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**“INAPPROPRIATE TECHNOLOGY” AND
INNOVATION SYSTEMS AT THE PERIPHERY:
notes on Celso Furtado’s contributions for a dialogue between
evolutionists and structuralists**

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notes on Celso Furtado’s contributions for a dialogue between evolutionists and structuralists***

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ABSTRACT

This paper focuses on “inappropriate technology” as formulated by Celso Furtado.

The concept of “inappropriate technology” may be, on the one hand, an enlightening assessment of the technological condition of underdevelopment and, on the other hand, a helpful “focusing device” for an agenda on innovation systems at the periphery. Furtado’s approach on inappropriate technology may uncover the social roots of the well know “low-growth trap” of less-developed economies.

Celso Furtado explains how inappropriate technology is related to the polarization “modernization-marginalization” that characterizes economies with immature systems of innovation, as the Brazilian economy. This concept also highlights how difficult it is to overcome the complex interplay among unequal income distribution, localized and blocked technical progress and unsustainable economic growth.

To overcome the inappropriate technology a dual institutional building seems to be necessary: the innovation systems might co-evolve with welfare systems.

Key Words: Celso Furtado, evolutionary theory, innovation systems, welfare systems, catching up process

JEL: B29, O30

RESUMO

Este artigo discute o conceito de “inadequação tecnológica” como formulado ao longo da obra de Celso Furtado.

O conceito de “inadequação tecnológica” é útil para uma avaliação da condição tecnológica de países subdesenvolvidos. Ao mesmo tempo pode contribuir para a elaboração de uma agenda para a formação e amadurecimento de sistemas de inovação na periferia. A abordagem de Celso Furtado pode contribuir para a compreensão das raízes sociais profundas que mantêm países subdesenvolvidos em condição de atraso tecnológico permanente.

A obra de Celso Furtado explica como “tecnologias inadequadas” estão relacionadas à polarização modernização-marginalização que caracteriza economias com sistemas imaturos de inovação, como o Brasil. O conceito de inadequação da tecnologia também aponta as dificuldades para superar a complexa inter-relação entre concentração de renda, progresso tecnológico localizado e bloqueado e ausência de *catching up*

Para a superação da polarização modernização-marginalização, a construção combinada de sistemas de inovação e sistemas de bem-estar é sugerida.

Palavras Chave: Celso Furtado, inadequação da tecnologia, teoria evolucionária, sistemas de inovação, sistemas de bem-estar social.

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INTRODUCTION

The polarization “modernization-marginalization” and its structural root are important subjects in Celso Furtado’s work.

Furtado’s main contribution to economic theory is on underdevelopment. The polarization “modernization-marginalization” is a feature of underdevelopment (Furtado, 1987).

In his view, underdevelopment is a historical process, a historical barrier to development, but a superable historical barrier. In his elaboration, there is a group of “high level underdeveloped economies”,¹ which involves countries like Brazil. UNDP (2001) shows how countries like India, South Africa, Mexico and Brazil combine traces of modernization with indicators of marginalization. This heterogeneity as a structural feature could be translated in a puzzle - the unequal and combined nature of their development (see D’Costa, 2002, for the Indian case). The puzzle is the combination of wealth and poverty, areas of technological development with areas of deep backwardness, in sum, modernization with marginalization. These social and historical features might be deeply rooted in their systems of innovation.

Therefore, the polarization “modernization-marginalization” would be relevant for the understanding of “high level underdeveloped economies” - economies that, at large, have immature national systems of innovation (Albuquerque, 2003).

The motivation of this paper is a result of previous investigation on the relationship between scientific and technological capabilities and human development in Brazil, taking the municipal level as reference (Machado et al., 2003). Not surprisingly, the results indicate the geographical co-localization (a sort of statistical correlation) between science and technology resources and indicators of poverty (slums, for instance). São Paulo and Rio de Janeiro are cities that concentrate *both* science and technology resources *and* slums. This co-localization is present in other Brazilian metropolitan regions.

In other words, a very preliminary investigation on geographical features of the Brazilian national innovation system (NSI, henceforth) identified a combination between “modernization and marginalization” (modern labs and slums, side by side).

Furtado (1987, p. 33) links the polarization “modernization-marginalization” with “inappropriate technology”.²

From the start it is necessary to differentiate Furtado’s concept from other versions of “inappropriate technology” (see section II.2). Amsden’s entry on “appropriate technology” (1987) describes some of these meanings, including the “small is beautiful” movement. Amsden makes no reference to Furtado’s interpretation.

¹ In the original: “Economias subdesenvolvidas de grau superior”.

² In the original: “A inadequação da tecnologia, a que se referiram os economistas latino-americanos de um ângulo sociológico, traduziu-se na polaridade modernização-marginalização” (Furtado, 1987, p. 33). Celso Furtado uses in Portuguese the word “inadequação”, that could be translated to “inadequacy” in English. As the development literature in English, and even a translation of Furtado’s chapter in Meier (1987 xxx), uses “inappropriate technology”, this is the term to be used in this paper.

This paper suggests that elaboration of Celso Furtado on this subject has a very specific meaning, and that this meaning is very important for the understanding of technological dynamics (or the limited nature of this dynamics) in peripheric countries.³

More specifically, it may be a contribution to the understanding of NSIs in the periphery.

First, it is a fine contribution for assessing the technological condition of underdevelopment. Inappropriate technology helps the understanding of the uneven and combined nature of development, highlights the deep historical roots of some socially non-inclusive features of these societies. These features are reflected and might be present in the resulting (immature) systems of innovation. And Freeman (1995) stresses the need for historical perspective in the study of national systems of innovation.

Second, it may be a guide for the transformation of national systems of innovation at the periphery. In countries with immature systems, that in Furtado's view face a "condition of stagnation at an intermediate level of development" (1986, p. 205), there is an important question: whether or not existing "islands of efficiency" will be able to push the rest of the country in a catching up process. This paper conjectures that this cannot be done without overcoming inappropriate technology. But, to overcome these deep-rooted problems is not an easy task. In evolutionary terms, the inappropriate technology may point for a "lock in" condition not easy to overcome.

This paper focus on the inappropriate technology may be seen as an attempt to connect two theoretical strengths (the evolutionary understanding of innovation and the structuralist approach of underdevelopment). The discussion on the inappropriate technology is in the intersection between innovation systems and underdevelopment.

In sum, Furtado's discussion on inappropriate technology presents a very interesting challenge to the elaboration of NSIs in the periphery, facing the question of how to escape the ever-repeating cycles of limited economic growth with permanent repositioning the polarization modernization-marginalization. To escape this repetition, catch-up is necessary and it should be supported by the maturation of NSIs. This maturation is for the breaking of the social perverse features that feeds the "modernization-marginalization" process. By its turn, this process of "modernization-marginalization" needs to be broken to allow the maturation of NSI.

