power transmission and distribution. A private company with 20% government ownership, JPSCo accounts for about 70% of installed generating capacity of 925 MW. Four independent power producers (IPPs) account for the remaining capacity. One of the IPPs, Wigton Windfarm has a capacity of 38.7MW exclusively from wind. This and a 3 MW wind turbine operated by JPSCo represent all the wind power energy on the national grid and account for 1.4% of total energy generated in 2009. The only other renewable source of energy on the national grid is hydropower accounting for 3.3% of energy generated in the same year. The rest was generated from fuel-powered plants (Makhijani et al., 2013).

As a monopoly in power transmission and distribution, and a dominant player in power generation, the Office of Utilities Regulation (OUR) regulates JPSCo. The OUR Act of 1995 (amended in 2000), among others, stipulates that the office will encourage competition and the development and use of indigenous

resources. However, the OUR has taken a lukewarm attitude towards, if not stymied, the development of RE sources in accordance with the national energy policy and its mandate. The office prepared an energy generation expansion plan for the country in 2010, a year after the national energy policy was adopted and the Vision 2030 Jamaica was implemented. The Generation Expansion Plan (OUR, 2010) provided three future energy demand forecasts (base, low and high) for the country. It also included three cases (scenarios) for energy expansion strategy. These involve natural gas, natural gas/coal and business-as-usual cases. Surprisingly, no case or strategy was provided for renewable sources. Instead, the plan included a brief narrative on the obstacles confronting RE projects in the country and indicated that the mid-term RE penetration target set by the national energy policy will not likely be achieved. As the government agency with the regulatory power and responsibility to effect energy diversification, the plan falls far short of a forward-looking strategy. At the minimum, the plan should have included a renewable energy case if only to indicate to the policy makers the magnitude of investment or the incentives needed to make the RE policy of the GOJ attainable.

Notwithstanding, international partners have conducted major studies on RE in Jamaica. In 2005, the United Nations' Economic Commission for Latin America and the Caribbean (ECLAC) sponsored a study on the RE potential in Jamaica (Loy and Coviello, 2005). The study concluded that there is an abundance of RE sources in the country and singled out the sugar processing industry as one of the largest sources of RE through the use of biomass for electricity generation. The study also indicated the need for better identification of existing potentials and on-site assessments and measurements as precursors for the achievement of long-term renewable energy goals.

The recommendations made by the ECLAC study were addressed in a recent study by the Worldwatch Institute (Makhijani et al, 2013). The study entailed a more comprehensive mapping of the RE potentials of Jamaica and provided scenarios for incorporating renewable energy sources in the country's energy mix. The study showed that not only is the 20% RE target achievable by 2030, a much higher target of 93% renewables by 2030 is also possible. That feat will entail investing in 3,500 MW of new renewable capacity, predominantly solar and wind power, over a period of 18 years. However, in a business-as-usual scenario, petroleum continues to dominate the energy source in a proportion similar to that of 2012.

On the practical side, the GOJ has been engaged in a protracted process of introducing LNG as an energy source in Jamaica. After signing a Memorandum of Understanding with the government of Trinidad and Tobago in 2004 to supply 1.15 million of metric tonnes annually, it was expected that two new combined cycle power plants will be built to run on LNG (Loy and Coviello, 2005). Ever since, the LNG project tender process has been mired in controversy resulting in numerous cancellations, with the most recent occurring in May 2014. A new process for selecting the preferred company to build a 380 MW plant that will run on LNG is now underway. Ten years after the idea was first floated as the ideal opportunity to cut the cost of electricity in Jamaica, a company to build and operate the proposed plant is yet to be determined. Meanwhile, consumers continue to endure high electricity price. Had the last tender process been successful, the winning bid would have guaranteed a price of US$0.13 per kWh which is just a third of the price currently paid by residential consumers. Delays in bringing the LNG project to reality has not only resulted in a jump in the projected investment cost, it has also progressively pushed the cost of electricity up as old and inefficient plants, a high proportion of which have outlived their useful economic life (OUR, 2010), continue to be operated and the cost passed on to the consumers.

Against this background, it is useful to determine what it will take to achieve a 20% target for renewable sources in the country's energy mix. Such information will be helpful to investors, regulators and policy makers in objectively and realistically assessing the renewable energy targets set in the national energy policy.

