**CHAPTER TWO**

**LITERATURE REVIEW**

* 1. **INTRODUCTION**

Over the past decade, most developing countries as the main development strategy look for the ways to increase their ICT infrastructures capacity due to encourage the rate of economic growth and to narrow the gap of economic activity with the developed countries. However, far too little attention in these countries has been paid to insight and understanding the complexity and ICT impacts dynamics in their social and environmental changes in addition of economic performance. If national planner does not consider the links between them, opportunities will be missed for yielding the desired results within a long time and in its turn. In this respect, it highlights a growing need for improving analytical support tools, which allow policy makers to test the dynamic responses to policy making.

This chapter reviews a number of studies that are relevant to two main concepts. First in section 2.2, the scope of analysis starts from the ICT impacts dynamics based on three perspectives (economic, social, and environmental). Each perspective presents the ICT impacts dynamics from theoretical and empirical studies. Second in section 2.3, models and tools for policy making in issue of ICT contribution to national development is discussed with some more space devoted to the developing country. In this section, we first have a brief discuss about the functions of economic model for macro policy and planning. Then, the limitations and challenges of conventional macroeconomic modeling and methods especially for developing countries are reviewed. Finally in section 2.4, system thinking approach by involving the creation of a system dynamics model is introduced as a powerful tool for analysis and policy making of the ICT role in national development.

**2.2 THE ICT IMPACTS DYNAMICS ON NATIONAL DEVELOPMENT**

Information and communication technology (ICT) refers to technologies that provide access to information through telecommunications. This includes telephone (both fixed line and mobile phones), wireless networks, and other communication mediums as well as the equipment and services associated with these technologies such as computer, network hardware and software. From the beginning of 1980s, when the information age was initiated, the world witnessed plenty of researches by applying numerous methodologies and models to investigate the contribution of ICT to economic prosperity and recommend policies for national planning.

Many studies have categorized ICT impacts as economic, social or (less frequently) environmental. However, the picture is usually more complex than this. For example, while some direct impacts of ICT use can be described as economic, there may be indirect impacts that are social or environmental. In addition, direct impacts may be both economic and social, related through human capital.

Nonetheless, the argument is based on solid conceptual–theoretical knowledge and empirical studies used selectively to sustain and/or illustrate roll of ICT in socioeconomic development. The analysis of the relevant sources has been systematic based on three perspectives (worldviews); economical, social and environmental ICT impacts dynamics. The three worldviews (Figure 2.1) is based on an up-to-date and systematic review of both theoretical and empirical literature. In other words, what is presented here is a meta-reflection on what emerges from several systematic reviews of relevant literature.

Before continuing this body of literature, labeled as worldviews of ICT impacts and roles, two notes are important. First, this is not an attempt to provide a thorough review of the literature on ICT. This literature is vast, and any attempt to make a comprehensive review would require a work of its own. Here the goal is to investigate different view point of ICT impacts and roles in macro-level and the concept, methods and models that support these analyses. Second, the researcher does not intend to discuss the details of the methods and models in general. They are too numerous to apply impacts of ICT on economic development. Here the concern is only those are applied for policy implications and understanding the ICT impact dynamic.

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| **Economic Growth**  **Productivity**  **Employment**  **Human Capital**  **Health**  **Social**  **Capital**  Poverty  **Sustainability**  **Education**  Social Worldviews  Economical Worldviews  Environmental Worldviews  **ICT Impacts Dynamics** |
| Figure 2.1: Economical, Social and Environmental perspectives of ICT Impacts Dynamics |

* + 1. **Economical Worldviews of ICT Impacts Dynamics**

From the economic perspective, most studies that investigated the contributions of ICT to economic performance are based on the growth accounting and the production function approach. This approach, which is based on Solow (1957) and Jorgenson (1966) work, considers the aggregate production function in the form of the production possibility frontier. The production function for examining the ICT’s impact on economic growth is characterized by decomposing the ICT and non-ICT in both aggregate output and input, as formulated by Jalava and Pohjola (2002):

Y(YtICT, YtO) = At ƒ(KtICT, KtO, Lt) (1)

where at any given time t, Y is the aggregate value added which assumed to consist of YICT which represent the value added of ICT goods and services, and YO represents the value added of other production. These outputs are possible through inputs consisting of ICT capital services KICT, other capital services KO and labor services L. The input function ƒ is augmented by parameter A as the level of technology or productivity which is assumed to be in the Hicks neutral or output-augmenting.

In function (1) ICT is modeled as a special form of capital to estimate its impact on output growth. Then, under the standard assumptions of competitive product and factor markets as well as constant returns to scale, growth accounting gives the share weighted growth of outputs as the sum of the share weighted inputs and growth in multi-factor productivity::

ΔlnYt = *β*ICT ΔlnYtICT + *β*O ΔlnYtO = ΔlnAt + *α*ICT ΔlnKtICT + *α*O ΔlnKtO + *α*L ΔlnLt (2)

where Δ refers to a first difference, i.e. Δ*x* = *x*t – *xt-1*, *β*’s and *α*’s denote the average nominal output and input shares respectively. The weights *β*ICT and *β*O denote the average nominal output shares of ICT and other production, respectively, and they sum to one. The weights *α*ICT , *α*O and *α*L also sum to one and represent the average nominal income shares of ICT capital, other capital and labor, respectively.

The common economical worldview which ICT has impact on the economy is based on Equation (2) that ICT can enhance economic growth in three basic ways as argued by Jalava and Pohjola (2002):

1. ICT production. the production of ICT goods and services contributes directly to the total value added generated in an economy;
2. ICT as a capital. the use of ICT capital as an input in the production of other goods and services can also make a significant contribution to economic growth;
3. ICT as a source of technological change. ICT can enhance economic growth via the impact of ICT industries on multi-factor productivity. If the rapid growth of ICT production is based on efficiency and productivity gains in these industries, this contributes to productivity growth at the macro level as well (Jalava and Pohjola 2002).

On the basis of the Methodological Approach, various analytical techniques or methods have been used to measure the economic impacts of ICT at the macroeconomic. In this respect, the methods and models can be classified between those that are estimated and those that are calibrated (Guerrieri, 2007). Although, both calibrated and estimated models have been used in this topic, the large and growing body of literature are based on estimated methodology and models.

Accordingly, the effects of ICT investment on the economy can be estimated from production function (or Equation 2) by using time-series methodology within a country or cross section data across countries. The empirical studies based on regression analysis provide evidence of high correlation between ICT and output and/or productivity growth. At the same time, growth accounting studies investigates the size of the impact of ICT on output and/or productivity growth. Moreover, as an alternative to the growth accounting, causality testing framework which first introduced by Granger (1969) has been extensively used in the empirical analysis to detect the direction of causality between ICT and economic variables. Later studies extend the topic using multiple regression models and multivariate systems, where ICT development and real GDP are exposed to be determined by other economic factors such as human capital, openness, privatization, foreign investment, etc along with ICT. This allows a comparative analysis to determine which inputs have the most significant impact on economic growth.

On the base of calibration approach, as an alternative framework in literature, Computable General Equilibrium (CGE) models have been applied to study ICT as a source of growth, beyond the conventional growth accounting exercises. Such models are firmly grounded in economic theory and do not attempt historical decompositions of aggregate growth (as the growth accounting approach does), but instead, quantify the contribution to growth of specific technological change (Greenwood and Krusell 2007). These models represent an intriguing and powerful device to assess the economy wide impact of the ICT on the behavior of the economy as a whole as well as the performance of its sectors.

***Empirical Studies by Growth Accounting and production function approach***

Although, the preliminary studies have reported little evidence on the contribution of ICT to economic growth and total factor productivity in the 70s and 80s in the U.S. economy (Oliner & Sichel 1994, Jorgenson & Stiroh, 1995), the collaboration between ICT and productivity growth was evident over the second half of the 90s in the U.S. economy (Jorgenson, 2001 and Jorgenson & Stiroh, 2000). Furthermore, several studies (e.g. Oliner & Sichel, 2000 and 2002, Baily & Lawrence, 2001, and Jorgenson, Ho & Stiroh, 2004 and 2007) have revealed that the effect of ICT-use on other industries (capital deepening) is more effective than ICT production itself.

Besides the studies in the U.S., other researchers examined this approach by considering an individual country or a group of countries. Most studies in developed and industrialized countries reported that ICT plays a key role in the second half of the 90s; for example, Niininen (2001) and Jalava & Pohjola (2005, 2007) in Finland; Oulton (2002) in U.K.; RWI and Gordon (2002) in Germany; Gretton, Gali & Parham (2002), Simon & Wardrop (2002) in Australia; Kegels, van Overbeke & van Zandweghe (2002) in Belgium; Miyagawa, Ito, & Harada, (2002) in Japan; Armstrong, Harchaoui, Jackson, & Tarkhani (2002), Khan & Santos (2002) in Canada, Cette, Kokoglu, & Mairesse (2002) in France; Van der Wiel (2002) in Netherlands; and Kim (2002) in South Korea. In general, these studies imply that there is a clear positive link between ICT development and economic growth, but it takes a long time to become visible in macroeconomic level. ICT capital growth accelerates productivity growth but with long lags between 5 -15 years (Basu & Fernald, 2007).