And here there is the rub: how to break this negative feedback, this strong "lock in"?

I. ENRICHING A DIALOGUE BETWEEN STRUCTURALIST AND EVOLUTIONARY THEORIES

Celso Furtado is a "pioneer in development" and a leading theorist of the structuralist school (Meier, 1987). The origins of the development theories during the 1940s and the 1950s are multi-national. Researchers from different countries - Lewis, Rosenstein-Rodan, Prébisch, Clark, Gerschenkron, Myrdal, Hirschman, and Celso Furtado, among others, according to Meier & Seers (1984) – were investigating different realities and different countries in Latin America, Asia, Africa and Southern Europe.

³ This paper focuses a very specific part of Furtado's elaboration. For a deeper and broader discussion on Furtado's seminal work, see Szmrecsányi (2001), Tavares (2000), Oliveira (2003), Bresser-Pereira & Rego (2001), among others.

The development theory helped to shape developmental policies and strategies, implemented in a huge number of countries. Amsden (2002) describes the contributions of developmental states for the “rise of the ‘rest’ ”. Rosenstein-Rodan (1984, p. 221) has a positive evaluation of all this movement: “the post-war period of development is a history of triumph – not of failure.... A billion people are still hungry, but it would now be two billion without the achievements that have been made”. These pioneers, however, are not naïve and they have criticisms on the whole process: for instance, Prebisch (1984, p. 191) highlights the need to “combine development with social equity and political advances”.

Brazil, South Africa, India and Mexico are countries that implemented development policies in the post-war period. However, they haven’t overcome underdevelopment. They have reached a new stage, as “high level underdeveloped economies” (Furtado, 1986, pp. 144-146). After the decades of developmental policies, the world is more complex and the layers of development more numerous.

Brazil, South Africa, India and Mexico have other common features, characterizing their “high level underdeveloped economies”: heterogeneity is a structural feature of these countries, both in social, industrial and in the science and technology dimensions.⁴ In terms of the literature of economics of technology these countries could be classified as “immature systems of innovation” (see data and references in Albuquerque, 2003).

To understand this set of countries with intermediate position (that could be called “high-level underdeveloped countries” by Furtado, the top of the “rest”, by Amsden, “semi-peripheral states” by Arrighi, “semi-industrialized countries” by Teitel or “immature NSIs” by this paper) a dialogue between evolutionists and structuralists seems to be necessary. This dialogue, of course, would improve the understanding of development in the 21st Century.

Explicitly or implicitly, there has been a systematic dialogue between the evolutionary and structuralist theories.

Explicitly, important scholars working at ECLA (a leading source of the structuralist approach) as Fernando Fanzylber and Jorge Katz discussed the role of innovation and change using evolutionary concepts since the 1970s and the 1980s.

Meirelles (1989, 1990), while working on NSIs, investigates the specificities of Latin America. Meirelles stresses the role of technology in Prebisch’s seminal work, emphasizing the contribution of the uneven distribution of the fruits of technical progress on the evaluation of the center-periphery system. This role of technology, according to Meirelles, points to a theoretical affinity between the ECLA tradition and the “neo-schumpeterian” theorists (1990, p. 32).

Initiatives as Globelics (led by Lundvall, see www.globelics.org) and the Catch up Project (led by Nelson, see <http://www.globelics-beijing.cn/paper/Richard%20R%20Nelson.pdf>) are indications of the growing commitment of leading evolutionary theorists with development issues.⁵ These initiatives express a dialogue between these two approaches.⁶

⁴ Since the first works of the “pioneers in development”, heterogeneity is seen as a structural feature of underdevelopment (see Lewis, 1954, for instance). As time goes by, the complexity of this heterogeneity has increased.

⁵ Nelson’s involvement with development issues is not new: in a 1956 paper, he discussed in a formal model the “low-growth trap” (Nelson, 1956).

⁶ An indirect link could be added, as Abramovitz (1989) has among his references several “pioneers in development” (Clark, Rosenstein-Rodan, Young, Gerschenkron and Tinbergen). Nelson (1998) indicates the relevance of Abramovitz to evolutionists.

It is understandable that this explicit and implicit dialogue has been taking place. Taking as reference evolutionary theorists as Freeman, Nelson, Rosenberg and Dosi, and taking Celso Furtado as a representative of the structuralist theory, even a superficial reading of both approaches would find at least eleven points of identity and similarity:

- 1) the centrality of technology for development;
- 2) the key role of the capital goods industry for economic development;
- 3) a non mono-causal understanding of development process;
- 4) a non log-linear vision of economic development;⁷
- 5) history matters;
- 6) institutions matter;
- 7) a theoretical approach that includes dialogue with other social sciences for the understanding of development process;
- 8) the identification of huge concentration of technological resources in the central countries (divergence of technological capabilities) and its implication for international income concentration (income divergence);
- 9) a convergent intuition of the impact of income concentration and of limited internal markets on the economic processes;
- 10) “orientation of technological progress” as an important issue;
- 11) identification of “vicious circles” of poverty and stagnation.

An intensification of the dialogue between the evolutionary and the structuralist approaches would be a theoretical cross-fertilization, jointing forces as they put together the strongest points of each approach. The structuralists may learn a lot with the elaboration on national systems of innovation (that could be seen as a synthesis of previous elaboration from the evolutionary approach), while the evolutionists may learn a lot with the elaboration on underdevelopment and its multifarious causes.⁸

This dialogue would contribute for development theory because development today has dilemmas and issues that are not necessarily the same from the post-war period. This feature seems to escape scholars as Krugman, for whom the trouble with the post-war development theories seems to lay only in their lack of formal modeling (Krugman, 1993).

After the 1950s deep changes have taken place in the world. Inter alia, the underdeveloped world is more complex and variegated, the level of internationalization of societies and economies is deeper, two technological revolutions have taken place, and last but not least, the role of science and technology for the overcoming of underdevelopment is much more important now. These deep

⁷ Adelman (2001) in an interesting chapter presents the “three fallacies” of conventional growth economics: 1) “underdevelopment has but a single cause”, 2) “a single criterion suffices for evaluating development performance”, and 3) “development is a log-linear process”. Both evolutionist and structuralists do not incur in any of these fallacies.

⁸ For instance, the word “underdevelopment” is not an entry in the index of *The Oxford Handbook of Innovation* (Fagerberg et al, 2004), although it has two important chapters on catching up (Fagerberg & Godinho, 2004; and Verspagen, 2004).

changes are enough to explain why the dialogue between evolutionists (with their concept of national systems of innovation) and structuralists (with their investigations of underdevelopment as an historical process) may contribute to understand the challenge of development in the 21st Century.

