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RESHAPING STANDARD MICROECONOMICS FOR POLITICAL ACTION: KENNETH J. ARROW AND THOMAS C. SCHELLING'S RAND CORPORATION PROJECTS ON RACIAL

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(very preliminary)

Abstract

The paper focuses on Arrow statistical discrimination theories and Schelling's models of segregation, and how their work can be considered as an illustration of "the introduction of the same policy tools [as war game theory] into domestic politics in Lyndon B. Johnson's Great Society Program" (Amadae, 2003: 10). In both contributions, abstract and formal theory serves as "a public policy tool" (Amadae, 2003: 9).

We underline how (i) certain methods employed within RAND Corp. during the Cold War like its "interdisciplinary approach" or its "system analysis" are applied in Arrow and Schelling's work on discrimination, and (ii) how certain tools which became the core of neoclassical economics are at the same time pervasive and challenged in Arrow and Schelling's respective work. In that sense, our analysis is slightly different from Amadae's one (2003) who sees in their work the illustration of the domination of rational choice theory in neoclassical economics. In our opinion, the two contributions have in common to be embedded in a neoclassical framework and illustrate a movement to amend this general framework for policy purpose.

The paper discusses the epistemological status of Arrow and Schelling works, i.e. how they shape a new trend of scientific knowledge, by their specific methodologies, and how their works stress the usual dichotomy between economics as a normative or a positive science. Methods have consequences on political actions and Policy recommendations. The tiny threshold between prediction and explanation in Arrow and Schelling's works imply a reflection on their epistemological status, especially because their respective amendments to standard theory are driven by the necessity of policy recommendations.

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INTRODUCTION

Basically, discrimination occurs when equal productivity is not rewarded by equal pay, or, more generally, when different outcomes, unrelated to productivity variables, are correlated to non-economic criteria linked to group affiliation. In Economics, thoughts on discrimination do exist prior to the generalization of the term in current language in the 1950's (Chassonnery-Zaïgouche, 2013) but becomes a focus of Labor Economics (and a central political issue) after World War II.

Myrdal's Carnegie Corporation report *An American Dilemma*, a symbol of the first generation of work on discrimination in Economics is strongly influenced by the institutionalist tradition in Economics (Myrdal, 1944). After the war, two models are presented as basis for the theoretical analysis of discrimination in a neoclassical perspective: Becker's model based on a "taste for discrimination", produced in his PhD dissertation (Becker, 1955; Becker, 1957; Becker, 1971); and Arrow and Phelps' theories of "statistical discrimination". The latter led to renew explanations of discriminatory behaviors: from subjective preference (taste) to cognitive bias based on beliefs, stereotypes and signal effect.

Racial segregation in housing, in public and private facilities and companies was a legally organized reality in United States from 1896 till 1964[3]. The end of legal segregation did not mean the vanishing of segregation mecanism in the American society.

Becker mentions this issue in one of its models (Becker, 1971: 22) but Thomas Schelling's model is the landmark of the discipline on this subject, especially because the rationale supporting is new:

> "Schelling is presenting a critique of a commonly-held view that segregation must be the product either of deliberate public policy or of strongly segregationist preferences. The checkerboard model is a counter-example to these claims: it shows that segregation could arise without either of those factors being present. On this reading, Schelling is making an important contribution to debates about segregation in the real world, but the contribution is conceptual: he is pointing to an error in an existing theory" (Sugden, 2000: 9).

As Sugden emphasizes, the unintentional character of an economic equilibrium is a major focus of Schelling's work, as it is also a central feature of Arrow's statistical discrimination model. The Becker tradition analyses discrimination as an intentional behavior resulting from tastes whereas statistical discrimination results form the the difficulty to identify productive characteristics of the individuals on a market.