3. Methodology

3.1 Analytical Model

Linear Programming (LP) is an optimization model that has been used extensively for energy planning. Zeng et al. (2011) provided a review of an extensive list of studies using optimization models for energy systems planning. These studies include those using LP and other forms of optimization models for planning energy systems (Kavrakoglu, 1980; Smith, 1980; Beck et al., 2008), incorporating renewables in the energy mix (Cormio et al., 2003), and assessing decarbonisation targets (Kannan, 2009; Kannan and Strachan, 2009).

In the present study, we apply LP to generate optimal combination of energy sources for Jamaica that will ensure that the RE targets for 2015, 2020 and 2030 are met. The model is specified as follows:

$$\underset{\Delta X}{\text{Min}}\, Z = \sum_{i}^{k}\sum_{t}^{T} c_i \Delta X_{it}$$

Subject to:

$$\sum_i^k \bar{X}_i = \overline{GC}$$
$$\bar{X}_i + \sum_t^T \Delta X_{it} \leq maxX_i \qquad \forall\, i$$
$$\sum_i^k \Delta X_{it} \geq \Delta D_t \qquad \forall\, t$$
$$\overline{GC} + \sum_t^T \Delta D_t = D_T$$
$$\sum_i^k \bar{X}_i + \sum_i^k \Delta X_{it} \geq 0.125 \times (\overline{GC} + \Delta D_t)\,, when\ t = 2015\ \&\ k \in RE$$
$$\sum_i^k \bar{X}_i + \sum_t^{T-1}\sum_i^k \Delta X_{it} \geq 0.15 \times (\overline{GC} + \sum_t^{T-1} \Delta D_t), when\ t = 2015, 2020\ \&\ k \in RE$$
$$\sum_i^k \bar{X}_i + \sum_t^T \sum_i^k \Delta X_{it} \geq 0.20 \times (\overline{GC} + \sum_t^T \Delta D_t) \qquad \forall\, t\ \&\ i \in RE$$
$$\Delta X_{it} = 0 \qquad where\ applicable$$
$$x \geq 0$$

Where, ΔX_{it} is the change in electricity generation from energy source *i* by period *t*;
c_i is the unit cost of capital for generating a kWh of electricity from energy source *i*;
$\bar{X}_i$ is the initial generating capacity of energy source *i* in year 2009;
$\overline{GC}$ is the total generating capacity from all sources in year 2009;
ΔX_{it} is the change in generating capacity of energy source *i* in year *t*;
$maxX_i$ is generating potential of energy source *i*;
ΔD_t is the additional demand for electricity in year *t* from the previous period;
D_T is the forecast for electricity demand in year 2030;
$i = 1, \ldots, k$ represents k different sources of electricity generation;
$t = 1, \ldots, T$ represents time periods 2015, 2020 and 2030;
x represents any variable in the model;
RE is the set of renewable energy sources; and
Z is the minimum aggregate cost of investment.

The objective function represents the capital portion of the levelized costs of electricity generation (LCOE) in Jamaica as a proxy for the investment cost needed to build new generating capacities to meet future energy demands. This "investment cost" is minimized while ensuring that the target for renewable energy in the energy mix for each of the three time periods (2015, 2020 and 2030) is satisfied. This is done with due cognizance of the capacity limit for each energy source in the country and electricity demand forecast. Other timeline restrictions are incorporated to provide for realistic results that ensure that only technically feasible options are included in the optimal results for any time period. For example, since LNG is not a feasible option for 2015, a restriction is placed in the model not to generate electricity from natural gas in 2015. Other accounting restrictions are included to ensure model consistency. The optimal result from the LP model will indicate additional electricity generated for each period to meet the demand requirement and the source.

For ease of modelling and to normalize the variability in efficiency inherent in the different RE sources, energy capacity is modelled in GWh and not in MW. This will ensure that the renewable energy target is measured against the amount of electricity generated and not just in terms of capacity installed.