II. THE INAPPROPRIATE TECHNOLOGY AS AN ASSESSMENT OF UNDERDEVELOPMENT

Celso Furtado's major contribution to economic theory is on underdevelopment: underdevelopment is an "autonomous historical process" (1986, p. 146). As a historical process, underdevelopment has its own roots, related to the emergence of capitalist development, to the way that technological progress shapes the international division of labor, creating a dynamic center and a periphery in which development is mainly a responsive process. Therefore, underdevelopment is not a necessary phase of a historical process of development, a phase that would be automatically superseded as time goes by.

In his book *Criatividade e dependência na civilização industrial* (1978) Furtado presents the "emergency and diffusion of industrial civilization".

The emergence of industrial civilization is connected with the industrial and bourgeois revolutions. Two tracks of this civilization are: 1) firms, seeking accumulation; 2) social organizations, struggling for "social diffusion of the fruits of the growing labor productivity that feeds accumulation" (p. 23). This process involves a structural relation between: 1) the level of accumulation; 2) the sophistication of productive techniques; 3) the diversification of consumer patterns of individuals and collectivities (p. 32).

The diffusion of industrial civilization is a different process. Countries and regions that lagged behind the Industrial Revolution and its initial diffusion have three ways of "indirect access" to industrial civilization: Japan and the former USSR exemplify two ways. The third way is linked to "structural dependency", characterizing the case of Latin American countries.

Looking to cases like Brazil,⁹ Furtado points that "integration in international markets ... is a way of access to industrial civilization, although in an indirect form" (p. 37). In this process, the workforce's transfer from self-subsistence activities towards "coffee, cocoa, rubber and other plantations originated purchasing power in international markets. This buying power allowed access to the fruits of technical progress to parts of the population" (p. 37).¹⁰ There is a sharp contrast between this way of indirect access and the others: "the consumer patterns have diversified with almost no evolution of productive techniques".

This specific "indirect access to industrial civilization is consequence of the structural rupture 'center-periphery'" that "...has ever since characterized the evolution of capitalism" (p. 37).

⁹ One of Furtado's major books is a classic of economic history: "Formação Econômica do Brasil".

¹⁰ In the original: "A transferência de mão-de-obra de atividades de auto-subsistência" ... "para plantações de café, de cacau, de borracha e outros, dava origem a um poder de compra nos mercados internacionais, mediante o qual certas populações passavam a ter acesso aos frutos do progresso técnico".

The industrialization of these economies with indirect access to industrial civilization is a result of the evolution of their “international relations”. This evolution reflects both internal and external factors. The industrialization is a reaction to tensions in international relations, more precisely, to problem in payment balances.¹¹

The specificity of the “dependent industrialization” can be seen clearly “in the evolution of internal social structures” (p. 40). The determinant of technology is the “diversification degree of the demand created by the social groups with indirect access to industrial civilization” (p. 41). The implications are noteworthy: 1) “the industrialization process assumes the form of an adaptation effort of the productive system to this sophisticated demand, with no links to pre-existing productive forces” (p. 41); 2) the result is a “capital intensive productive subsystem with no correspondence to the society’s accumulation level, with *low capacity of new job creation*” (p. 41). If the starting point is a reality of “structural labor surplus” (or unlimited supply of labor, as Lewis puts forward), the results are socially perverse. And the dependence links renew themselves as time goes by.

The interconnections between new demand created by the center and the internal arrangements of countries shocked by the waves emanated from the Industrial Revolution created possibilities for development at the periphery. But the resulting social arrangements also created severe limits in the ability and will of local leading social groups to absorb technology from the center.

Underdevelopment is a stalemate, a “historical trap” (1992). But it is superable (surmountable): South Korea and Taiwan are two recent examples of how this “historical trap” can be overcome (1992, p. 51).¹²

II.1. Dependency, international division of labor and underdevelopment

Prebisch elaboration on the concept of “center and periphery” stresses the role of technological progress from the beginning, paying attention to “the question of the international dissemination of technology and the distribution of its fruits” (1984, p. 176).

Technology is a key factor for the understanding of development in Furtado’s view. As Furtado puts forward, his starting point is “the relationship between underdevelopment and external dependency, from the standpoint of the effects of technological progress” (2003b, p. 7).¹³

For a dialogue with evolutionists it is important a comment on Soete’s (1981) criticisms of the “technological dependency”: Soete deals with less elaborated visions of the subject, therefore Furtado’s elaboration is out of reach of his criticisms (by the way, Furtado is not among the authors discussed by Soete: the references are Sercovitch, Theotonio dos Santos, Merhav, among others).

There are two main criticisms from Soete.

¹¹ Suzigan (1986) presents a reinterpretation of Furtado’s elaboration of the origins and beginnings of Brazilian industrialization.

¹² Evolutionists have been studying in depth South Korea and Taiwan, as examples of successful catching up process (for an up-to-dated survey, see Fagerberg & Godinho, 2004): this is another point for a dialogue.

¹³ In the original: “As relações entre o subdesenvolvimento e dependência externa, observados do ângulo dos efeitos do progresso tecnológico, são o ponto de partida de uma linha de reflexão...”

First: “technologic self-sufficiency” is a problem and the theory misses the fact that countries like Sweden and Japan are “technological dependents” (p. 199). The definition of “technological dependency” is a deficit in the technological balance of payments (pp. 200-201).

Second: the “technological dependency argument” “seriously” underestimates “the benefits and dynamic spill-over effects of imported technology or the so-called ‘transfer’ of technology” (pp. 201). This criticism leads to a call for more investigations on the “crucial role for developing countries of the international diffusion of technology on development ‘shortcuts’” (p. 204).

These criticisms have nothing to do with Furtado. He is very clear on the subject of self-sufficiency: “isolation is not a solution, the goal is to minimize the costs of dependency and to explore all ways to substitute *interdependency* for dependency” (1978, p. 114) (my italics, EA).¹⁴ The reference for Soete’s criticism in this point is Cardettini, for whom “total autarky would be the only state of the economy where technological dependence would not arise” (apud Soete, p. 199).¹⁵ Furtado is also very clear on the subject of the role of foreign technology in his agenda for development, highlighting the need of a “huge effort for the assimilation of known techniques” (1968, p. 84-85).