From another perspective, relationship between ICT and economic performance can be scanned through cross-country comparisons that most of them magnify the gap between them. The earlier significant studies for comparison of OECD and European Union countries (e.g. Daveri, 2000, Daveri, 2002; Colecchia and Schreyer, 2001; Van Ark, et al., 2002; Timmer, Ypma, and Van Ark, 2003) showed that ICT’s contribution to the economic growth in U.S. and Canada has been larger than other countries; meanwhile, there is a different growth contribution of ICT between European Union countries. Recently, Jiménez-Rodríguez (2012) using panel-vector autoregression models as one of the sofisticated modeling method that extends the empirical work on ICT impacts on three key variables – real output, employment, and labor productivity. This study conducted based on the data of the some European Union-15 (EU-15) countries and the USA and it is claimed by her that this is the first time that such a methodology has been used to this aim. Finally it is concluded that the ICT investment is positive for the economies of these countries, giving rise to larger growth in real output, employment, and labor productivity at the industrial level.

On the other hand, comparative studies between developed and developing countries (see Dewan & Kraemer, 2000; Pohjola, 2001) indicated that in contrast to developed countries, developing ones did not experience significant returns from ICT development. At the same time, the results of those studies that focused only on developing economies are consistent with the results which reported a limited impact of ICT development on economic growth (e.g. Avgerou, 1998 and Wang, 1999 in Taiwan; Meng & Li, 2002 in China). In Middle East area, Nour (2002) by using data from Egypt and some of the Persian Gulf countries reported that the correlation between ICT development and economic growth was positive but was not significant. However, unlike the most developing countries, the East Asian and South East Asian countries have benefited successfully from ICT in their economic and social development (Jussawalla & Taylor, 2003). According to Kuppusamy, Pahlavani, and Saleh (2008) ICT investment has had a positive and significant long-run relationship with economic growth in Australia, Malaysia and Singapore.

Piatkowski (2002) claimed that ICT investment in less-developed countries is not much enough to assess their impact on output growth. Investment in ICT appears to be less growth-enhancing in a number of countries where the levels of ICT investment are smaller (Colecchia & Schreyer, 2002; Daveri, 2002; Vijselaar & Albers, 2002). Therefore, due to the lack of capital investment and related knowledge as well as the existing lag behind ICT diffusion, the role of the ICT investment in developing countries is not clear enough (Meng & Li, 2002). Elsewhere, Lee, Gholami and Tong (2005) suggest that some threshold of ICT capital must be gained before their effect becomes measurable. Thus, they suggest to developing countries to promote the use of ICT and provide the environmental conditions to sustain the effective use of ICT. Furthermore, Grace, Kenny, and Qiang (2003) added that some less-developed countries would endanger to fall into a poverty trap in the case that ICT threshold effects come true. That is, if development of ICT is related to the income level and if income growth is affected by a threshold of ICT capital, then low-income countries less likely benefit from opportunities provided by ICT development.

In the general discussion on ICT and development, the focus has been on ICT-use. For example, Oulton (2010) use the results of growth accounting and the insights from a two-sector growth model (in which the first sector produces consumer goods and non-ICT capital goods while the second sector produces ICT products). He concludes that the main boost to growth comes from ICT use, not ICT production. Even a country which has zero ICT production can benefit via improving terms of trade. However, it is important that developing countries build up technological capability in ICT, and studies show that it is not possible if developing countries remain passive adopters of Western technology. Hence, the neglect of ICT production capabilities has the potential danger of perpetuating technological dependence on the one hand and forgoing opportunities for income and employment generation on the other (Oseph, 2004).

Putting all together, most of these studies have mainly been inspired by the growth accounting methodology. These approaches provide a simple and consistent method which can be used as a starting point to identify the contribution of the various inputs to aggregate growth, and thus to derive the relative importance of ICT to economic growth. However, the results are somewhat fragile and depend on data periods, specifications and econometric techniques (Stiroh, 2008). Moreover, the majority of the models are based on single equations, thus their ability to take into account structural aspects and changes is limited (Guerrieri, 2007).

The mixed results from these studies illustrate that; first, ICT contribution gap is evident among countries. ICT contribution to economic growth and total productivity growth in the U.S. and Canada is more than other countries while in Europe, it has been more sporadic. In other regions except new industry countries in South East Asian, apparently other developing countries were not able to take advantage of ICT in order to speed up the rate of output growth and productivity in their countries. Second, In spite of the general view of ICT contribution in developed economies, it is expected to observe a lag between the investment in ICT and its impact on the whole economy; in other words, the ICT effect on GDP or productivity takes a long time to become visible. Third, some studies find that the most positive impact of ICT on growth is not as straightforward as it seems; since, it is reported that the effect of ICT-use on other industries (capital deepening) is more effective than ICT production itself. However, the length of lag and how long it takes for the spillovers to occur is not clear. Finally, the contribution of ICT is visible when a significant threshold ICT capital is achieved. The various results from different countries and regions keep fresh the debate on the contribution of ICT on economic growth (Qiang, Pitt & Ayers, 2004).

***Empirical Studies by Causality Analysis Method***

Pervious part of literature reviewed the relationship between ICT development and economic growth exclusive of considering the direction of causality. Actually, causality studies target the link between ICT development and economic growth by investigating the existence of causal relationships as well as the direction of causality. Moreover, the importance of reverse causality is due to the fact that there is a bilateral relationship between better communication system and higher income. That is, the better communication systems lead to higher incomes and higher incomes in turn may improve communication systems.

Preliminary work on causality tests between ICT development and economic growth was carried out by Cronin, Parker, Colleran and Gold (1991) that have reported a bidirectional causal relationship between them in the U.S. economy. Later studies also confirmed this bidirectional causal relationship ( see Cronin, Parker, Colleran, & Gold, 1993). In addition, another work suggested that investment in telecommunications infrastructure in U.S. is causally related to the nation's total factor productivity (Cronin, Colleran, Herbert, & Lewitzky, 1993). For the U.S. economy also there are two causality analysis studies by applying the same data set over the period of 1947–1996 with different results. Based on Beil, Ford and Jackson’s (2005) study, the Granger-Sims causality test confirmed that economic output causes telecommunication investment, but investment by telecommunication firms does not cause output. In contrast, Wolde-Rufael (2007) who used another version of the Granger causality test proposed by Toda and Yamamoto (1995) found that there was bidirectional causality between the two variables.

An earlier cross-country study (Madden & Savage, 1998) on the causality test also reported a bidirectional relationship between ICT development and economic growth in Central and Eastern Europe countries. In another study with a panel of data for 30 countries (15 industrialized and 15 developing countries) Dutta (2001) generally confirms both directions of causality but causality direction of ICT infrastructure to economic activity was stronger than opposite direction. Five years later, Datta and Mbarika (2006) have reported an evidence of causality running from ICT infrastructure to service‐sector growth by a panel of data for 90 countries that equally ordered into three groups of low income, middle-income and high income.

One of the most significant current discussions in the causal relationship between ICT development and economic growth is that bidirectional or unidirectional of causality dependents on the level of income, ICT infrastructure or other factors. A large-scale study that examined the causality for 105 countries (Shiu & Lam, 2008a) revealed bidirectional causality in high-income level and European countries but unidirectional causality in countries with lower income levels that runs from economic growth to ICT development. They suggest that less-developed countries should create the environmental conditions called “critical mass” by promoting greater ICT penetration rates. In another study, Lam and Shiu (2010) also confirmed their pervious results, in particular, by assessing the mobile’s effect on economic growth. Chakraborty and Nandi (2003) by panel data of 12 Asian developing countries in two categories, high and low degree of privatization, pointed out that causality was bidirectional only for the high degree of privatization group but for the other group, ICT development led economic growth. In 2011, Chakraborty and Nandi’s study by a panel of 93 different countries from Asia, Europe, Latin-America and Africa suggests that for relatively less-developed countries, ICT infrastructure (Mainline teledensity) and per capita growth strongly reinforce each other in contrast to relatively developed countries. As a result, various factors of each country such as level of development, income, ICT penetration rate, and degree of privatization may be determined the causality and its direction between this two variables.

Nonetheless, the reverse causality issues in the causal relationship between ICT development and economic growth is not straightforward to be addressed. For example, Yoo and Kwak (2004) found a bidirectional causal relationship in South Korea, Cieslik and Kaniewsk’s (2004) reported that causality ran from ICT infrastructure to income at the regional level in Poland. While, Shiu and Lam (2008b) in China identified the existence of one-way direction from economic growth to ICT development. Elsewhere, in a study based on a data panel of ten Latin American countries conducted by Veeramacheneni, Ekanayake, and Vogel (2007) the results showed that the seven out of ten countries have bidirectional Granger causality in the short-run, in two other countries economic growth Granger causes ICT, and one country alone has causality running from ICT to economic growth. Recently, two similar studies by Lee and Becker (2011) in one hand and Lee (2011) on the other hand, have been done about European Union member countries and three of the Northeast Asian countries (China, Japan and South Korea) respectively. They concluded that the Granger causality test could not support the causality direction from ICT to growth in short-run. Totally, findings of causality analysis in current empirical studies are different among the countries and it supports the idea that special conditions of each country influence the results of the causality direction between these two variables.