3.2 Data

The National Energy Policy (Ministry of Energy and Mining, 2009), OUR (2010) and Worldwatch (2013) were the main sources of data. The National Energy Policy served as the source for renewable energy targets for Jamaica. OUR (2010)'s base forecast for future electricity demand in Jamaica was used to set the minimum requirement for additional electricity generation by the three timelines. The existing capacity for oil-powered plants and potential capacities for RE sources were derived from Makhijani et al. (2013). The capacity for natural gas-fired plants was set at the original total capacity of 480 MW tendered by the OUR for the LNG project. Makhijani et al. (2013) reported a system loss (technical and non-technical) of 22.3% in 2011. To accommodate this reality in the optimal plan, a system loss of 20% was provided for in the input data. The capital portion of the levelized cost of electricity generation reported by Makhijani et al. (2013) represents the per unit cost of electricity generation attributable to the initial capital invested in the generation capacity. This value was used as a proxy for the unit cost of investment. Therefore, while it provides a realistic measure of the relative costs of investment for different energy sources, it does not represent the actual cost of upfront investment needed to build the new capacities.

4. Results

Current estimate from the Ministry of Science, Technology, Energy and Mining (formerly Ministry of Energy and Mining) indicates that the renewable energy share has increased from 5% in 2008 to about 8% in 2014. Using trend analysis, a linear and an exponential projection of the trend were compared to the policy targets (Figure 1). The analysis shows that if the current trend continues on a linear path, the renewable energy target will not be met for any of the timeline years. However, in the case of an exponential growth in renewable energy sources, the target will be met only for 2030, after investment in renewables would have been ratcheted up between now and 2025, at which time the growth in accelerated investment will be equivalent to the required growth in investment had the target been met all along.

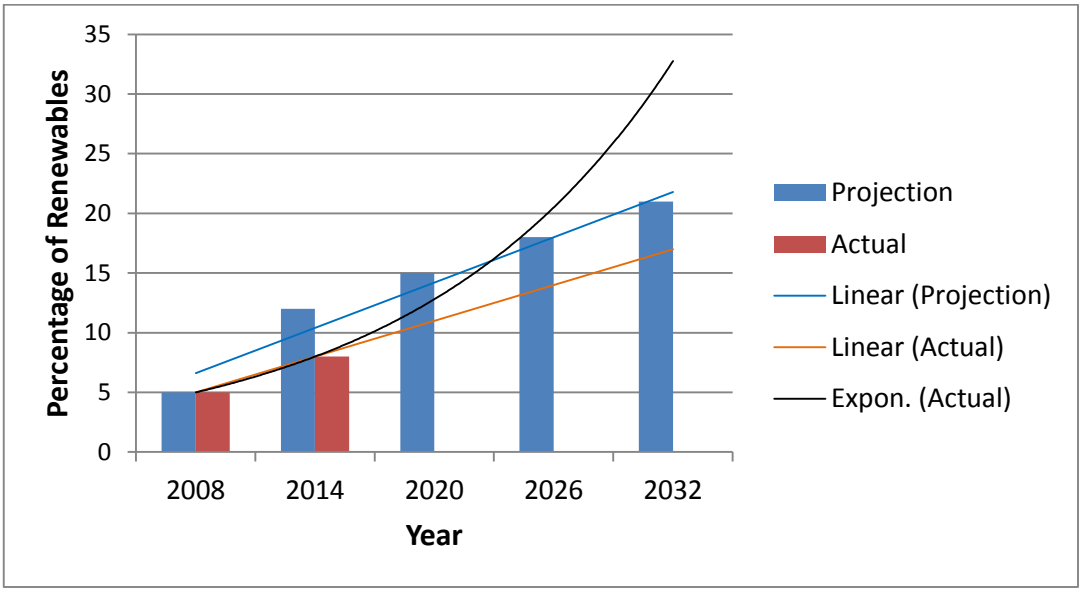

Figure 1. *Alternative Trajectories for Reaching Renewable Energy Targets for Jamaica*

The optimal LP result for achieving the renewable energy target for 2015, 2020 and 2030 is presented in Table 1. The result shows the optimal combination of renewable sources to include wind power, hydropower and bagasse power, but not solar power. By 2015, additional fuel-based capacity needs to be installed to produce 201 GWh of electricity. By the same year, major investments in wind power capacity must be made to produce 971 GWh of electricity. The only additional investment required between 2015 and 2020 is in natural gas plant(s) that have enough capacity to generate 1574 GWh of electricity. A more diversified energy-mix would be attained by 2030 with new investments in wind power (374 GWh), hydropower (126 GWh), bagasse power (596 GWh) and natural gas power (2631 GWh). Overall, the renewable energy target will be surpassed for 2015 and 2020, and met for 2030. In 2030, natural gas will account for one-third of electricity generation in addition to 20% produced from renewable sources.