Furtado’s elaboration on dependency is much more sophisticated and nuanced than Soete’s criticism of naive versions of dependency would suggest (underdevelopment is only a consequence of the rich countries that do not leave room for the poor countries...). In a 1966 book, Furtado distinguishes between external constraints to development (chapter 2) and the internal factors blocking development (chapter 3: limitations of internal market, nature of import substitution industrialization, impact of unequal income distribution, weakness of local capital goods sector). The bulk of the discussion suggested by this paper lies on the “internal constraints” to development (in this point probably lies the greater structuralists’ contribution to the proposed dialogue). The need of changes in the international framework seems to be more consensual: UNDP (2001) is a good reference (IPRs, trade rules etc). Of course there is debate on the scope and speed of these changes. This need for change is highlighted in initiatives led by evolutionists as Globelics and the Catch-up Project. By the way, the reorganization of international relations is a persistent subject of Furtado work (see 1968, Part II; and 1986, Chapter 24, specially the topic “Restructuring the international economy”).

In a synthetic definition of development, Furtado establishes the links between the dynamics of capital accumulation and innovation: “accumulation, through innovation, is only the vector for the introduction of changes in the productive system and in the social structures that is development” (1978, p. 48).¹⁶

Underdevelopment is “consequence of a disequilibrium in the assimilation of new technologies generated by industrial capitalism” (1992, p. 41).¹⁷ A dependent economy is characterized by “the subordinate role of technological progress” (2003b, p. 107).¹⁸

¹⁴ In the original: “Se admitimos que o isolamento não é solução, o objetivo estratégico passa a ser minimizar o custo da dependência e explorar todos os caminhos que conduzem à substituição desta pela interdependência”.

¹⁵ O.Cardettini, (1976), *Technological dependency and self-reliance in underdeveloped countries*. Lima, STPI, mimeo.

¹⁶ In the original: “... a acumulação é apenas o vetor que permite, através da inovação, introduzir modificações no sistema produtivo e nas estruturas sociais que chamamos desenvolvimento”.

¹⁷ In the original: “... o subdesenvolvimento é fruto de um desequilíbrio na assimilação de novas tecnologias produzidas pelo capitalismo industrial”.

¹⁸ In the original: “O que caracteriza uma economia dependente é que nela o progresso tecnológico desempenha um papel subalterno”.

II.2. An interregnum: What does differentiate Furtado's approach?

This section suggests that Furtado's elaboration on inappropriate technology is much more complex and nuanced than the meanings normally attached to this subject.

Amsden (1987) surveys the various meanings of appropriate technology in *The New Palgrave*. During the 1950s and 1960s the debate was on the subject of "choice of technique", to maximize the output growth (Eckhaus, 1962 and Sen, 1964 are examples of this line), in the 1970s the debate was on the technology appropriate to maximize employment. Amsden (1987) mentions Schumacher's *Small is beautiful* and a so-called Appropriate Technology Movement. For her, this movement identified appropriate technology and self-reliance.

In the intersection between evolutionists and structuralists, Meirelles (1989, pp. 147-156) discusses the "problem of appropriate technology", specially the neoclassical version of the subject (Eckhaus, 1962). For Meirelles, a labor division between developed and underdeveloped countries in R&D activities is a necessary but not sufficient condition for an appropriate technology (p. 149). He articulates the technology used with the patterns of competition in operation (à-la Steindl), indicating the existence of "technical barriers" to the use of labor-intensive techniques. Correctly, Meirelles points that the goal of internal efforts on R&D cannot be to avoid "capital-intensification". Therefore, capital-intensive techniques may be part of the appropriate technology solution.

Teitel (1978) summarizes the "conventional wisdom" on "inappropriate technology": 1) Less-industrialized countries (LICs) are passive recipients of technology transferred from the industrialized countries (ICs); 2) that this technology is generally transferred *en bloc* with little or no adaptation; 3) that the prices of the factors of production are severely distorted in LICs, leading to excessive utilization of capital and underutilization of labor". Teitel's discussion is very interesting, and the results of his investigation useful for the criticism of naive versions of inappropriate technology. However, his investigation is centered around specific techniques and on efforts at firm level (and it is useful due to this focus: Teitel is discussing some "islands of efficiency" that exist in immature NSIs). The results are interesting both in the cases of success in adaptation of foreign technologies and in the cases of failure in this adaptation.

Teitel finds "strong indications" of the effort necessary to use foreign technologies: "the technologies acquired are usually adapted in greater or lesser degree to local conditions" (p. 367). Therefore, the use of foreign technology needs non-trivial efforts.

Teitel also identifies "a number of cases of industrial technologies that are inappropriate because of different factors": "response unsuited to market requirements"; "failure to use and/or adapt to supply of local materials"; "failure to adapt to a different scale of production"; "insufficient use of labor due to distortions of the price of factors and other restrictions"; "import of unsuitable machinery"; "selection of unsuitable technology" (p. 367)

Teitel concludes the paper noting the existence of "several cases of successful technological adaptation, especially in the more industrialized among the LICs". The successful cases found in Teitel's questionnaires probably are related to sectors where "partial catch up" has been achieved: for instance, in his paper there are references to the Brazilian steel industry (p. 367). Integrating these

findings to the structuralist approach, it could be said that these successful cases add new layers to the technological heterogeneity prevailing in underdeveloped countries (especially in the “high level underdeveloped countries”). In his conclusion, Teitel expects that “the adaptation and creation of technology in these countries will continue to grow, especially with, inter alia, “the creation and expansion of scientific and technological infrastructure” (p. 368). This is a link to the elaboration on NSI.

Furtado’s view on inappropriate technology is more complex and nuanced than the simplistic versions. Furtado would share the criticisms of Meirelles and Teitel to the simplistic views on inappropriate technology. Far from the small is beautiful approach, the limitations of the conventional wisdom on factors endowments and the simplification on the self-reliance reaction against inappropriate technology, Furtado’s elaboration stresses another issue. The interesting points from Teitel’s paper indicates the possibility of partial and localized catch-up, highlights how these partial catch-ups depend upon internal efforts and not on a passive adoption of technology. From Furtado’s standpoint, the issue here is why the catch up is only partial and localized.

The point of this paper is that Furtado’s view stresses another issue: the overall relationship between the technological orientation of underdeveloped countries and their social unequal condition. Inappropriate technology incorporates this in a nutshell, and translating to the concepts of the economics of technology, the NSIs reflect and reproduce this relationship.

II.3. The structural roots of the inappropriate technology

The subject “inappropriate technology” is developed by Furtado at least in three writings.

In *Um projeto para o Brasil* (1968) Furtado presents his initial statement on this subject, mentioning “the penetration of an inadequate technology, that is, not in accord with the factors constellation” (1968, p. 178). The subject is clearly not an important theme, although in the agenda for development later discussed Furtado stresses the need for a “huge effort for the assimilation of known techniques” (p. 84-85).