The present paper focuses on Arrow statistical discrimination theories and Schelling's models of segregation. The two authors both analyze emergent phenomena and are sensible to the non-market aspects of economic phenomena:

[3] Racial segregation is structural element of the post-war era in the United States, especially because "Jim Crow" legislations are still effective. The "Jim Crow Legislations" are a set of laws which organized the segregation between black and white people in the United States from 1876 to 1964. This system, governed by the "separate but equal" principle, was challenged by the 1954 *Brown vs. Board of Education Act* (347 U.S. 483, May 17, 1954) that ends segregation in schools, and was abolished with the 1964 *Civil Rights Act*.

> "Enough has been said to suggest that market-based theories give an inadequate account of the effects of racial discrimination on economic magnitudes and the effects of racial discrimination. It is increasingly recognized that many social interactions with economic implications are not mediated through a depersonalized market, but rather through the cumulative effect of individual choices" (Arrow, 1998: 97).

Contrary to standard microeconomics and mainstream game theory,

> "the key hypothesis of [Schelling's] approach is that economies are not just collections of homogeneous agents but complex dynamic systems characterized by dispersed interaction among heterogeneous agents acting locally on each other in some place" (Innocenti, 2007: 421).

This shared conception of dynamics and emergence is illustrated in their applied works at the end of the 1960s, at the RAND Corporation.

The RAND Corporation is known to be the first think tank in a modern sense of the term and one of the central institutions of American research effort during the Cold War. People at the RAND are responsible for the game theory spreading from defense strategic issues to domestic issues. Arrow initiated reflexion on game theory through his relationship with John Harsanyi and Schelling contributed to the diffusion of game theory even outside economics. Schelling highlighted that game theory should not be considered as a "mathematical 'toolbox'" (Gioccoli, 2003) but as a conceptual framework for social scientists:

> "In the late 1950s Schelling was actively involved in the Rand Corporation, where the mathematical foundations of game theory were being laid, he addressed some criticisms to game theory that conflicted with some of the principles endorsed by that same community" (Innocenti, 2007: 417).

Our paper focuses on an illustration of "the introduction of the same policy tools [as war game theory] into domestic politics in Lyndon B. Johnson's Great Society Program" (Amadae, 2003: 10). In both contributions, abstract and formal theory serves as "a public policy tool" and are illustrations of the use and diffusion of rational choice theory as a decision-making theory in the Cold War political context (Amadae, 2003: 9).

Sugden (2000: 12) claims that Schelling's models are "similar to the neoclassical model of markets in their use of highly simplified assumptions" but for others analysts:

> "[Schelling's] views on rationality contrast with what is found in the standard microeconomic apparatus; his reception among economists was late in coming; his work is not mathematically or quantitatively sophisticated; and his use of game theory is different" (Rivzi, 2007: 40).

The two authors both ascribe to individual rationality but they revendicate an enrichement of rational choice theory. Because they assert unintentionnality of collective choice, and because there is emergence in interdependent individuals choices in discrimination and residential segregation, an axiomatic approach of choices cannot prevails. Indeed, individual methodological choice is explicitly stressed in their approachs.

The paper aims at highlighting that the way both Arrow and Schelling conceive the role of economics as a science for action, has impacted their conception of economic theories and models. The paper shows how this conception is revealed in their respective works at the RAND on racial inequalities in the late 1960s. This relationship between economics and political actions implies the need to enrich standard microeconomics and even to reshape its fundamental behavioral hypothesis. They both highlight some methodological and analytical breaks from standard microeconomics.

The paper is structured as follows. The first part present the origins of both contributions in relation to general context, *i.e.* ow factual, political and institutional context, influence Schelling and Arrow. We will underline, how the way research was done at the RAND Corporation is the central pillar of this context. The second part is a presentation of Arrow and Schelling's models in which we underline their analitical and conceptual specificities in order to understand, in the last part of the paper, their methodological claims. The last part, discuss, the epistemological status of Arrow and Schelling works, i.e. how they shape a new trend of scientific knowledge, by their specific methodologies, and how their works stress the usual dichotomy between economics as a normative or a positive science. Methods have consequences on political actions and Policy recommandations. The tiny threshold between prediction and explanation in Arrow and Schelling's works imply a reflection on their epistemological status, especially because their respective amendments to standard theory are driven by the necessity of policy recommandations.