Putting all together, the mixed results from empirical causality studies in current literature indicate either bidirectional, unidirectional or non-casual relationship between ICT development and economic growth. In more developed countries and regions with a higher level of income and ICT infrastructure, generally bidirectional causality is evident. Moreover, some findings indicate that the direction of causality is dependent on various factors of each country such as the level of income, ICT infrastructure, privatization, and so on. However, the subject of causal direction between ICT and output growth in less-developed countries is still under debate. Thus, it is desirable for any developing country with ICT development strategy to carry out a careful empirical causality analysis, since the results of the causality test can help the national planner to make policies of allocation restricted resources for boosting national economy. On the assumption that empirical evidence supports causality running form ICT infrastructure to economic growth, then the resources should be allocated to ICT-industry sector. While, for causality evidence in the opposite direction, more resources should be allocated to other most important industries for boosting national economy, so the ICT-industry sector will benefit from economic growth.

***ICT Studies by General Equilibrium Models***

A computable general equilibrium (CGE) model is grounded in the fundamentals of microeconomics: the idea that a competitive market economy reaches an equilibrium of supply and demand, determined by the demand functions and production functions of consumers and firms. For assessing the role played by the ICT in a dynamic context, computable dynamic general equilibrium (DGE) models have been used as an alternative framework in the following studies. The key advantage of the DGE approach over the conventional growth accounting exercises, according to Bakhshi and Larsen (2005), is that the macroeconomic implications of a shock to investment-specific technological progress can be simulated in a forward-looking environment.

One attempt that tries to shed light on the effect of ICT expansion on output and labor productivity growth based on computable dynamic general equilibrium (DGE) model carried out by Bakhshi and Larsen (2005) in the UK economy. Their study follows the DGE models which applied to technological changes that first carried out by Greenwood Hercowitz & Krusell (1997, 2000). They have decomposed labor productivity growth along the balanced growth path of the UK economy into investment-specific and sector neutral technological progress. The findings in this study shows that contributions from ICT-specific technological progress appear very large (around 20-30% of total labor productivity growth) and it is suggested that sustained improvements in labor productivity growth from this source will rely on continued sharp declines in the relative price of ICT goods.

In another study, a DCG model developed by Martínez, Rodríguez, & Torres (2008) in Spain economy to investigate the effect of ICT expansion on output and labor productivity growth based on two previous work (i.e Greenwood Hercowitz & Krusell 1997, 2000 and Bakhshi and Larsen 2005). They defined a production function with six different capital inputs, three of them corresponding to non-ICT inputs (constructions, machinery and transport equipment) whereas the other three correspond to hardware, software and communications equipment. Finally, the Calibration of the model suggests that the contribution of ICT to Spanish productivity growth is very relevant, whereas the contribution of non-ICT capital has been even negative. Additionally, over the sample period 1995–2002, the steady-state of Spanish economy is characterized by a negative productivity growth rate, despite an increasing effort in ICT investment. As happened in other past technological revolutions, it seems to be clear that the relevant (but potential) benefits of ICT need time to come true.

Martínez, Rodríguez and Torres (2010) have recently developed a DGE model to study the ICT-specific technological change and productivity growth in US economic growth. Akin to their pervious work, they have disaggregated the Capital inputs into six capital assets due to decompose the sources of productivity growth into a richer and more informative framework. They conclude that as a whole, ICT-specific technological change accounts for about 35% of total growth in labor productivity in US economy.

To sum up, these works used DGE models based on neoclassical growth model in which two key elements are present: the existence of different types of capital and the presence of technological change specific to the production of capital due to decompose the dynamics of productivity into implicit and neutral technological progress. In addition of the works that mentioned above other works such as Kiley (2001), Pakko (2002, 2005) all for US economy and Carlaw and Kosempel (2004) for the Canadian economy provide examples of this methodology applied to technological changes. As usual in these cases, decompositions are only possible on the basis of certain assumptions (cost-minimizing producers, competitive factor markets, wellmeasured input and output, and constant returns to scale), which are unlikely to be fully satisfied in under develop or even developing economies. On the other hand it should also be considered that the nature of such models often cope with a large dimension (i.e. a large number of equations necessary to adequately represent the economy). The detailed level of sectoral specification of some of the models accounts for the huge number of equations, reported (in some cases with an order of thousands of equations). As the literature points out, in conclusion, the developed economies are successfully to use these models and methodology.

* + 1. **Social Worldviews of ICT Impacts Dynamics**

As far as the social worldview is concerned the interaction between ICT and other variables affecting the overall society is not be taken into account in economical perspective. Taylor and Zhang (2007) argued, one thing both early and current studies have in common is that they aggregate large amounts of data (by counting things), and then apply statistical analytical tools to correlate multiple factors to identify relationships between information stocks, flows and technology with other factors. All of them utilize similar data collected by various national and international organizations. Some of them reduce their results to a single number or ranking. However, measuring computers, cables, and connections tells us very little about the actual state of society. It has been observed that, in order to understand the information society, we must go beyond measurements of the diffusion of pieces of hardware and even increases of information in stocks or flows and investigate the social context within which these developments are taking place. (Pruulmann-Vengerfeldt 2006). Therefore, as the following discuses will reveal, there have been some attempts to conceptualize the role of ICT in the context of socioeconomic development based on social perspective.

The framework developed by Sein and Harindranath (2004) presents three different conceptualizations of ICT: its use, how it is viewed and how it impacts development (Figure 2.2). This model posits that new technologies impact society through three effects: the first order or primary effect (i.e., simple substitution of old technology by the new), the second order or secondary effect (i.e., an increase in the phenomenon enabled by the technology) and the third order or tertiary effect (i.e., the generation of new technology related businesses and societal change).

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| **ICT Views**   * **Tool**: a means to achieve something * **Computational**: the machine in ICT * **Ensemble**: part of a bigger “package” * **Proxy**: what it represents   **ICT Use**   * as a **commodity** * **supporting** development activities * as **driver** of economy * **directed** at specific development activities   **ICT Impact**   * **First order**: substitution * **Second order:** increase in the phenomenon * **Third order**: emergence of new structures   **Human Development**   * Choice of healthy life * Choice to be educated * Choice to decent standard of living * Political freedom and democracy * Human rights * Other implicit factors: wealth distribution, social mobility. |
| Figure 2.2: Integrative framework of ICT in development (source: Sein and Harindranath, 2004) |

Although the impact concept has a hierarchy by definition (i.e., the tertiary effect of a new technology has a greater impact on society than the secondary effect), they emphasize that the primary and secondary effects are necessary conditions for development, but not sufficient. They argue that we need to look at the tertiary effects for an understanding of ICT influence on national development which they conceptualize in terms of human development ((Harindranath & Sein 2007).

Concerning the importance of assessing the social impact of ICT on development, ITU and OECD have proposed two comprehensive conceptual models for assessing socioeconomic impacts of ICT.

In 2005, ITU and Orbicam present ICT-OI (ICT Opportunity Index) conceptual framework which is the result of the merger of two well-known initiatives, ITU’s Digital Access Index (DAI) and Orbicom’s Monitoring the Digital Divide/Infostate conceptual framework and model (Sciadas, Guiguère, et al. 2005). The conceptualization begins with the basics. The overriding issue of a society concerns the quality of life of its people. In that regard, the economy plays the key role, but it is situated all along within the broader socio-economic, geopolitical and cultural environment of a country. ICTs affect everything and they are treated as an economic and social reality (Sciadas, 2005).

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| **PRODUCTIVE CAPACITY**  Labor  Capital  ICT skills  ICT infrastructure  ICT uptake  ICT intensity of use  **CONCUMPTION**  **Infostate**  **Infodensity**  **Info-use**  }  {  {  **ECONOMY** |
| Figure 2.3: The ICT-OI conceptual framework, which is set within the socio-economic, geopolitical and cultural environment of every economy. Source ITU 2005 |

The conceptual framework (Figure 2.3) allows linkages of ICT to economic development through the country’s productive capacity and use of ICT. The framework, which is closely linked to economic theory, is based on a dual nature of ICT; ICT is a productive asset, as well as a consumable (Taylor & Zhang 2007). As Sciadas (2005) argued in that setting, the conceptual framework developed the notions of a country’s infodensity and info-use. Infodensity refers to the slice of a country’s overall capital and labour stocks, which are ICT capital and ICT labour stocks and indicative of productive capacity. Info-use refers to the consumption flows of ICTs. Technically, it is possible to aggregate the two and arrive at the degree of a country’s ‘ICT-ization’, or infostate. The Digital Divide is then defined as the relative difference in infostates among economies. Thus,

Infodensity = sum of all ICT stocks (capital and labour)

Info-use = consumption flows of ICTs/period

Infostate = aggregation of infodensity and info-use

OECD (2007) proposes a more comprehensive conceptual model for information society statistics which presented in Figure 2.4. As the model shows, impacts reflect the general model in that there are impacts of every aspect of the information society.

According to this conceptual model, the Information Society is defined in terms of supply and demand. Supply includes the ICT producing sectors, whose measurement is more advanced, and which have a demonstrated and clear impact on productivity and GDP. Demand refers to the use of ICT and eServices that the rest of economy and society makes as a result of businesses, government, as well as public service providers, and citizens' activities. As long as users as defined above buy ICT products and services, this fuels the ICT and media/content producing sectors and contributes to their demonstrated impact. On the other hand, the way demand-side actors use ICT has been described mainly as a source of many other potential impacts (Misuraca, Codagnone, et al. in press).