In *Teoria e Política do Desenvolvimento Econômico* (1986, see Szmrecsányi, 2001, for information on the previous editions of this book) this subject is more elaborated. In this book, the discussion on “inappropriate technology” concludes his chapter on “income distribution and accumulation in industrial capitalism”. Here, Furtado articulates the “orientation of technological progress” in the center and its “transposition” for another historical context, the periphery.

In his contribution for the *Pioneers in Development - Underdevelopment: to conform or to reform* (1987) – in a synthetic presentation, Furtado stresses the historical roots of the issue: “without a perception of the nature of late industrialization (oriented towards import substitution) it is not possible to understand the ‘inappropriate technology’ that creates the unemployment” (1987, p. 17).¹⁹ “As the consumer patterns of the minority that appropriates the social surplus must follow the life style

¹⁹ In the original: “Sem uma percepção da natureza da industrialização retardada (orientada para a substituição de importações), não será possível entender a ‘inadequação da tecnologia’ que gera o desemprego da mão-de-obra”.

of the countries that lead the technological progress (and using capital-intensive techniques), any attempt to “adapt” the technology will be repudiated” (p. 18).²⁰

What is the causal chain that links patterns of income distribution to the inappropriate technology?

- 1) Formation of a social-economic elite, in general in the exporting activities related to agricultural goods demanded by countries at the center;
- 2) This wealthy social-economic elite (never greater than ten percent of the population) imports consumer patterns similar to the countries where the technological revolution was taking place;
- 3) this high-income minority imports goods from developed countries to consolidate their consumer patterns;
- 4) in a further stage of development, the process of import substitution internalizes the production of that goods (protection for consumer goods internal production),
- 5) this protection for internal consumer goods production co-exists with subsidies for the import of capital goods, subsidies that at least temporarily block the development of an internal capital goods industry (this temporary blockade has lasting effects for the internal technological development, as both the evolutionists and the structuralists would stress) ;
- 6) this combination of protection for consumer goods industry and subsidies for imports of capital goods underlies a specific developmental trajectory with productivity gains combined with the growth of unemployment (a growing structural employment surplus);
- 7) as time goes by, a lagged internal production of part of capital goods for these consumer goods industries may take place (pushing the economy to the stage of “high level underdeveloped economy”);²¹
- 8) but as the technological progress at the center keeps introducing new products, as the technological revolutions are part of the capitalist dynamics (here there is an important connection with the elaboration on long waves of capitalist development, as Freeman et al, 2001, would summarize), pushed by the “waves” initiated by each new technological revolution, the process described repeat itself again and again, with new imports, new import substitution and import of capital goods related to the new import substitution;
- 9) the end result is a process of modernization and marginalization; a process permanently renewed by the dynamics triggered by technological revolutions at the center; on the one hand the modernization side (in the begging there were hats and expensive clothes, then imported cars, then imported phones, then imported PCs and so on), on the other hand the marginalization side (the home-less, the computer-less etc);

²⁰ In the original: “Na medida em que os padrões de consumo da minoria que se apropria do excedente devem acompanhar o estilo de vida dos países que lideram o progresso tecnológico(e que se instalaram em elevado nível de capitalização), qualquer tentativa visando a ‘adaptar’ a tecnologia será repudiada”.

²¹ In the original: “A fase superior do subdesenvolvimento é alcançada quando se diversifica o núcleo industrial, capacitando-se este para produzir parte dos equipamentos requeridos para que se efetue o desenvolvimento” (1986, p. 145).

- 10) regarding modernization, local industries are “pushed” by the adoption and by the permanent update of consumer patterns diffused from developed countries; this continuous effort, as the technological revolutions take place at the center, at least allowed the Brazilian economy to preserve a more or less stable “gap” vis-à-vis developed countries;²²
- 11) regarding marginalization, the unemployment generated by the use of capital-intensive techniques is not absorbed by the underdeveloped local capital goods firms (that when they evolve, they do it in a lagged and incomplete way), this unemployment affects the structural surplus labor;²³
- 12) this process of “modernization-marginalization” leads to a permanent renovation of structural dualism: once there was a dualism between agriculture and industry, then between the traditional and modern sectors; and now there are dualism between formal and informal sectors of modern sectors as industry and services (Furtado writes, “industrialization has been aggravating the dualism in the labor market”, 2003b, p. 97);²⁴
- 13) the overall balance is a more complex and a deeper social heterogeneity (2003a, p. 11), that is incorporated in all sectors of activity, including the scientific and technological dimensions;
- 14) structural heterogeneity, with this combination between “modernization-marginalization”, leads to a complex internal organization: Gilberto Freyre stressed the co-existence and simultaneity of different “social times”, in a work on Brazil in the early 20th Century (this is truer in the beginning of the 21st Century!). Souza (2000) presents an interpretation of Gilberto Freyre’s work, stressing this persistent renew of duality, now symbolized by the contrast between rich and isolated villas and slums.²⁵

Celso Furtado sums up this process: “the major cause of productivity gains in an industrialized peripheric economy seems to be the diversification of consumer patterns of high-income minorities, without repercussions on the living standards of the majority” (1986, p. 182).²⁶ Limitations of internal market size impact (negatively) the possibilities of technical progress, breaking the development push earlier than necessary for a sustainable process of catch up.

²² According to the Penn World Table, the averages catch up indicators for Brazil ($Y = \text{Brazilian GDP per capita} / \text{US GDP per capita}$) are: 16.1 in the 1950s, 17.2 in the 1960s, 23.4 in the 1970s, 24.9 in the 1980s and 21.8 in the 1990s (data for only 1990-1992).

²³ This lagged (and incomplete) development of capital goods sectors may be integrated to Pavitt’s 1984 paper: translating this to Pavitt’s taxonomy, the “science-based firms” and the “specialized suppliers firms” are always weak (or even absent) in internal industrial structures. These weaknesses are reflected in the balance of payments, which is another key subject of structuralist elaboration as a source of external vulnerability of these economies. Freeman (1995, p. 21) comments the “vulnerability of national economies to external shocks” as a contemporary issue.

²⁴ The persistence of features of pre-war features of underdevelopment may be seen in the data regarding workers employed in “domestic services”. For Lewis (1954, pp. 408-409), the 16% of Barbados’ population working in domestic services is an indication of the “disguised unemployment”. Almost 19,6% of the workforce is employed as “domestic workers” in Brazil, data for 2000 (According to Gaspari, quoting a paper from Márcio Pochman, in FSP, 14/03/2004, p. A10).