SCIENCE FOR ACTION: THE RAND CORP. TRADITION AND THE ORIGINS OF THE TWO CONTRIBUTIONS

Between 1965 and the 1970s, the RAND Corporation supported several projects on poverty, and especially on racial inequalities. In this perspective, McCall developed the first model of Job Search (1970), Arrow offers a first theory of statistical discrimination (1968, 1971, 1972, 1973) and Schelling formalized his segregation models (1969, 1971a, 1971b, 1972). This first section aims at presenting the political and institutional contexts in which Arrow's work on discrimination and Schelling's model of segregation were built.

THE INTELLECTUAL CONTEXT

After the Second World War, the intellectual and political context in United States on racial issues is characterized by the Cold War context and the rise of the Civil Rights Mouvement. The contradiction between the "American creed" and the segregation system was the focus of a major study published right after the Second World War: *An American*

Dilemma[4] (Myrdal, 1944). A number of studies concentrate on the earnings differentials as a measure of racial inequalities (Turner, 1952; Zeman, 1955; Welch, 1967; Duncan, 1970).
At the same time that Becker's work was awakening a renewed interest (second edition of *The Economics of Discrimination*), the opening of new data sets entailed a big push in development of the measure of discrimination. Data sets are one of the results of the "War Against Poverty" that endorses an institutional struggle against racial inequity during the Kennedy and Jonhson Administrations. This set of social reforms culminates with the *Civil Right Act* of 1964 (Brinkley, 1991: 472), which creates the *Equal Employment Opportunity Commission*. This commission played a great role in adding the *Survey of Economic Opportunity*[5] to the Census data and supporting the Panel Study of Income Dynamics of the University of Michigan[6]. These two datasets are the basis for the measurement of discrimination based on observational data (Oaxaca, 1971, 1973; Blinder, 1973). Empirical studies were also conducted in Britain (Daniel, 1968; Jowel, Prescott-Clarke, 1970) and in United States to measure discrimination and segregation through experimental studies[7].
Academic research on racial issues was promoted by federal institutions but also by a major research-oriented institution: the RAND Corporation, whose focus move from defense and strategic research to domestic issues -- essentially along the lines of the "Great Society" reforms' requirements.

INSTITUTIONAL CONTEXT: THE RAND CORP. IN THE 1970S

Since its creation in 1945, two main features characterize the RAND Corporation. From a theoretical point of view, its research programs are interdisciplinary (Sent, 2007: 461). This methodology built during the Cold War for military purpose has always been followed after. This interdisciplinarity translates in Economics *via* the use of mathematics and quantitative methods. The RAND Corporation played an active role in "the changing nature of mathematics and mathematical economics" (Sent, 2007: 458-59) which gave rise to "the success of the new methods with which neoclassical economists came out of WWII" (*ibid.,* 459). At the end of the war, economics "became associated with a certain tool-kit as opposed to a particular area of study" (*ibid.*: 458). This change is particularly visible in the RAND methodology, and the making of a "tool-box" to analyze current social or strategic issues.

[4] When Myrdal edits *An American Dilemma: The Negro Problem and Modern Democracy* in 1944, the summa of 1,500 pages is regarded as a masterpiece of sociology. The dilemma is between the "American creed", *i.e.* the values of the American democracy and equal opportunity principle, and the system of segregation. Myrdal produced a methodological critique of the notion of equilibrium used in economics and proposed a theory of cumulative causation – inspired by Wicksell's cumulative process and based on the formal model developped in *Monetary Equilibrium* (Myrdal, 1939). Paul Samuelson called the model an anticipation of Keynes' work (ferraton, 2008: 12). Myrdal's study, which was commissioned by the Carnergi Corporation, was quoted in he *Brown vs. Board of Education* (footnote 11) decision as an evidence in favor of equality.
[5] SEO U.S. Office of Economic Opportunity. Washington, DC : U.S. Dept. of Commerce, Bureau of the Census [producer]. College Park, MD: National Archives and Records Administration.
[6] This data based was produced by the Survey Research Centre of the University of Michigan and is considered as the longest running longitudinal household survey in the world, beginning in 1968.
[7] Audit testing involved field experiments which mainly dealt with paired application of two candidates differing only in characteristics tested in the study (gender, race etc.). For a review of experiments on discrimination and segregation in economics, see Anderson *et al.* (2006) and Riach and Rich (2002).