Table 1. *Historical and Required New Electricity Generation to Meet Future Electricity Demand in Jamaica (2009-2030)*[1]

Historical (2009) Generation		**Recommended Additional Generation**			
Source	**Electricity (GWh)**	**Source**	**Electricity (GWh) by Year**		
			2015	**2020**	**2030**
Petroleum	4819	Petroleum	201		
Wind	71	Wind	971		375
Hydro	167	Hydro			126
		Solar			
		Bagasse			596
		Natural Gas		1574	2631
Total	**5057**		**1172**	**1574**	**3728**

[1] *Results incorporate a 20% system loss due to technical and non-technical losses.*

The composition of the different RE sources in the renewable energy share is shown in Figure 2. Wind power is the dominant RE source in the optimal mix for the three timelines accounting for at least 60% of

renewables at any point in time. Hydropower remains fairly stable at about 13% across the periods while bagasse power accounts for about a quarter in 2030. The result provides evidence that the renewable energy targets are technically feasible and the attainment of the targets will facilitate the diversification of energy sources in Jamaica.

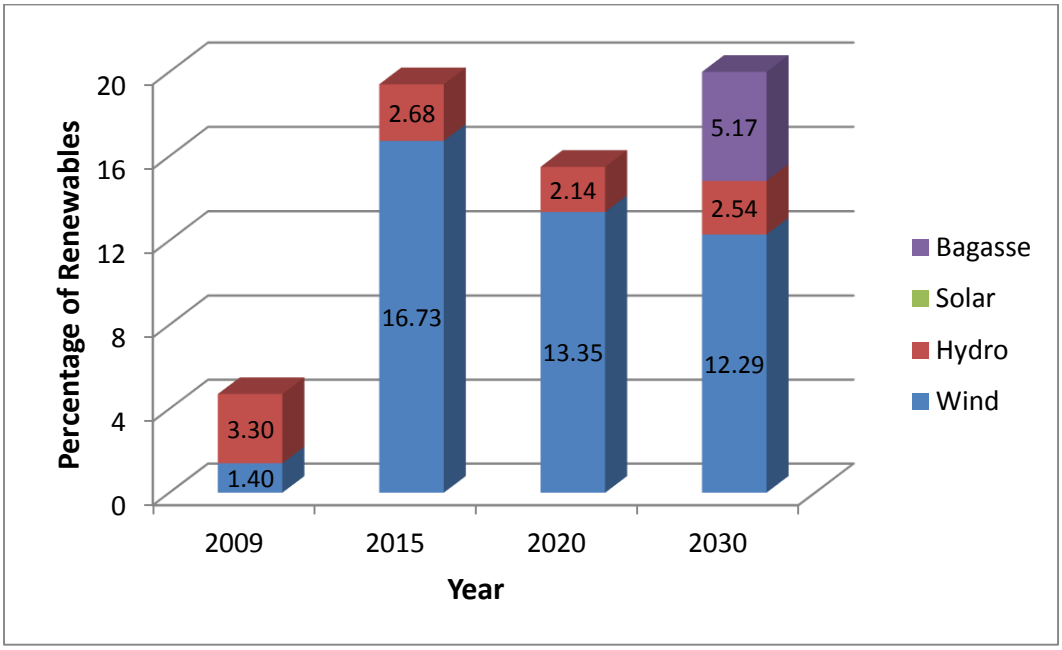

Figure 2. *Share of Renewable Sources of Energy in the Optimal Plan for Electricity Generation in Jamaica (2009-2030)*

5. Discussion

Although the optimal result shows technical feasibility, the practicality of this happening is highly improbable. For this to be a reality, major investments in wind farms need to be made in a period of a year and a half. At the moment, more attention is devoted to introducing LNG in the energy mix and that process has taken 10 years without any practical results. JPSCo has not shown any interest to invest in wind farms or any other forms of RE on a massive scale. The OUR has either shown lack of interest in pushing for RE or not offered any encouragement to JPSCo and other IPPs to invest in RE. This is against the backdrop of increasing public displeasure with high electricity prices and a more recent pronouncement by the government that the target for RE by 2030 is no longer 20% but 30%. This apparent discordant in the policy of the government on one hand and the action or inaction of the regulator and power generating companies on the other is troubling and brings to question the evidence-base for energy policy promulgation in Jamaica.