²⁵ A good illustration of how technology incorporates the perverse social features of marginalization, is the Brazilian excellency in the “armored vehicles industry”, part of a general strength of “security sector” in the Brazilian economy. In a very simplistic formulation, there is a link between the polarization of wealthy and poverty in geographical proximity, marginalization, criminality and huge investments by rich in security. The result is a reality that the observation of John Bond, Chairman of HSBC: “there are more armored cars in Brazil than any other country” (*Gazeta Mercantil*, 4/03/2004, p. 1). The dynamic impact of a strong “armored cars industry” is certainly unable to feed any catching up process!

²⁶ In the original: “Mais precisamente: o principal fator causante da elevação de produtividade na economia periférica industrializada parece ser a diversificação dos padrões de consumo das minorias de altas rendas, sem que o processo tenha necessariamente repercussões nas condições de vida da grande maioria da população”.

What is the main message of this elaboration? What is the major contribution from Furtado's concept of "inappropriate technology" to the evolutionary approach? To overcome underdevelopment technology is a key factor, but it is not enough. Underdevelopment is not a mere consequence of lack of institutions, therefore its overcoming is not only a problem of institutional-building. The development process is not only a quantitative one (more resources, more institutions, etc etc).

There are successful stories of firms, universities, cases of success in the control of diseases - consequence of Brazilian science - there are partial connections between the scientific and technological institutions. These escapes from the strong logic of underdevelopment may be taken as references of possible routes for the catch up process.

There are decisive qualitative steps that seem to be precondition for the whole developmental process. The key step might be the untangling of a deep-rooted institutional arrangement, useful for social classes and sectors that allow huge profits for a wealthy minority.²⁷

This deep-rooted institutional arrangement could be translated to the evolutionary language as a very special case of "lock in" phenomenon. Nelson (2004, p. 12) points the social resistance for the catch up process in the periphery: "Achieving the needed reforms in economic structure may well be a more difficult task than gaining the scientific and engineering knowledge needed to operate the new technologies". One reason "is the political power of old firms and industries, and the difficulties they may have in transforming themselves. For comfortable, well-connected, old firms, creative destruction is not a welcome thing. Politically and socially, creative destruction is not easy to handle".

This paper conjectures that development depends on breaking this crucial "lock in".

Again, here there is the rub: how to break this strong institutional (negative) logic? How to escape this vicious cycle of limited growth, limited technological up-to-date and continuous structural underdevelopment?

III. FURTADO ON THE ROLE OF TECHNOLOGY FOR OVERCOMING UNDERDEVELOPMENT

As underdevelopment has a strong technological determination, as seen in section II, an important question is how Furtado puts forward the contribution of technology for overcoming underdevelopment.

In *Subdesenvolvimento e estagnação* (1966), Furtado discusses "institutional changes" as precondition of Latin American development. Among these, Furtado highlights one institutional change that would influence "the orientation of technological progress, given the specific requirements of present phase of development of regions economies and of modernization of social structures" (pp. 39-40).²⁸ Therefore, Furtado suggests that a change in the orientation of technological progress is a precondition for development. This statement, very initial and tentative, flags an important issue since earlier stages of Furtado's elaboration: development is not only the absorption of technology generated abroad. However, this statement is not further elaborated in this book.

In the first essay of *Um projeto para o Brasil* (1968), Furtado presents an important section on research and investments in human resources. In this section he criticizes the previous Brazilian development for "it was done without aiming at technological autonomy" (p. 85). Coherently, in this

²⁷ According to the Brazilian Central Bank, in 2003, Brazilian residents officially declared US\$ 72 billion in foreign accounts (*Folha de São Paulo*, 22/02/2004, p. B4).

²⁸ In the original: "influir na própria orientação do progresso tecnológico, em função de requerimentos específicos da presente fase de desenvolvimento das economias regionais e da modernização das estruturas sociais".

section Furtado explains the need of “a big effort for the adaptation of known techniques” and emphasizes that “in a development plan...assimilation, adaptation and creation of new techniques should be top priority” (1968, pp. 84-85).^{29 30}

This combination of using known techniques (assimilation of techniques invented abroad), which use presupposes adaptation (not an effortless process, would the evolutionists stress) and creation of new techniques is very important. This combination among assimilation, adaptation and creation points to the multifarious tasks for the process of technological development. Next section links this three-folded approach to challenges that national systems of innovation should face to overcome underdevelopment.

In *Criatividade e dependência na civilização industrial* (1978), probably the book that Furtado went further in his views on technology, there is an articulation between dependency and control of technology (by the center). There are five power resources underlying the “so-called international economic order”: 1) control of technology; 2) control of finance; 3) control of markets; 4) control of the access to non-renewable natural resources; 5) control of the access to low-wage labor (1978, p. 115). In this book, the control of technology is seen as the key resource shaping the “international power structure” (1978, pp. 116).³¹ This technological domination tends to be strengthened by the proliferation of transnational corporations. Therefore, summing up, “the struggle against dependency is an effort to nullify the effects of the monopoly of this resource owned by central countries” (p. 117).³²

Dependency is, in first place, technological dependence (1978, p. 123). Therefore, the main question is: how to confront technological dependency? Furtado answers: “gathering other power resources to neutralize, at least partially, the weight of technological dependence – this is the essential effort that peripheric countries should implement to advance the development process” (p. 123). What are the preconditions to face the technological dimension of dependency? “The struggle in the technological front becomes feasible only with the control of expressive internal market share and with the existence of a critical mass of financial resources” (p. 123).³³ Is Furtado in this elaboration in line with the early Schumpeter and his *Theory of economic development*, with his view that “monetary markets are the headquarters of capitalism” and that the “main function of monetary or capital market is the commerce of credit aiming to finance development” (Schumpeter, 1911, p. 86)? There is a point here, which should be in any reasonable research agenda on peripheric NSIs: the relationship between the financial system and the rest of NSI’s institutions. Translating this point to the language of the next

²⁹ In the original: “no plano de uma política de desenvolvimento ... a assimilação, a adaptação e a criação de novas técnicas deverão colocar-se no primeiro plano”.

³⁰ This paragraph was kept in a French version of Furtado’s elaboration (1970), but omitted in the new Brazilian edition of this book (2003b).

³¹ The role of technology in Furtado’s work is now subject of an interesting debate among structuralists in Brazil. Tavares (2000, 131-132), for instance, assumes a different starting point (vis-à-vis the ECLA school): argues that the role of international money is more important than the role of technical progress in shaping the domination schemes of the capitalist system.

³² In the original: “dos recursos de poder referidos, o primeiro – o controle da tecnologia – constitui atualmente a trava mestra da estrutura de poder internacional. Reduzida a suas últimas consequências, a luta contra a dependência vem a ser um esforço para anular os efeitos do monopólio desse recurso detido pelos países centrais”.