Second, since its early days, RAND Corp. is characterized by its tight links with the US Government. Even if the RAND became independent in 1948[8], its research has always been oriented toward national interests. The success of The RAND Corp. is well known for "its influence in the arena of Policy formulation" (Hounshell, 1998: 241). Indeed, "during the war, heavy demands had been placed on economists to develop tools for solving policy problems" (Sent, 2007: 458), and, especially, decision-making problems (Amadae, 2003). From the 1950s, the RAND corporation evolves from a "pure Cold War institution" (Hounshell, 1998: 240) to a major think-tank working on a wide range of subjects.

Before the end of the Cold War, the budget allocated for miliary researchs only were redistributed in other domains and for instance, in social and civilian domains like racial issues. Hounshell (1998: 267) emphasizes that "by the late 1960s, an increasing percent of RAND's budget went for domestic research, and the analytical methods, tool, and penchant for research that RAND had manifested at the height of the Cold War were actively engaged in the "War on poverty". The RAND Corporation's switch from a focus on defense and Nuclear issues to a more open range of working subject could be seen as the reflect of diversification as well as the the growing importance of racial issues in Post-War America. Aside the importance of the post WWII context[9], segregation and racial discrimination at home were analysed by the Soviets as an illustration of the American imperialism at a domestic level (Cohen, 2004). In this regard, large parts of Arrow's 1968 and 1971 reports are devoted to argue against Marxian analysis of discrimination as an illustration of a theory of exploitation[10].

THE ORIGIN OF THE TWO CONTRIBUTIONS

Both Arrow and Schelling's starting point is the standard neoclassical theory they contribute to establish. Gary S. Becker's work on discrimination and segregation is the theoretical foundation of the neoclassical legacy on racial issues.

In the late 1950s, Becker's work on discrimination opened a research program in academic economics: how to explain and measure market discrimination? His answer was based on what Stiglitz called the "preference-trade model[11]" (Becker, 1855, 1957; Stiglitz, 1973).

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[8] RAND stands for Research ANd Development. The think-tank was established as "an independent non-profit research and development organization and [was] funded largely by the United Air Force up to 1962" (Hounshell, 1998: 240).

[9] "Another key facet of Myrdal's argument was to set the study in an international context, predicting that, for Americans, having defined World War II as a struggle for liberty and equality and against Nazi racism would force a redefinition and reexamination of race in the United States" (Cohen, 2004: 4).

[10] "It is certainly a common view that in some sense racial discrimination is a device by which the whites in the aggregate, gain at the expense of the blacks. Hence, the whole problem is to be interpreted as an exploitative relation. There is a stable relation here; the values inherent in discrimination uphold a structure that is profitable to those holding those values. On purely methodological grounds, I do not think such a view can be denied, provided it works, though is contrary to the tradition of economics. Economic explanation for discrimination or other phenomena tend to run in individualistic terms, and the models presented earlier are no exception. Economists ask what motivates an employer or an individual worker. They tend not to accept as an explanation a statement that employers as a class would gain by discrimination, for they ask what would prevent an individual employer from refusing to discriminate if he prefers and thereby profit" (Arrow, 1971: 24-25).