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| **ICT supply (producers and production)**  **Which industries?** Constitute the ICT sector  **Which entities?** Produce ICT goods and services  **About them?** Industry, size, other characteristics  **About their products?** Type of, and revenue from, ICT goods and services produced  **How much?** Expenditure, wages & salaries, income, profit, value added, capital expenditure  **How long?** Business demographics, established vs new entities  **Employment?** How many persons are employed, their occupations, qualifications, gender; demand for skills  **Where?** Location of operations, customers, suppliers Innovation Innovative activities of producers (patenting, R&D)  **What impacts?** On the entity, economy, society, environment  **ICT demand (users and uses)**  **Which entities?** Use ICT G&S  **About them?** Industry, size, socio-demographic and labour force characteristics etc.  **Which activities?** Use of the Internet, e-business, ecommerce  **How?** Technologies used, means of Internet access, changes in technology, IT security measures  **How much**? E-commerce income and expenditure, ICT expenditure and investment  **When?** Most recent use, when started using, frequency, time use patterns  **Employment**? Use of ICT by those employed, ICT specialists and generalists, demand for skills, nature of work affected by ICT  **Where?** Location of users, customers, suppliers  **Why? Why not**? Motivations and barriers  **What impacts?** On the entity, economy, society, environment  **ICT in a wider context........for example**  Social and economic factors affecting ICT use and development, e.g. education and income levels  Effect of domestic policy and regulatory environment on ICT infrastructure and use  Global factors and relationships  Influence of other factors on ICT impacts e.g. skills and innovation. |
| Figure 2.4: the conceptual framework information society statistics. Source: OECD 2005 |

In addition, various factors have an impact on ICT, for example, the domestic policy and regulatory environment, and global factors and relationships. The influence of other factors on ICT impacts, for example, skills and innovation as important co-factors in the impact of ICT on firm performance (Roberts 2007).

Generally, the nature of ICT is such that its use and impacts extend well beyond the economic domain. This is so because ICTs are general purpose technologies that can be used for a broad range of everyday activities. The complexity and diversity of ICT impacts are important reasons for the interest in the ICT ’phenomenon’. Therefore, a host of questions, and even controversy, have surrounded it ranging from the economic (both macro and micro), to the social (exclusion, cohesion), the socio-economic (the digital divide), the political (e-democracy), the cultural and beyond. However, these characteristics also help to explain why measurement of ICT impacts is not a simple undertaking (OECD 2011).

As these conceptual frameworks reveal, ICT has different impacts on socioeconomic development; hence a social dimension is an important condition for a model to properly evaluate the impact of ICT. However, the measurement of the social impacts of ICT has received less attention from official statisticians than the measurement of economic impacts (OECD 2007). The social impacts of ICT are likely to be harder to measure because, on one hand, a social variable is more subjective and multi-faceted than productivity and economic growth. On the other hand, Statistics on social impacts of ICT tend to be of an intermediate nature. It should also be noted that there is not a simple division between social and economic impacts. Most of the topics which have been included here as social also have economic implications even social capital, which is embedded in an economic framework (DCITA, 2005a). Another major reason that ICT impacts are difficult to measure is that any impact of one factor on another is difficult to demonstrate because a positive correlation cannot readily be attributed to a cause-and-effect relationship (OECD 2007). These characteristics also help to explain why measurement of ICT impacts is not a simple undertaking.

Consequently, ICTs do not have simple and straightforward effects in socio-economic development. However, some survey data on final impacts exist that can delineate the ICT effects in socioeconomic development.

***Studies on social impacts of ICT***

One of the most significant effects is that ICT changes the way people work and what types of jobs are available. It can also change where people work, with home-based work enabled by ICT having potentially beneficial impacts for individuals and their employers. With new ICTs, jobs may be lost or created, and this raises the issue of capabilities needed to take advantage of the opportunities ICTs create (Rubery & Grimshaw 2001). Access to information provides people with the opportunity “to undertake production, engage in labour markets, and participate in reciprocal exchanges” with other people (Ellis 2000, p.31). According to OECD (2007), two survey-based studies, one in OECD countries, reported that the proportion of employees who were either ICT specialists or ICT users was between 20% and 30% in 2004 (OECD, 2006c), and in the United Kingdom the proportion of the workforce who tele-worked’ using both a telephone and a computer rose from 3% of the total workforce in 1997 to 7% in 2005 (ONS, 2005). According to the World Bank (2009), women in India and the Philippines benefit disproportionately from employment opportunities in IT services and ITES, with women accounting for about 65 per cent of professional and technical workers in the Philippines, and 30 per cent in India. According to OECD (2012a), the recent financial crisis has put pressure on the ICT labour market, but recovery in ICT services employment and ICT-skilled employment has been much faster than across the economy as a whole, leading to employment gains in the last quarter of 2010. Clearly, the impact of such changes could be significant for economies and societies.

In the education domain, effect of ICT is one of the considerable policy interests; because, education is a basic human right, and it is a precondition of economic and social development. Wagner et al (2005) notes that “ICTs are currently being used widely to aid education in many developing countries, and it appears that there is increasing demand for their use in education by policymakers and parents in developing countries. As Baliamoune‐Lutz, (2003) argued at least in theory, ICT diffusion is expected to have a positive influence on education. As ICT users have access to means that would enhance learning and skills. However, he point out the empirical literature which presents ambiguous findings. In countries where literacy and education mlevels are low, using computers in schools may not improve learning, and hence will not help keep students in school. Thus, the effect of ICT on education may be insignificant. On the other hand, having more personal computers may not necessarily mean they are used in schools. In many developing countries, the government is the largest buyer of computers mainly for use by civil servants (or for high-ranking government officials). There is no empirical evidence in support of the influence of ICT diffusion on education (contemporaneous causality) except in the case of mobile phones (Baliamoune‐Lutz, 2003).

In the health domain, the studies point out that the Internet can be a useful source of information about health from an individual’s point of view and also use of ICT improves health by enhancing patient services and health systems (UNCTAD, 2011). Unfortunately, there are very few statistics on ICT’s impact on health, positive or negative. Evidence from the USA and Canada, which are among the most advanced in this respect, suggests that the Internet is effective in helping people deal with the uncertainty introduced by health care problems (2010). In 2005, the Pew Internet and American Life Report survey noted that 80% of US based Internet users had used the Internet as a source for health information with a typical user searching for at least five topics (Fox 2005). The socio-economic and financial impacts of interoperable electronic health records and e-prescribing systems were investigated via several case studies in Europe and the United States. Evaluation was based on cost–benefit analyses; for all cases, the socio-economic gains to society exceeded the costs (European Commission, 2010). However, there is no doubt that ICT can also have negative effects on health, for instance, occupational overuse injuries associated with computer use.

As society and social changes have always been associated with the development of technology, the interactions between ICT and social capital have drawn both researchers’ and policymakers’ attention (Yang & KURNIA 2009). Because, it is found to directly and indirectly influence many aspects of social life, such as quality of life. However, little is known about the relationship between ICT and social capital. The initial studies that have specifically looked at the impact of ICT on social capital, Norris, 2003 concludes that the Internet seems to widen the experience of community. As another means of communication, it facilitates existing social relationships as well as helps build patterns of civic engagement and socialization (Chen, Boase, & Wellman, 2002; Quan-Haase & Wellman, 2002). According to Steinmueller (2004) social networks are influenced by (and influence) ICTs. Statistics Finland (OECD, 2007) studied the links between ICT and social capital and found significant correlations between ICT use and the components of social capital, community involvement and size of the social network. An ITU study (2006) cited similar evidence from South Africa concerning the use of mobile phones to improve relationships with friends and family. It leads to major transformations in social contact and civic involvement away from local and group-based solidarities and toward more spatially dispersed and sparsely knit interest-based social networks (Barlow, Birkets, Kelly, & Slouka, 1995; Wellman, Quan-Haase, Witte, & Hampton, 2001).

The studies in developing economies point out both positive and negative effects of ICT on society. On the positive side, ICTs are viewed as crucial in the development agenda because they can be used in public administration, business, education, health, and environment, among others (WSIS 2003). In fact, Waverman, Meschi, and Fuss (2005) explain that telecommunication networks are part of social overhead capital; as are expenditure on education, health services, and roads. As a result, the economic and social return of ICT development is larger than the private return of the network provider. Proponents of ICTs (World Bank 2002, UNDP 2001; Pohjola, 2002; Braga, 1998) take an optimistic view and highlight the positive effects of the Internet and other forms of ICTs to create new economic, social and political opportunities for developing countries.

On the negative side, ICT roll-out has generally increased inequality, benefited mostly the wealthy, and had little impact on quality of life (Forestier et.al. 2002). ICTs due to existing socio-economic inequalities lead to a widening of the socio-economic gap within developing countries (Panos, 1998; Wade, 2002; Gumucio, 2001). For example, while ICTs have been instrumental in the development of India’s information technology industry, this has not helped reduce the inequality between the rich and the poor in India’s society (UNDP 2001, Warschauer 2004).

Because of their more collectivist culture, Asian countries have had a lot of public debate about the effects of ICT use on social cohesion and sociability (Castells et al. 2007; Katz 2006). Pessimistic accounts have zoomed in on the forces which allegedly drive apart families and undermine people’s commitment to the groups they belong to. Through its entertainment and information capabilities it draws people away from family and friends (Nie, 2001; Nie, Hillygus, & Erbring, 2002). On the other hand there is increasing concern about the impact on children of Internet use, for example, exposure to undesirable content and the overuse of Internet applications such as online games; the use of the Internet to disseminate images of pornography and violence against women; Internet-based crime; copyright infringement; and security and privacy concerns (UNCTAD, 2011).