³³ In the original: “A luta na frente tecnológica somente se torna viável quando foi assegurado o controle de importantes segmentos do mercado interno e reunida massa crítica de recursos financeiros”.

section, Furtado would be writing that the process of technological catching up has a financial precondition.

Although the “struggle in the technological front” should wait for market and financial preconditions, there are intermediate steps that should be taken: “creation of links of authentic interdependence, without technological autonomy; attempt to change the orientation of technology without the control of technology” (p. 124).³⁴

In his more theoretical book (*Teoria e Política do Desenvolvimento Econômico*, 1986), Furtado has several important points, beyond the discussion of the inappropriate technology, as put forward in the previous section. Explaining the consequences of industrialization through the process of import substitution and the emergence of the “high level underdeveloped economies”, he shows how it faded. To resume development, “high level underdeveloped economies” must “endow their economies with own dynamic centers” (p. 205-206). Again, in terms of the next section, this “own dynamic centers” cannot exist without the maturing of NSIs.

Furtado introduces here the subject of “selection of techniques aiming at social objectives” (p. 187 and p. 240).

In an essay from *Brasil: a construção interrompida* (1992) Furtado stresses that underdevelopment is superable: South Korea and Taiwan are two recent examples of how underdevelopment as a “historical trap” can be overcome (1992, p. 51). For Furtado, there are two necessary conditions for the overcoming of underdevelopment: 1) “social homogenization” and 2) “the creation of an efficient productive system, endowed with relative technological autonomy” (1992, p. 52).

Summing up, Furtado’s elaboration on the role of technology for the overcoming of underdevelopment highlights: 1) reorientation of technological progress is important (1966); 2) technological autonomy was not a priority during the Brazilian industrialization (1968); 3) to confront “technological dependence” resources from other areas are necessary (internal market and financial resources), although one might try to change the orientation of technology even without controlling it (1978); 4) the overcoming of the “barrier of underdevelopment” has a “relative technological autonomy” as a necessary precondition (1992).

Furtado seems to be rephrasing the role of technology as he elaborates his views on development (and evaluate the practical results of industrialization). In the tension of this rephrasing process there is a clear understanding of a specific role for technology, certainly determined by the role that technology has in his view in shaping the international division of labor.

³⁴ In the original: “De uma maneira imediata, trata-se de criar vínculos de autêntica interdependência, sem dispor de autonomia tecnológica; de tentar modificar a orientação da tecnologia sem ter o controle desta...”.

IV. NSI AND APPROPRIATE TECHNOLOGY

What is “appropriate technology”, as formulated by Furtado and after the exploratory dialogue between evolutionary and structuralist approaches? Technology is appropriate when it feeds an overall process of catching up (combining assimilation, adaptation and creation of new techniques) and when it breaks the perverse combination of “modernization-marginalization”.

This section suggests one point for the dialogue between structuralists and evolutionists: appropriate technology as a reference for public policies. As discussed in previous sections, Furtado’s concept of inappropriate technology enlightens the understanding of present-day NSIs in the periphery.

Appropriate technology may be seen as a reference for public policies (for maturation of NSIs in the periphery) and as result of steps forward in the maturation of peripheric NSIs.

The complexity of the internal structure of contemporary underdeveloped countries underlies this discussion. The heterogeneity, the reality of deep inequality in all realms of economic and social life could be read as with two messages: as bad news, indicating a huge social problem to be overcome. But, as good news, showing sectors and regions where, in the language of NSI, “partial connections” between its components are operating. Probably, Teitel’s argument may be integrated here, as he shows that where technology is absorbed there are real local effort and not only passive reception.

The problem is the localized nature of these successful cases of technology assimilation. It is important to note that in almost all successful cases there is a kind of mini-NSI working, with an integration between universities or research institutes and the economic/industrial sector: 1) steel industry: the process of internal capability can be traced back to the *Escola de Minas* and all schools that in a certain way descend from that pioneer institution (see Mazzoleni, 2003); 2) petrochemicals: there are strong connections between Petrobrás research center and universities as UFRJ and others; 3) EMBRAER: connected to *Instituto Tecnológico da Aeronáutica*; 4) agro-industrial sector: there is a central role for EMBRAPA, etc.

However these important exceptions, the polarization “modernization-marginalization”, born out of the causal chain described in section II.3, is necessarily inscribed in the existing institutions of the Brazilian NSI. Therefore, the route for the “maturation” of the Brazilian NSI is not only the quantitative expansion of existing institutions. Certainly there are problems related to the lack of critical mass in science and technology. But the NSI institutions that have been functional for the Brazilian economy so far, are not the institutional framework necessary for a successful catching up process.

Again, the social deep-rooted factors reflected in the inappropriate technology block the spreading and the diffusion of these well-succeeded practices to small sectors and few regions. Bernardes et al (2003) put forward the need to double (or to treble) the resources devoted to science in Brazil to reach a “threshold” that might be overcome before triggering a more interactive (and generalized) relationship between science and technology. These investments in the scientific infrastructure are not isolated (and have as a prerequisite) huge investments in education and

universities. The availability of higher education resources in the US, according to Rosenberg (2000), enabled American universities to have “economic responsiveness”. For Rosenberg, “its great size ... has made it possible to maintain a high degree of specialization and diversity within a very large system” (p. 41). A large country as Brazil (and India, Mexico and South Africa) needs this combination of specialization and diversity. Therefore, size matters. And restrictions on the increase of university enrollments are consequences of marginalization issues, that affect the whole educational trajectory of the poorest sectors of the population.

Furtado stresses a three-folded process of technological catching up, involving assimilation, adaptation (of know techniques) and creation (of new techniques).³⁵ This three-folded process of technological catch up should be related to minimize the structural labor surplus. How to combine this process of generalization of catch up? Probably a more precise way to pose the question is this: how to generalize these successful partial catch up?

Given that economies as the Brazilian have been able to achieve partial catch up, in terms of sectors and regions, the polarization modernization-marginalization could help here.

The partial and localized nature of successful catch up is a blocking factor for further development. For instance, São Paulo as the more developed state in Brazil has an international location (taking patents and scientific papers statistics as reference) near Argentina and Chile, and very far from Spain. An interpretation of these data suggests probably a specificity of “large countries” NSI formation: advanced regions have their own (nationally isolated) development blocked by less-developed regions.

If the “marginalization” side of the polarization blocks further development and the spreading of catch up, policies to overcome marginalization should come to the center stage of public policies. A reduction in marginalization side of the polarization would spark new demands, growing internal market and new challenges (and opportunities) for local industries (old and new).

Furtado emphasizes that “development in Brazil today is essentially the solution of the social problem” (2003a, p. 14). And he emphasizes the combination of “social homogeneity” with “the creation of an efficient productive system, endowed with relative technological autonomy” - an Eastern Asian lesson for overcoming underdevelopment (1992).