[11] "If an individual has a 'taste for discrimination', he must act as if he were willing to pay something, either directly or in the form of a reduced income, to be associated with some persons instead of others" (Becker, 1971, 14)

ARROW: A COMMISSIONED WORK ON THE ECONOMICS OF INFORMATION THAT EVENTUALLY BECOME A THEORY OF DISCRIMINATION

At the begining of the 1970s, meanwhile a second edition of *The Economics of Discrimination* was published (Becker, 1971), the RAND Corporation commissioned a report on information that eventually became Arrow's "theory of Statistical discrimination". His initial work was a part of a RAND Corporation project on the measurement of discrimination (Arrow, 1968). The first letter between RAND and Arrow mentions only a project on new theoretical developments due to the treatment of information in Economics[12]. A theory and a mathematical model of statistical discrimination were then presented at a Princeton conference on discrimination[13] and published in 1972 (Pascal, 1972) and in a new version in 1973 (Ashenfelter, Rees, 1973).

This work is both a continuation of Becker's model and constitutes a reflection on the use of neoclassical economic theory to study discrimination:

> "The intention of this report is to demonstrate the advantages and disadvantages of neoclassical analysis as a tool for studying racial discrimination in the economic sphere and to suggest possible areas of fruitful research" (Arrow, 1971, v).

By fulfilling this study of neoclassical tools, Arrow ends up with a new theory of discrimination and a sharp criticism of Becker's tastes-based model.

In the 1968 paper, Arrow points the lack of consistency between the differents models of discrimination Becker proposes (Arrow, 1968: 9-10). He discusses the confusion Becker made between white benefits's from discrimination at an individual and at a group level (Arrow, 1968: 16). He is not satisfied by the "lack of specificity" of the taste-based hypothesis (Arrow, 1971: 9-10). The latter concerns two different aspects: the lack of specificity on the nature of the taste (the difference in the distribution and the difference in tastes, as for example, the dislike depends on the nature of the association) and the fact that the taste could be the result of economic interactions and are not to be taken as given[14]. The first motivation for Arrow's theory of statistical discrimination was a departure from an explanation in terms of tastes by asking the question wether discrimination is possible when individuals have mild tastes for discrimination or no tastes at all.

The first report was done during the same period of time as Pascal's work on discrimination in baseball (Pascal, 1972) and Schelling model of segregation (1969, 1970); the latter being also a sharp criticism of Becker's work.

SCHELLING SEGREGATION MODEL IN CONTEXT

In several interviews after the Nobel Prize, Schelling tells the story of the conception of his dynamic models of segregation. He describes a context in the United States in which

[12] Kenneth J. Arrow Papers 1939-2011, Duke University. David M. Rubenstein Rare Book & Manuscript Library, Accession (2000-0222) 1077-1980, Box 2.

[13] "Conference on Discrimination in Labor Markets", 7th and 8th October 1971, Princeton University, supported by the Industrial Relation Section and the Woodrow Wilson School of Public and International Affairs.

[14] Arrow is much more critical in his last paper on discrimination, characterizing Becker's taste-based *ad hoc* hypothesis as tautological. He adds: "Attributing taste to impersonal entities [large corporations] is a hypothesis of dubious usefulness" (Arrow, 1998: 95).

> "Many American neighborhoods were either mostly white or mostly black. One possible explanation for this, of course, was rampant racism. But I was curious about how this might emerge in a world were racism was not particularly acute, where in fact people might prefer racial diversity" (Schelling, in *Region Focus,* 2005: 40)[15].

From an analytical perspective, he is extremely critical about Becker's book *The Economics of Discrimination*, and his treatment of discrimination. He claims that Becker:

> "had a piece of machinery that was cranking out results, and that he wasn't sufficiently interested in racial segregation to look and see what was going on. He just decided to throw a parameter into a preference function, giving everybody a "taste" for being with or not being with people of another color [...] What he is primarily interested in is showing that traditional economic models are all you need. [...] he doesn't appear to think there is anything to learn from outside economics. He is not interested in coupling the methodology of economics with the methodology of sociology."(Schelling in Swedberg, 1990: 194).