There are a number of adverse impacts of ICT on the privacy and security of individuals and organizations. They include commercial losses from denial of service attacks, data loss through theft or corruption and disclosure of confidential data. Far more serious potential negative impacts could arise because of the increasing reliance of critical infrastructure on ICT and the serious consequences of failure. Such impacts can affect societies and economies, as well as individual businesses (OECD, 2008c).

In conclusion, the social perspective on the determinants and effects of ICT has emphasized the crucial role played in society. While ICT does indeed offer potential to improve aspects of life for all peoples, it carries with it serious concerns over positive and negative social effects. ICT can affect social aspect such as health and education services, governance, the way people work and so force. Hence, a social dimension is an important condition for a model to properly investigate the impact of ICT especially in developing countries.

* + 1. **Environmental Worldviews of ICT Impacts Dynamics**

Measurement of the relationship between ICT and the environment is a relatively new topic in development. The scope of environment is limited to aspects where ICT is likely to be a strong positive or negative factor, that is, climate change, energy use and waste (UNCTAD 2011).

OECD (2009b) proposed a comprehensive conceptual framework for considering the relationship between ICT and the environment (Figure 2.5). It is an elaboration of the OECD’s conceptual model for the information society (OECD, 2009a).

The Supply side covers ICT products as agents to improve environmental outcomes (improved efficiency of existing products and processes, dematerialization, essential role of ICT in monitoring, modeling, administration and dissemination) and as contributors to environmental damage (energy use and emissions in manufacturing, transport and operation, pollution from disposal). The positive role of ICT includes both mitigation and adaptation.

The Demand side covers use of ICT to improve environmental outcomes (efficiency, dematerialization, monitoring, modeling, administration and dissemination) and uses of ICT that result in environmental damage (energy usage in operation, purchasing decisions and pollution from disposal).

Indirect factors involved in ICT and the environment: Indirect positive impacts of ICT on the environment no doubt exist, though these are likely to be impossible to measure. They could include the important role of ICT in promoting a knowledge based society and subsequent link between education/knowledge and actions that have a positive effect on the environment (such as reduction in birth-rates and other acts of individuals that promote sustainable development). Arguably, ICT also has an indirect negative impact on the environment.

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| environment.jpg |
| Figure 2.5: the conceptual framework for considering the relationship between ICT and the environment. Source: OECD 2009 |

The proposed conceptual model recognizes the following impacts of ICT on the environment (OECD 2009b):

• Positive impacts, such as its potential to improve the efficiency of a range of energy-using processes and equipment, facilitation of dematerialization and ICT’s role in climate change monitoring and modelling, dissemination of information, and administration of carbon-pollution-reduction schemes;

• Negative impacts from energy needs and greenhouse gas emissions arising from ICT use, the manufacturing and transport of ICT products and pollution from disposal of e-waste.

Some impacts of ICT on environmental outcomes can be easily demonstrated by using scientific knowledge and other available information. For example, the greenhouse gas emissions attributable to power hungry data servers can be calculated if their power use and source of power are known. For some other aspects, impacts are more difficult to measure, for example, the impact of Internet purchasing on greenhouse gas emissions. Indirect impacts are even more difficult to measure, for example, the positive role of ICT in facilitating a knowledge-based society with an awareness of environmental issues.

Finally, as Houghton (2009) argued the impacts of ICT on the environment can be direct (such as energy consumption and e-waste), indirect (such as intelligent transport systems, buildings and smart grids) or third-order and rebound which is the impacts enabled by the direct or indirect use of ICTs, such as greater use of more energy efficient transport. in the sense that the efficiency gains may result in lower energy costs and, thereby, increased use, such that the potential emissions reductions from energy efficiency gains are lost to rebound effects. These can be direct (e.g. where a fuel efficient vehicle enables someone to drive further at no additional costs), or indirect (e.g. where the fuel costs saved are spent on other energy intensive activities, such as an overseas flight). Exactly what the impacts of ICT are, and to what extent there may be rebound effects, are widely discussed topics. However, it is clear that attempts to measure the impacts of ICT on the environment should take account of the potential rebound effects and the entire life cycle, rather than simply the direct impacts of the product or application itself (Plepys 2002; Yi and Thomas 2007; Hilty 2008; etc.).

Despite the importance of the topic, empirical evidence on the impact of ICT on environmental outcomes is lacking. Several analytical studies have attempted to estimate the impact, for example, the Climate Group and GeSI (2008) estimated that the ICT sector and ICT products are responsible for about 2 per cent of global greenhouse gas emissions and that this will grow unless mitigated. They also found that the greatest potential for a positive impact of ICT is its use to increase the energy efficiency of industrial processes that are high greenhouse gas emitters: power transmission and distribution, the heating and cooling of buildings, manufacturing and transport. A 2004 report commissioned by the European Commission’s Institute for Prospective Technological Studies found a greater potential for greenhouse gas reduction through dematerialization (Institute for Prospective Technological Studies, 2004).

In the negative side, recycling of e-waste is a particular problem for some developing countries, with adverse health impacts. E-waste stands for waste electrical and electronic equipment and describes old, end-of-life or discarded appliances using electricity, including computers, consumer electronics and fridges, which have been disposed of by their original users (Global Knowledge Partnerships in e-Waste Recycling, 2011). In rebound effects study, Plepys (2002) argued that the paperless office has not yet eventuated, e-commerce may not save energy if it encourages long distance delivery, tele-working can increase the home use of energy and demand for electronic equipment, such as routers and printers, and so on.

In conclusion, the relationship between ICTs and the environment is complex and multifaceted, as ICTs can play both positive and negative roles. Positive impacts can come from dematerialization and online delivery, transport and travel substitution, a host of monitoring and management applications, greater energy efficiency in production and use, and product stewardship and recycling. Negative impacts can come from either energy consumption and the materials used in the production and distribution of ICT equipment or energy consumption in use directly and for cooling, short product life cycles and e-waste, and exploitative applications. Although, ICTs can contribute to the resource and energy efficiency, some studies point the difficulties in avoiding rebound effects and realizing the potential benefits.

**Merging the Worldviews of ICT Impacts Dynamics**

The diversity of these three perspectives represented enriches the literature, providing an abundant range of ICT impacts dynamics. The proposed conceptual models defined the roll of ICT in development from economical, social and environmental perspective:

First, from the economical perspective, ICT has had, and will continue to have, significant economic implications. Directly and indirectly, nearly every economic variable of interest is affected with resulting implications for productivity improvement and economic growth. The literature usually distinguishes three ways in which ICT has impact on the economy: first the role of ICT producers on the economy’s total value added or GDP; second through capital deepening which is the result of increasing the overall investment; third by contributing to Total Factor Productivity growth which is the result of ICT using. In other words, economic growth that is the increasing ability of a nation to produce more goods and services can occur by increased productivity of existing resources (land, capital and labor) use by using ICT. Second, from social perspective the nature of ICT is such that its use and impacts extend well beyond the economic domain. ICT does indeed offer potential to improve aspects of life for all peoples and the new modes of individual behavior have emerged, including new or modified means of personal communication and interaction; therefore, it carries with it serious concerns over positive and negative social effects. ICT can affect social aspect such as health and education services, governance, the way people work and so force. These complementary roles of ICT make it appropriate to link ICT planning to a national socioeconomic development. Finally, from environmental perspective the relationship between ICTs and the environment is complex and multifaceted, as ICTs can play both positive and negative roles as well as rebound effects.

Based on the conceptual frameworks ICT has become major players on the development arena by a dynamic, multi-dimensional interrelationship between ICT and the economic, social and environment context. However, although, empirical studies in the developed economies suggest that ICTs do have a strong role in development, the conditions in developing economies are very different and the link between cause and effect is still under debate. On the other hand, development efforts in information technologies have been concentrated in only a developed countries. In these countries again, a handful of key ICT companies control an overwhelming proportion of world’s ICT resources. The majority of the population in developing countries will not benefit directly from it.

Nowadays, there are two different points of view about ICT, optimists who consider ICT as a solution way for all the problems and the ICT pessimists who would argue for penicillin and not Pentium first (Asemi, 2006). Both the pessimists and the optimists have a number of stories to tell in support of their arguments. Such differences are important for policymakers who wish to incorporate future new economy. While, one can argue ICT as an antecedent of socio-economic development, a reverse argument can also be made. There is little doubt that ICT has promoted profound economic, social and environment change in developing economies. In this respect, the different schools of thoughts distinguish themselves by emphasizing either the positive or negative impacts of ICTs on people’s lives, or stress that the impacts will vary depending on the local and social context in which the ICT program is being carried out.

With respect to developing nations, the literature is limited in resources when it comes to assessing the impacts of ICT on development although it represents an important element for policy and decision makers. These countries also suffer from the limitation of examining the relationship between ICT and social and environmental variables. While studies in this field have been relatively few in the developed countries, that have not been the case in the developing ones, where these issues are intensely studied, debated, and often acted upon, with the findings implemented in national strategies.

Consequently, ICT development in developing countries may not contribute to economic development the same way it did in developed countries. In this case, we need to know what role ICT can play in the development processes of developing countries. However, factors determining ICT role in development are numerous but they are difficult to translate into a quantitative analysis and the modeling ICT as general purpose technology involves a high degree of complexity. It is therefore important, when one attempts to model the impact of ICT on economic performance, it is necessary to take into account the interaction with social and environmental variables. Despite the fact that existing models cannot represent the reality, new approach and model needs explicit representations of the context in which policy issues (e.g. social, economic and environmental) arise. Moreover, where policies are formulated and implemented, enriches their analysis and provides useful insights to policy makers by including human dimension and soft variables in the model.