These thoughts may be translated into a necessary combination of innovation systems (Nelson, 1993; Freeman, 1995) with welfare systems (Esping-Andersen, 1990, 1996).³⁶ To overcome the polarization modernization-marginalization, a combined construction of innovation and welfare systems can be a public policy long-range goal. Underlining this combined institutional building, there is a theoretical elaboration on the positive feedbacks between efficiency and growth (NSIs) and equality (Welfare Systems).³⁷

³⁵ “Creation of new techniques” might be related to new needs arising from the incorporation (‘de-marginalization’) of new population sectors to the internal market. The control of Chagas’ disease is an example of this point: only with internal capability (scientific, health services, education etc) could this very specific problem be at least controlled (Fernandes, 2005).

³⁶ The dialogue between evolutionists and Esping-Anderson is not new (for instance, see Nelson, 2002).

³⁷ Arrow (1984) discusses the trade off between growth and equity.

How this combination could take place?

From the welfare system to the NSI: 1) the main links are straightforward: a- nutrition and health: basic condition for education and work; b- education: contributing for learning by doing, prerequisite for activities of a knowledge-based economy; c- work conditions (safety, healthy environment, accidents prevention, reduction of working hours, etc): productivity improvements, learning by doing, problem shooting, workers' involvement in technical change; furthermore, 2) Reduction of unemployment, internal market expansion, and division of labor.; and 3) Welfare institutions mitigating "friction" in the labor market due to technical change: a- during a catching up process, technical progress may destroy some occupations and demand new ones (labor training and retraining would be necessary); b- Welfare institutions might establish "flexibility" (workers mobility) without high social costs: this would reinforce a precondition for a more dynamic society, allowing a permanent process of "labor repositioning" pushed by technological revolutions.

From the other direction, the NSI improving welfare conditions: 1) In general: output and productivity growth are sources of welfare improvements; 2) Technical progress as a tool for improvement in labor conditions (priority for automation of working places that causes occupational diseases, for example); 3) scientific community as "focusing device": definition of targets that are "country-specific" (for example, biotechnology development combined with medical research about prevalent diseases, etc). 4) "Mission-oriented" projects: defined in terms of economically feasible technical solutions to particular social problems (as suggested by Freeman, 1996, to particular environmental problems).

Two notes on these mutual relationships are worthwhile.

First, there is interplay between the dynamics of job creation and the existing heterogeneity of labor conditions (from people in the structural labor surplus areas to high tech jobs in industries and universities). This huge differentiation means a large room for upward social mobility. There are a lot of cases where the low-wages jobs are starting points. But, Esping-Anderson stresses the necessary dynamic nature of the process: “.. ‘lousy jobs’ will constitute only a marginal welfare problem (and even may be beneficial) if they are merely stop-gap, or easy first-entry, jobs for school leavers or immigrant workers. They are a major problem if they become life cycle traps” (1996, pp. 25-26). Noting that “education and skills offer the best odds for people to move on to better jobs”, Esping-Anderson concludes, “a low-wage-based employment strategy may be reconciled with equality if there exists guarantees of mobility and improvement” (p. 26). There is a prerequisite for the supply of “education and skills”: a good education system, connected with the scientific infrastructure for permanent update in assimilation and adaptation of techniques. And the “guarantees of mobility and improvement” , for cases like Brazil, can only come from a successful catching up process. Earlier in his chapter, Esping-Anderson pointed that the “Scandinavian route” managed the “surplus of ‘deindustrialized’ largely unskilled, masses with retraining and job creation” (p. 18).

Second, the role of health sector in shaping mature NSIs during catch up processes. From Freeman (1996), the suggestion of “mission-oriented” projects, taking as references health problems. This is probably an unavoidable step (given the 10/90 gap, see GFHR, 2002). This emphasis would have a positive impact on the simultaneous building of innovation and welfare systems, as the health innovation system is located in the intersection between the two systems.

This emphasis on health may help to shape the specialization of scientific capability, pushing the country towards a comparative advantage in medical related disciplines (Lattimore & Revesz; 1996, p. 14). This pattern of specialization would help to contain the marginalization side of the polarity.

CONCLUDING REMARKS

This paper has a very simple point: Celso Furtado's elaboration may contribute for evolutionist formulation on underdeveloped countries. A theoretical challenge to both evolutionists and structuralists may arise from a careful interpretation of his work, especially focusing the role of technology on the structural rupture center-periphery and the relationship between inappropriate technology and the polarization 'modernization-marginalization'.

To transform the inappropriate technology is to break the deep links that root the social inequality in the NSI profile. Not easy to handle, but an unavoidable step. Therefore, the task of a simultaneous building of innovation systems and of welfare systems might be a way to overcome underdevelopment. And a task that aims to end the polarization "modernization-marginalization": instead of modern labs coexisting with slums, modern labs contributing to wither away poverty.

This paper conjectures that the institutional response to the polarization modernization-modernization is the combined formation of innovation and welfare systems. This combination between the formation (or maturation) of an innovation system and the formation of a welfare system may be the "institutional innovation" underlying the Brazilian catching up process.

For further research:

- 1) In a theoretical view, it is useful to explore more: a) the contributions from the understanding of underdevelopment to the elaboration of a catching up agenda for immature NSIs; b) the implications of the combined formation of innovation systems and welfare systems;
- 2) In the public policy side, it is necessary to resume, in a more informed way – adapted for a 21st Century agenda -, the discussion on combinations between planning and market³⁸: a) Feasibility of a public policy long-range goal of combined formation of innovation and welfare systems feasible; b) What mix between market and public (state and non-state) institutions is capable of this target?
- 3) In the social front, it is necessary to define through which channels marginalization blocks the virtuous cycle between growth and welfare gains (and how the evolution of NSI institutions may affect these channels, especially through "mission-oriented" projects);
- 4) How are the quantitative changes (resources for critical mass in education and science) related to the qualitative changes?

³⁸ Nelson (2002) discusses the mix between market and public institutions that shapes NSIs in developed economies. This mix is an old subject of the pioneers in development's agenda (Meier, 1984), involving a special attention on the role of planning for the overall process of overcoming underdevelopment (an important subject on Furtado's work, see Furtado 1987, for instance).

- 5) Case studies of successful experiences and of “partial connections” already working in immature systems of innovation (what lessons may be drawn?);
- 6) Focusing the financial dimension, how its reform would change the supply of credit for innovators and for sustainable catch up process;
- 7) Last, but not least, a dialogue between economics, sociology and political sciences is necessary to address the political preconditions of catching up process in democratic societies (there is a political component in the marginalization side of the polarization).

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