Hence, considering this rough critic of Becker and considering the context in the United States he describes, he explains how his work on residential segregation started:

> "I was at RAND in the summer of 1967. I wrote a chapter called "the process of neighborhood tipping" (in Anthony Pascal's book) at RAND. Probably between the summer of 1967 and summer 1968 I did my checkerboard work. I took it to RAND and asked RAND to computerize it for me. I kept on working on this issue for another year or two. But the checkboard stuff I did not do at RAND and I did not get the idea at RAND. I had a strong intuition that you can get a lot of things like fairly extreme segregation through the dynamics of movement. And I was sure that there would be an existing litterature at on that. So, one summer when I was at RAND – RAND has a pretty good Library – I got all of the bound volumes of two or three journals in sociology, believing I would find what I wanted [...] And I could not find anything. I decided [...] I'll have to make it all up" (Schelling in Aydinonat, 2005: 4).

We will underline how (i) certain methodes employed within RAND Corp. during the Cold War like its "interdisciplinary approach" or its "system analysis" are applied in Arrow and Schelling's work on discrimination[16], and (ii) how certain tools which became the core of neoclassical economics are at the same time pervasive and challenged in Arrow and Schelling's respective work. In that sense, our analysis is slightly different than Amadae's one (2003) who sees in their work the illustration of the domination of rational choice theory in neoclassical economics. In our opinion, the two contribtions have in common to be embedded in a neoclassical framework *and* illustrate a movement to amend this general framework for policy purpose.

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[15] A full version of Schelling's interview is available on www.richmondfed.org.

16 In fact Houshell (*ibid.*: 245-46) claims that: "systems analysis became a widely diffused analytical methodology in the 1960s not only in defense related work, but also in civilian social Policy research".

ARROW'S AND SCHELLING'S CONTRIBUTIONS AND THEIR CONSEQUENCES

This section presents the two contributions and their analytical consequences in the field.

ARROW'S STATISTICAL THEORY OF DISCRIMINATION

The first objective of Arrow's contribution is to explore the usefulness of economic theory to study discrimination:

> "The real subject of this Memorandum is economic theory itself, or more precisely, the use and meaning of neoclassical price theory in application to the allocation of ressources and the distribution of income in the real world" (Arrow, 1971, 1).

In doing so, he actually develops and amends Becker's model, and, later, build a new theory of discrimination.

Arrow first develops the taste-based discrimination model in a more systematic way[17]. Questioning the narrative of discrimination's elimination by competition pressure, he directly asks "whether profit maximization does overshadow utility maximization [based on preference]" in the case of discrimination (Arrow, 1971: v). In a model with tastes, competition rules out discrimination. Arrow states that some employers "greedier than others", with or without taste for discrimination, "will take advantage of the gap between black and white labor wages by demanding black labor" (Arrow, 1971: 11). In the long run, economic theory predicts a fall in wages differential. Arrow offers a link between profit and utility maximization – a link that stands in the case of perfect as well as imperfect competition:

> "Competition will force firms to maximize profits, since otherwise they won't survive. Even under imperfect competition, profit maximizers will find it profitable to take over firms from utility maximizers" (Arrow, 1971: 12).

This statement calls for a rethinking the meaning of long-run competition. One of the major criticisms against Becker's model was its inconsistence with direct observational data and the persistence of discrimination in the long-run.
Contrary to later work, a great part of the RAND Report is devoted to counter-argument the Marxist hypothesis, which coheres with the ideological orientation of many RAND's work at that time (see Amadae, 2003). Even if Arrow recognizes group interest and social presure as working forces, he reinforces the individualistic foundations of economic theory: "greeding" tendencies among employers will help reduce discrimination: "We must really ask who

[17] "On the demand side, the tastes of employers offer the simplest explanation of wage differences. Wages for black workers will fall short of their marginal product by the marginal rate of substitution between black workers and profits, the rate being computed at the black/white ratio in the labor force" (Arrow, 1971: v).

benefits, and how are the exploitative agreements carried out? [...] The exploitation of blacks can work if the tendency of individual employers to buy the cheapest labor is somehow suppressed" (Arrow, 1971: 25). Arrow uses the same argument as Becker (1971: 8) but still think further research on the relationship between profit and discrimination has to be done:

> "[T]he crucial question, to my mind still an open one, is whether the acceptance and preservation of racial attitudes are in some way related to their profitablity to the group" (Arrow, 1971: 26).