**2.2 MODELS AND TOOLS FOR ASSESSING ICT CONTRIBUTION TO NATIONAL DEVELOPMENT**

As all economists know, the economy is very complex; that is why they try to simplify that complexity as much as possible and make it understandable by formal structural analytic model (Colander, 2008). Many policy measures in the macroeconomic sphere can only be understood and discussed properly with the help of a model which sets out the key relationships between the macroeconomic variables. Such a model is an important instrument in considering relevant relationships, if only because in a model all accounting identities are observed.

Various conventional models or methods have been used to measure the economic impacts of ICT at the macroeconomic; however, most of them cannot provide a fully satisfactory analysis of the transmission mechanism of ICT for development. Therefore, this part of study discuses about conventional economic models and methods with the purpose of identifying their limitation for policy making in general. The purpose of the assessment is twofold. On the one hand, the evaluation is useful in order to recognize the limitation of conventional model for modeling the socioeconomic in developing countries. On the other hand we suggest an alternative approach for considering the dynamic and complexity of the real word in the models.

**2.2.1 The general functions of a model for nation planning**

Most of economic models in the macro level such as Keynesian or neo-classical growth models, the social accounting matrix, the general equilibrium model and so forth deal with predicting and growth assignment. As Howitt (2002) claimed, an economic planner can conduct three tasks with economic models: interpreting the observed actions; forecasting economic phenomena; controlling or affecting certain economic outcomes. In such a way, economists and developmental policymakers create models to find out the result of change, to compute the growth impact and to predict the needed resource (Kooros & Badeaux, 2007).

Although, macroeconomic models can be a powerful tool for forecasting and policy analyses, their significant contribution is in assisting to deeper understanding of dynamic behavior in complex economic phenomena or system. Dynamics of a system are characterized by changing variables over time as they interact together. Since, the causes and effects links involve time delays or basically, actions and reactions are detached in time and place it is hard to predict changes (Barlas, 2009). In fact, the most complex behaviors usually are not from the complexity of the components themselves, but they arise from the interactions (feedbacks) among them (Sterman 2000). Furthermore, most dynamics phenomena are non-linear which can generate a wide diversity of complex patterns of dynamic behavior. In this respect, as the amount of components in a situation increase, the complexity of the components increases nonlinearly. More importantly, since typical economic phenomena involve human actors, the human dimension itself adds an extra level of complexity (Barlas, 2009). In this concern, the main reasons that a planner creates macro-models for national or regional planning is to understand and capture complex and dynamic interrelationships among variables at the macroeconomic level where everything relates to everything else. In other word if macroeconomic planners try to understand economic phenomena and how economic variables interact together, then they need models.

In addition to understanding economic phenomena, forecasting future performance is another ordinary use of macroeconomic models. A model needs to cover the most important peculiarities of an economy to forecast of future behavior. “An economic forecast should provide information about (1) the economy’s direction of movement, (2) the timing of any turning point, (3) the magnitude of the change and (4) the length of time over which a movement is expected to persist “ (Fildes & Stekler, 2002, P.436). Similarly, evaluating the impact of quantitative policy scenarios is the aim of most planning models, which can be determined by its response to sensitivity analysis and changes on the limitations (Howitt, 2002). The scenario designing allows policy maker to ask ‘what if?’ questions. In this concern, the purpose of the model was to identify high leverage policies to spur economic development in the region. In the sense that, the model was used to assess the effects of many of the policies then in use (Sterman 2000).

**2.2.2 Conventional methods and models for economic policy**

Conventionally, the majority of applicable economic models are based on the theoretical foundation to understand economic behavior and mathematical equations for formulations of economic theories and/or use statistic method (econometrics) to explain economic phenomena and also to forecast economic variable changes or behavior based on policies. On the side of theoretical foundation, economic theories mentioned in standard textbooks are quite normally under the neoclassical economic assumption that is a static model of free markets (McCauley & Küffner, 2004). However, in macro level where major concern on economic theorists has been economic growth, policy measures can only be discussed and understood accurately with the help of a model as an important instrument which sets out the key relationships between the macroeconomic variables. (Don & Verbruggen, 2006).

Figure 2.6 demonstrate a spectrum of models that connects the conventional modeling methods which aim to exhibit coherence with the ideas of economic theories and those that attempt to cohere with the data. As Pagan (2003) argued economics has primacy for those modeling strategies located at the empirical coherence boundary while statistics is dominant at theoretical coherence boundary. For instance, Computable General Equilibrium (CGE) models are based on microeconomic laws - a demonstration of the demand and supply systems through competitive market mechanisms - to simulate an entire economic system to direct to macroeconomic analysis (Little 1995), while, Vector Autoregressive (VAR) models have been used widely in empirical studies for studying macroeconomic aggregates for predicting, policy analysis, and interpreting time series (Sargent & Sims, 2011).

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| Empirical Coherence  Theoretical Coherence  Computable General Equilibrium (CGE)  Dynamic Computable General Equilibrium (DGE) and so on  Vector Autoregressive (VAR)  Error Correction Model (ECM)  and so on |
| Figure 2.6: The spectrum of conventional macroeconomic models |

In this context, the macroeconomic models which located at left side of graph integrate microeconomic mechanisms and institutional features into a consistent macro-economic framework and consider feedback mechanisms between all markets. In these models, all behavioral equations (demand and supply) are derived from microeconomic principle (i.e. the Walrasian representations of the economy and equilibrium in product and factor markets). In contrast, macroeconomic models which located at right side of graph use historical data to calculate the underlying model’s parameters through a verity of possible estimation methods. In the sense that much academic work in econometrics is closer to empirical coherence boundary (Pagan, 2003). That is often it is concerned with the construction of complex statistical models that are designed to fit increasingly elusive characteristics of the data. Consequently, these models can be distinguished by the essential role that data plays in informing the model structure.

Both types of models are used for analyzing the ICT contribution to economy economic performance. The empirical models based on sophisticated econometric techniques provide evidence of high correlation between ICT and economic performance. The existing CGE models represent an intriguing and powerful device to assess the economy wide impact of the ICT on the behavior of the economy as a whole as well as the performance of its sectors. They quantify for consistent comparative analysis of policy scenarios and offer opportunities for modelling the impact of ICT on international competitiveness.

**2.2.2 General Weakness of Conventional Methods and Models**

All these modeling methods helped policy makers greatly to think about development and investigate the potential effects of various policy alternatives; however, they have a number of limitations. The following discussion will reveal the main criticisms addressed to application of these models in macro level especially in developing economy.

Initially, as development economists aware of the models at the degree of theoretical coherence, simply cannot apply in developing economies, since they are based on perfect market assumptions that can be found in developed economies just approximately. In the concern, CGE models allow for consistent comparative analysis of policy scenarios by ensuring that in all scenarios the whole economic system remains in general equilibrium. As usual in these cases, theory might be forced on the model adopted as in the case where perfect competition in factors markets is to be proved at aggregate, albeit sectoral level. However, one common observation of growth in developing economies is that markets are rarely in equilibrium and there is no tendency to equilibria as well (Shilling, 2003). In other word, the assumptions such as cost-minimizing producers, competitive factor markets, well measured input and output, and constant returns to scale are unlikely to be fully satisfied. In this case, the equilibria are not ruled in their markets so it is difficult to use models based on pure theories. Thus, this in itself identifies a series of conflicts faced by development economists. Moreover, the CGE modeling requires huge databases, which comes from the combination of different sources; therefore, their timeliness is often jeopardized with outdated sources (Junior & Galvao 2008).

On the other hand, the models at the degree of empirical coherence only become applicable when the behavioral relationships in them are practically quantified by applying econometric techniques based on real data. In this concern, long time series of historical observations is necessary to do so; therefore, a reliable data set is crucial in producing accurate results (Pollitt et al. 2007). In this respect, insufficient availability and quality of the required data in developing economies play a major role. Then the models will not be evaluated mainly on the properties of its statistic techniques. Moreover, many modelers focus excessively on replication of historical data without regard to the appropriateness of underlying assumptions, robustness, and the sensitivity of results to assumptions about model boundary and feedback structure (Sterman, 2002). A first problem has been the measurement issues involved in the definition of the ICT sector itself, and in the economic evaluation of its different components (the ICT goods)

Another common criticism of econometric models of which its outcomes rest on empirically-estimated parameters is that, although, these models are powerful tool for decision support; the conditions when it was first used were different from today. It shows that predictions based on statistics are becoming less precise in the turbulent environment of today (Cancer, V., 2006). In other words, they are subject to the Lucas Critique, that is, it is a naivety to try to predict the effect of a future policy experiment based on the relationships estimated from historical data (Pollitt et al. 2007). Since the future is not the extension of the past—hence is uncertain—it will be different from anything we have seen before (Edkins, 2000). Flanagan (1999) noticed that very few studies have gone back and asked the question: Were our past forecasts correct?

Having said this, a lot of economists have recognized these limitations to find proper ways to be advised to developing countries. However, it is difficult to do so in the context of conventional models and theory (Shilling, 2003). Obviously, selection of the best model to do research is an art in order to balance the requirements of realism which complicate the model and pragmatic solution based on the data and computational requirements. Economic policy models not only must be simple enough to what extent that the decision maker can recognize the model concept, but also be manageable and able to replicate the data (Howitt, 2002). Consequently, the model builder is faced up to a trade –off between the policymakers’ desires, theoretical economists and econometricians (Don & Verbruggen, 2006).