Although no real analysis has ever been provided as the evidence for setting the renewable energy target in Jamaica, anecdotal evidence suggests that the target is technically achievable. The recent report by Worldwatch Institute (Makhijani et al., 2013) showing that Jamaica could attain 93% RE in its energy mix by 2030 would have validated that perception and the recent shift in the target from 20% to 30% may not have been unconnected to that study. What will be more useful for policy makers and energy stakeholders in Jamaica, however, is an indicative plan or plans of what sort of investments need to happen and when for these targets to be achieved. To our knowledge, no such study has been done despite the need for it.

The current study fills the gap in evidence-based economic analysis that is required to inform practical energy planning, as it relates to RE, in Jamaica. Our findings indicate that the 20% RE target is technically achievable. Our study also reveals a rather surprising finding that investing in solar energy is not optimal for the country. Contrary to increasing popularity of solar panels in Jamaica, given current investment climate and costs, solar energy is not recommended as an energy option for electricity generation for the national grid. At first glance, this finding appears contrary to that reported in Makhijani et al. (2013) that showed solar energy as the major source of RE for a 93% RE penetration. A closer look at their results will show that a higher percentage of wind energy is indicated at lower RE penetration and the share of solar energy only increases at higher penetration. The current study provides evidence that at lower RE penetration target, solar power will not be an optimal choice. The inclusion of solar energy at lower levels of RE penetration, as shown by Makhijani et al. (2013), will only be economically justified if there are expectations and future plans to expand

on solar energy, in which case early investments will drive down costs on future units as the scale of installation is increased significantly. A market for RE that is 73% larger will provide such an incentive and hence the reason for the difference in the results between this study and Makhijani et al. (2013).

The findings of this study should provide a basis for serious dialog in the energy sector of Jamaica on the reality of GOJ's RE target. As at present, this target is stated more conveniently as a slogan than pursued as a policy objective. It is high time the government realises that the target will not be achieved unless meaningful actions needed to actualize it take place. The first step in that line of actions is to know how the target can be achieved and what it will take to achieve it. This study has shown one of possibly several ways in which the target can be achieved. As more information is provided by stakeholders, the model can be applied to generate alternative plans under different scenarios. However, until such a time, this study provides a good starting point for instigating a much needed debate on the RE target policy in Jamaica.

6. Conclusions

Vision 2030 Jamaica, the national development plan for Jamaica, and the country's national energy policy have set a renewable energy target of 20% for the country by 2030. Previous studies (Loy and Coviello, 2005; Makhijani et al., 2013) have shown that Jamaica has great potentials for renewable energy and the government is now mulling a 30% target for renewables by 2030. Meanwhile, RE penetration in Jamaica remains at about 8% and is far short of 12% that it should have been had the country been on track to achieving the policy target. Many observers consider electricity prices to be too high in Jamaica and the introduction of renewable energy, among other benefits, is expected to lower cost of energy in the medium to long term. However, there are renewable energy sceptics within the energy sector and concrete large scale investments to actualize the target are yet to be made. Also, until this study, no economic analysis has been done to guide policy implementation in relation to the attainment of the RE target.

The results of this study indicate that the RE target is technically achievable. This will be done through investment in additional wind power, hydropower and bagasse power generating capacities between now and 2030. Surprisingly, solar power is not competitive and not recommended for the national grid for a 20% RE penetration. When the required investment for the target to be achieved is measured against actual growth in RE sources in Jamaica, it becomes highly improbable that the 20% target will be achieved talk less of a 30% target. Therefore, this study provides the much needed evidence-base analysis that is lacking in policy analysis in relation to the RE target in Jamaica. Unless the government gets serious about promoting RE, the prospects for a sustainable low-carbon feature for Jamaica are bleak and public concerns about high electricity prices and anaemic economic growth, in the face of government's inaction to meaningfully facilitate RE, may actually lead to popular support for using coal, a high CO_2-emitting energy source. This scenario is becoming increasingly likely as the government moves forward on its plan to engage the China Habour Engineering Company (CHEC) to build a logistic hub in Jamaica. The project is expected to result in a US$1.5 billion investment in Jamaica and create 10,000 new jobs. CHEC has signified its plan to generate its own energy using coal as it considers the price of electricity in Jamaica to be too high for its planned investment. This and other realities of the local setting suggest that a low-carbon future for Jamaica is, for the moment, unsustainable.

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