This agenda was not followed (Schwab, 1986). Arrow instead develops an alternative theory to answer "why does not competition from the victims of discrimination reduce wages in the preferred occupations and permit them to enter?" (Arrow, 1971: 24).

The main argument Arrow develops is that even with competitive pressure, change is costly. An employer makes a "personnal investment" every time he hires or fires a worker. Those fixed costs are the main costs of change and explain that even if profitable differences in wages exists in a competitive environment, the mecanism of equalization does not work properly[18]. The possibility for change rests upon the level of the differences in wages. The narrative does not contradict competition mecanism but introduce time in a broader sense:

> "Obviously, in a situation like this, where there are costs to change, history matters a good deal. [...] If we starts from a position where black workers enter an essentially all-white world, the social feelings of racialism by employers and employees, both of the same and complementary types, will lead to a difference in wages. The forces of competition and the tendency to profit-maximization operate to mitigate these differences. However, the basic fact of a personnel investment prevents these counteracting tendencies from working with full force. In the end, we remain with wage differences coupled with tendencies to segregation" (Arrow, 1971: 19-20).

Arrow adds that perceptions, not tastes, are the prominent factor in determining the demand for black labor, perceptions based on the "prominence of skin color" as a cheap source of information. The major hypothesis here came from the main result of the economics of information: when relaxing the perfect information hypothesis, information become costly. What will become the theory of statistical discrimination is expressed only at the end of the 1971 report:

> "The inefficiency that arises here because employers do not know the qualifications of workers as well as the workers do is the same principle as that caused by "adverse selection" in insurance. [...] The effects of this model are similar to those based on tastes, but the causes are different. We would still want to know why the subjective probabilities are differents. The simplest explanation is prejudice, in the literal sense of that term; that is, a judgement about abilities made in advance of the evidence and not altered by it" (Arrow, 1971: 21-22).

This intuition is the main basis for the latter development of that will become an alternative theory to Becker's one.

[18] Differences in wages will persist "[I]f the firm starts with an all-white labor force, it will not find it profitable to fire that force, in which its personnel capital has already been sunk, and hire all-black force in which a new investment has to be made simply because black wages are now slightly less than white wages" (Arrow, 1971: 20).

Arrow presented a slightly different version of the 1971 report at a conference entitled "Discrimination in Labor Markets". The proceedings were published by Ashenfelter and Rees (1973). Arrow first identifies "a failure of convexity" that modifies Becker's model and – later – replaces "taste" by perceptions and stereotypes. The main assumption of the statistical discrimination model is that determining the productivity of an employee is costly. Then, discrimination "can be thought of as reflecting not tastes but perception of reality" (Arrow, 1973: 23). The objective is still theory-oriented – "to use as far as possible neoclassical tools in the analysis of discrimination" (Arrow, 1973: 4) – and led Arrow to propose a new theory of discrimination[19].

What is essential is the amendment to standard neoclassical theory. According to Arrow, the particular nature of discrimination as a phenomenon requires the "abandonment" of some standard assumptions such as costless adjustments, perfect information and perfect capital markets:

> "The abandonment of each of these assumptions is motivated by a clearly compelling reason in the theoretical structure of the subject" (Arrow, 1973: 4).

The change is methodology is guided by the nature of the subject – discrimination, what Arrow later calls the "empirical constraints on theory" (Arrow, 1998: 92).