There are many critiques of macroeconomic models in the literature that dealing with their policy formulation (see for example Junior & Galvao 2008; Don & Verbruggen, 2006). Although, these models have been found to be especially useful for regional planning (Letcher et al., 2005). One common limitation these models are the fact that some of them although are based on economics’ behavioral theories, are the results of a mathematical algorithm not a specific behavioral procedure, so these models tend to be ‘black boxes’ (Shilling, 2003). Mathematical rules including equations and optimization techniques as well as statistic analysis play significant roles developing these models. In the real world, as the complexity of economic is more than its constant feature to be reflected in a simple set of equations, a solution cannot be provided by more complex models and declines to a black box model when the why and what of the model’s outcomes are not understandable (Don & Verbruggen, 2006). In addition, as mentioned before the socioeconomic phenomena involve human dimensions and non-linear feedback interaction between variables that increase the complexity of phenomena. It implies that at even small size economic policy problems, which involve more than ten variables, a non-linear feedback system seems hard to track both mathematically and intuitively (Barlas, 2007).

Another most significant current challenge of conventional economic modeling methods is to deal with “soft” (unmeasured) variables. Forrester (1961), founder of the System Dynamics methodology, and Sterman (2000) argued that variables are not only numerical data, but if soft (unmeasured) variables are significant to the purpose should be included in our models. For instants, total production in the economic growth of a country would depend on many soft variables other than the traditional variables of capital and labor such as social and environmental factors. Although classical economics has addressed a majority of limiting factors in political, social, demographic and environmental domains, have often been ignored in the mathematical tradition of neoclassical models, because this factor deals with soft variables that are not easy to quantify but at the same time have significant effect on behavior of the economy (Saeed 2005). Omitting important structures or variables due to unavailability of numerical data is, in fact, less scientific and precise than applying the best evaluation to estimate their values (Sterman, 2002).

The last not the least, in the most socioeconomic systems there are many unstructured problem situations and major challenge for the policy makers is better to understand what is happening in the real world. Then, the need for solving unstructured and messy problems led researchers to search for flexible models, considering “softer” models would better signify various points of view to fulfill this need (Graeml and et. al, 2004). Hence, better understanding of complex systems may involve the models that are useful in addressing dynamic and unstructured problem. This modeling approach is useful to engage human beings, and offers a conceptual model for existing structure in the real world (Wit, 2011).

All in all, the conventional macroeconomic modeling methods mostly have concentrated on mathematics applicable and statistical techniques through a series of restricted models. Nevertheless, that approaches in complex and dynamic real-world with the recent fast changes does not work well. For the modeling of the unstructured complex system of today, the behavior of which exhibits dramatic dynamics, it is necessary to use a different tool, or to combine various approaches and integrate methodologies. Furthermore, being neutral with respect to any particular economic theory, recently a great deal of studies have been focused on Systems thinking paradigm that is capable to provide a different perspective on economic and development issues as an alternative that focuses on a better understanding of a complex and dynamic of the system which often concerned with the human aspects.

* 1. **CONTRIBUTION OF SYSTEM THINKING APPROACHES IN SOCIOECONOMIC MODELING**

Systems thinking is the process of understanding how things influence one another within a whole that it has been defined as an approach to problem solving, by viewing "problems" as parts of an overall system, rather than reacting to specific part, outcomes or events and potentially contributing to further development of unintended consequences. Systems thinking focus on cyclical rather than linear cause and effect. As a result of such thinking, new insights may be gained into how the system works, why it has problems, how it can be improved or how changes made to one component of the system may impact the other components. (Sardiwal, 2010)

The use of systems thinking approach by involving the creation of a system dynamics model has been given increasing attention in recent years and has found application in a wide range of areas; for example population, ecological and economic systems, which usually interact strongly with each other. Reach out to development planners and policy makers to examine various development strategies in a nation system dynamic approach help to determine which options offered the best chances for real development and to help formulate more desirable strategic paths.

System dynamics model provides a means for better understanding the impact of alternative policies and their implementation in the form of decisions. The simulation model itself is a simplification of an existing, detailed system dynamics model used to inform the national development planning process. Meadows and Robinson (1985) review a range of methodologies and include system dynamics amongst them. The authors explore the nature of models, the biases and hidden assumptions of different modeling methods, the pragmatics of the modeling process, and the impact of modeling on the real world. The models used methods including econometrics, linear programming, input/output analysis, and system dynamics. They make a cogent case for the usefulness of system dynamics in national economic planning.

The importance of System Dynamics for economics was recognized from the beginning by founder Jay Forrester (1976). As Olaya (2009) said, in 1956, Forrester has a strong criticism of economic models in a “note” to the Faculty Research Seminar, the first ever MIT “D-memo”, for sketching the worldview of what would be known as “system dynamics”. Based on his assessment and techniques developments in the same note, Forrester conceived “a new avenue of attack for understanding the firm and the economy” (Forrester 1975 p. 336) envisaging a new kind of models that would include aspects such as: Dynamic structure; Information flows; Decision criteria; Non‐linear systems; Differential equations; Incremental changes in variables; Model complexity; Empirical solutions; Symbolism and correspondence with real counterparts; Structure over coefficient accuracy. These dimensions are described in Table 2.1.

Forrester (1976) used system dynamic modeling approach to create a national model for U.S. which was designed to public policy analysis. The model was a computer simulation model of social and economic changes in the United States and the purpose of the model was to explain the forces that underlie major national difficulties, clarify feasible futures, and examine policies that can lead to more desirable behavior. Totally, the model concluded six principal sectors including production, financial, labor, demographic, household, and government that will treat the highly interrelated issues of inflation, unemployment, recession, balance of payments, energy, and environment. Forrester's national economic model is a classic example, in connection with the national model project of Forrester two models are created by Senge (1978) and Sterman (1981).

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| Table 2.1: Economic model dimensions suggested by Forrester (1975) | |
| **Aspect** | **Description** |
| ***Dynamic structure*** | Detailed attention to the sequences of actions which occur in the system being studied and to the forces which trigger or temper such actions, with a particular concern on the controlling influences of lags and delays. |
| ***Information flows*** | Explicit recognition of information flow channels and information transformation with time and transmission |
| ***Decision criteria*** | Re‐examination of the proper decision criteria which must not be defined as depending only on current values of gross economic variables; instead, such criteria must be traced to the motivations, hopes, objectives and optimism of the people involved, including as well what he calls business man's intuition which represents a disordered accumulation of basic insights into how people and social systems react. The hope for the future lies in generating an orderly arrangement of basic insights. |
| ***Non‐linear systems*** | Economic systems present most – if not all – of the time highly non‐linear characteristics. |
| ***Differential equations*** | The behavior of economic systems should be better described by non‐linear differential equations since they have been developed to describe delays, momentum, elasticity, reservoirs, and accelerations, which are better suited quantities for describing the economic world. In practice these equations would be handled as incremental difference equations in order to obtain numerical solutions. |
| ***Incremental changes in variables*** | To prefer the formulation of a model in terms of the motivations that cause incremental changes in a variable since the new value of a variable can be found by solving the equations for its incremental change and then adding the change to the preceding full value of the variable. |
| ***Model complexity*** | Much complex and complete models can be developed with these techniques. |
| ***Empirical solutions*** | It is useless to look for explicit unique or “correct” solutions; instead, these models provide diverse solutions according to the different assumptions about the model structure and the initial values of the variables. |
| ***Symbolism and correspondence with real counterparts*** | The possibility of having a pictorial representation – a flow diagram – whose processes of information, money, goods, and people, are moved, i. e. simulated, time-step-by-time-step from place to place. |
| ***Structure over coefficient accuracy*** | To prefer a structure in which we have confidence using intuitively estimated coefficients instead of using unlikely structures with accurately derived coefficients from statistical data. |
| Adapted from Olaya (2009). | |

Various system dynamics models have been built in order to support national planning in developing countries. Four well-known of these models are demonstrated in Table 2.2. First example is the system dynamics model that was proposed by Saeed (1994) including the broad decision rules that underlie resource allocation, production, and income disbursement processes of a developing country economic system.

The International Institute for Applied Systems Analysis (IIASA) is a non-governmental research organization located in Austria which is sponsored by scientific National Member Organizations (NMOs) in Austria, Bulgaria, Czech Republic, Finland, Germany, Hungary, Japan, Republic of Kazakhstan, Netherlands, Norway, Poland, Russian Federation, Slovak Republic, Sweden, Ukraine, and the United States of America. The IIASA research team developed complex national and case study simulation models for Botswana, Mozambique, and Namibia. The models consist of the following sectoral models, which are linked: population, HIV/AIDS, and education; economy (national economy and labor force models); and environment (water demand and supply).

In a special research project undertaken for the government of the State of Sarawak in East Malaysia, Dangerfield (2006) created a System Dynamics model for policy analysis with an emphasis on economic and social planning to vision 2020. The model has three main aspects to be handled and an appropriate triangulation of these components is key to managing a successful transition to a knowledge economy: the supply of suitably trained human capital and entrepreneurs, the demand side of a k-economy, and the state of the ICT infrastructure, which in some senses mediates the evolution of the drivers of supply and demand.

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| Table 2.2: well- known System Dynamics Models for National Planning | | | |
| **Model** | **Purpose** | **Size** | **Model outcomes and insights/ learning goals** |
| Sustainable development models (Saeed 1994) | Generic models sustainable development | Small-medium | Understanding of the fundamental characteristics of effective policies |
| Population Development Environment (IIASA 2001) | Demographics, natural resource management | Medium-large | Formulation of detailed development strategies to comply with an overall development vision and to derive implications  for midterm budgeting |
| Sarawak (Malaysia) model (Dangerfield 2007) | Transition to knowledge economy | Medium-large |
| Threshold 21 (MI from 1994 until now) | Comprehensive cross-sector analysis | Large |

Among these models, Millennium Institute’s Threshold 21 (T21) model explicitly integrates economic, social, and environmental factors (Barney, 2002; Barney & Pedercini, 2003) that is a dynamic simulation tool to support comprehensive, integrated long-term development planning.

A high level conceptual view of a dynamic macroeconomic model is illustrated in the Figure 6 with the linkages among the economy, society, and environment subsystems. Within each sub-system are a number of sectors, modules, and structural relations that interact with each other and with factors in the other parts. In T21 nearly everything is influencing, directly or indirectly, everything else. All except one sector, in fact, receive inputs from other sectors and generate outputs used elsewhere. These inter-component connections are critically important in a model being used by policy makers to guiding a country towards a sustainable future.

A model comparison has been made by dott. Matteo Pedercini of the University of Bergen evaluating eight models against the comprehensive development framework (CDF) criteria (Gerald, Barney, Pedercini). They reported that in the most of them effects on the local society and environment are not taken into account. Only recently, computer models (Threshold 21) have been used to perform integrated analysis of socioeconomic-environmental systems.

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| Figure 2.7: Conceptual view of the cross-subsystem linkages. Source: MI |

Threshold 21 is providing insight into the potential impact of development policies across a wide range of sectors, and revealing how different strategies interact to achieve desired goals and objectives. Based on country-driven goals, T21 allows users to generate scenarios indicating the future consequences of the proposed strategies. Users can then trace changes in outcomes back to the assumptions and polices that produced those changes. Threshold 21 appears to be the most useful methodological tool considered in national planning for more than 25 countries in terms of its potential contribution to creating a comprehensive approach to development planning. Table 2.3 presents the countries that applied Threshold 21by different focus of application.

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| Table 2.3: application of Threshold 21by different countries | | | |
| **date** | **country** | **Focus of application** | **Reference** |
| 1994-6 | Bangladesh | Health care, nutrition, education. to analyze important child development issues in Bangladesh. | MI (2007) |
| 1996-7 | Tunisia | Water, revised fertility. to support coherent planning several ministries and agencies. | MI (2007) |
| 1997 | Benin | MEP, HDI, and GDI indicators | MI (2007) |
| Cambodia | Effects of war | MI (2007) |
| Malawi | to help its government translate the Vision 2020 goals into measurable objectives. HIV/AIDS, Income distribution, and informal sectors | MI (2007) |
| 1998 | Italy | an exploration of how best Italy could achieve its various international environmental commitments. Refined agriculture and nutrition sectors; added greenhouse gas emissions | MI (2007) |
| Cambodia | to test an algorithm for modeling war effects within an integrated framework that combines society, economy and environment. | MI (2007) |
| 1999 | China | Relative prices, transportation, Chinese interface | Pedercini, Gerald & Barney, |
| 2000 | Somaliland | Rangeland economy | MI (2007) |
| 2001 | Ghana | No new sectors | Pedercini, & Barney (2004) |
| Guyana | Structural Adjustment of sugar and bauxite industries | MI (2007) |
| 2002 | USA | Forest and energy sectors | MI (2007) |
| Bhutan | to investigate impacts of climate change on Bhutan. Hydropower, Gross National Happiness, and SAM | MI (2007) |
| Thailand | to look at population, reproductive health, and HIV/AIDS. | MI (2007) |
| Papua, Indonesia | To integrating development planning with biodiversity conservation. Provincial (regional) level model with highways, dams, GNrP, and illegal logging. | MI (2007) |
| 2003 | Mozambique | Agenda 2025, Micro credit, agricultural extension, mega -projects, new roads, Millennium Development Goals (MDG) | MI (2007) |
| Cape Verde | Poverty reduction strategy paper for the World Bank (PRSP). Including tourist, monetary sector , balance of payments. | MI (2007) |
| 2004 | Saint Lucia | Environment and resource details; banana and oil price shock | MI (2007) |
| USA | Demand driven production and intermediate goods | MI (2007) |
| Ghana | To assess the impact of MDG-related interventions on the national economic and social development, and the synergies (or lack thereof) among them. Includes 14 MDG interventions: malaria, tuberculosis, infant care, maternal care, HIV/AIDS prevention and treatment, access to energy, clean water, sanitation, agriculture improvements, education, transportation. | Pedercini, & Barney (2010) |
| 2005 | Mali | Poverty reduction strategy paper for the World Bank (PRSP). | Pedercini, Sanogo, & Camara 2007 |

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| **date** | **country** | **Focus of application** | **Reference** |
| 2007 | Jamaica | Development Plan with focus on Crime, natural disasters, sugar cane production | Qu, Morris & Shilling 2011 |
| USA | Analyses of current and future energy use, and is being deployed to mobilize action on sustainable energy future for America. | MI (2011) |
| North America (encompassing USA, Candaa and Mexico) | It examines the impacts of various assumptions about fossil fuel availability and use and test scenarios such as the consequences of energy peaks and shifts to alternative energy sources to demonstrate their likely impact on human wellbeing. | MI (2011) |
| 2008 | Lolland | To examine the impacts of mega renewable energy projects on the local economy and environment. | MI (2011) |
| USA | Analyzing the socio-economic and environmental impacts of CAFE standards (H.R. 1506, H.R. 2927m and Revised Markey Bills), and the National Renewable Portfolio Standards (RPS) H.R. 969 Bill. | MI (2011) |
| 2009 | USA | To examine how increases in energy prices would affect the competitiveness of US manufacturing industry in the long term. | MI (2011) |
| 2010 | Senegal | To support the quantification of the scenarios of the Etude Prospective Senegal 2035, the national vision document. | MI (2011) |
| Swaziland | To support the quantification of the scenarios of the national MDG report, and Economic Recovery Strategy, a long-term planning exercise on the possible futures for Swaziland. | MI (2011) |
| UNEP Green Economy Report | A comprehensive global and national sectoral models was developed to analyze how green policies and investments contribute to macroeconomic performance, generate high quality jobs, and reduce poverty, while also mitigating climate change impacts. | MI (2011) |
| 2011 | Kenya | To coherent national development policies that encourage sustainable development, poverty eradication, and increased wellbeing of vulnerable groups, especially women and children, within the context of Vision 2030. | MI (2011) |
| Mali | The previous model was expanded with additional sector to do a more comprehensive analysis of the determinants of poverty in Mali and analyze the consistency between the national poverty reduction strategy and the Millennium Development Goals. | MI (2011) |
| Economic Community of West African States (ECOWAS) | Two regional and fifteen national models. Analysis of development policy options to guide formulation of coherent regional integration and national sustainable economic growth and development programs. | MI (2011) |

In the issue of the system dynamic contribution to economics and economic modeling, Radzicki (2009) comprehensively defined the principle ways that system dynamics is used for economic modeling. The first involves translating an existing economic model into a system dynamics format. it is valuable because it enables well-known economic models to be represented in a common format, which makes comparing and contrasting their assumptions, concepts, structures, behaviors, etc., fairly easy. second involves creating an economic model from scratch by following the rules and guidelines of the system dynamics paradigm. It is valuable because it usually yields models that are more realistic and that produce results that are “counterintuitive” and thus thought‐provoking. The third way that system dynamics can be used for economic modeling is a “hybrid” approach in which a well known economic model is translated into a system dynamics format, critiqued, and then improved by modifying it so that it more closely adheres to the principles of system dynamics modeling. This approach attempts to blend the advantages of the first two approaches.

Generally, macroeconomic models are not fit to all type of economic planning, so, it would be complicated tasks to attempt to construct a model that explain all interesting macroeconomic phenomena. For this reason, national policymakers and advisors tend to adopt a more eclectic approach to create models to explain any particular aspect of a national economy. In this respect System dynamics models through an iterative process of structure identification, mapping, and simulation a model emerges that can explain (mimic) a system's problematic behavior and serve as a vehicle for policy design and testing.

In conclusion, systems thinking approach by involving the creation of a Systems dynamics models offer opportunities to include much more of the interactions in a socio-economic structure than conventional economic models for assessing the role of ICT in development. It can create linkages to health, education, and other social and environmental factors beside economical factors that are impacted by ICT development. It can generate feedback from all sectors to each other. In addition, it can include soft variables that are hard to include in conventional models. Therefore, Systems dynamics offers an approach to combine economic and broader social and environmental factors into a single, coherent framework that can be adapted to satisfy the constraints of an economic system. Systems dynamics model can be much more realistic in transparently tending toward equilibria. They could make it much easier to understand how equilibrium is reached, over what time frame, and whether it can be reached in a sustainable manner. Systems dynamics models also allow easier determination of time paths to reach equilibrium and the sequential impacts of different options. While it is hard to make systems dynamics models optimize results, as economists like to do, they are likely to show how different types of behavior, represented by different structures, lead to different results. In addition, the policy maker can decide which optimum is. That is a little more like the real world.