Arrow's new definition of discrimination is related to productivity variables: discrimination implies the valuation in the market of "personal characteristics of the worker unrelated to productivity" (Arrow, 1973: 3). Statistical discrimination occurs when individuals use "projection" of group productivity (based on statistical reasoning or beliefs) to hire or value an individual in a market. For example, if an employer thinks women are less productive than men on average, he may discriminate against a woman in a hiring process. In this model, Arrow presents discrimination as a rational process to decision-making in a market environment without any additional hypothesis on preference. Determining the productivity of an employee is costly – which is a part of what he previously refers as the "personal investment" in the hiring process. If employers think black workers are less productive than white workers in average, they expect to hire them at a lower wage. Discrimination is a consequence of productivity projections which differ from employers and for demographic groups[20]. The causal explanation of those beliefs is still needed:

> "Once we shift the explanation of discriminatory behavior from unanalyzable (or at any rate unanalyzed) tastes to beliefs, we are led to seek to explain these beliefs" (Arrow, 1973: 27).

Arrow mentions explanation, coming from other fields of social sciences. The first one is based on Festinger's psychological work concerning "cognitive dissonance": projections concerning average productivity of particular groups tend to be justified according to beliefs and previous (or current) experience. He then discusses the possibility of selfufilling prophecies, later explored in the literature (Lundberg, Starz, 1983). He formalizes (what he calls later) a "model

[19] Edmund Phelps developped a similar theory, based on "an exact statistical model", first exposed in *Inflation policy and unemployment Theory* (Phelps, 1972: 24-27). The term "statistical discrimination" was first use by Phelps (Arrow, 1976: 235).

[20] Phelps' view is similar on this point. Personal characteristics are taken "as a proxy for relevant data not sampled". This belief may come from "employer's previous statistical experience" or "might stem from prevailing sociological beliefs that blacks and women grow up disadvantaged due to racial hostility or at least prejudices toward them in the society (in which case the discrimination is self-perpetuating)" (Phelps, 1972: 659).

of perceptual equilibrium": "[r]ational adaptation by women to employer attitudes justifies employer attitudes to some extent" (Arrow, 1976: 234). This rational adaptation to lower economic opportunity is based on the hypothesis that "workers are being treated as groups and not as individuals[21]" (Arrow, 1976: 234).

One of the characteristics of Arrow's model is its coherence with neoclassical framework and rational choice theory while relaxing major hypothesis. He also proposes another explanation than racism of crude prejudice to explain discriminatory behaviors[22]. What is relevant here is that the modification of standard framework is both required by the nature of the subject and he need for policy recommendation.

SCHELLING'S SEGREGATION MODEL

In the late 1960s, in four major contributions (1969; 1971a; 1971b; 1972), Schelling developped three models of residential segregation and tipping[23]. His main concern is to explain how can segregation in the United States rise from "discriminatory individual behavior" (Schelling, 2006: 254). According to Schelling, this kind of behavior is induced by

> "an awareness, concious or unconcious, of sex or age or religion or color or whatever the basis of segregation is, an awareness that influences decisions on where to live, whom to sit by, what occupation to join or to avoid, whom to play with, or whom to talk" (*ibidem*).

Collectively, this kind of behavior can lead to residential segregation. Hence, Schelling's main concern is to look at the process leading to a segregated area:

> "To understand what kinds of segregation or integration may result from individual choice, we have to look at the processes by which various mixture and separations are brought about. We have to look at the incentives and the behavior that the incentives motivate, and particularly the way that different individuals comprising the society impinge on each other's choices and react to each other's presence" (Schelling, *ibid.*: 259).

The first and "only" requirement of the models is a twofold population (blacks and whites, pluses and zeros, etc.). The distinction between them relies on the definition of neighborhood.

In the "Spatial proximity model", each individual defines his own neighoborhood, i.e. "there are no objective neighborhood boundaries; everybody defines his neighborhood by reference to his own location" (*ibid.,* 260). Individuals evaluate the color ratio of their own neighborhood. If

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[21] By exposing (what he calls later) a "model of perceptual equilibrium": "[r]ational adaptation by women to employer attitudes justifies employer attitudes to some extent" (Arrow, &çè6, 1976: 234). This rational adaptation to lower economic opportunity is based on the hypothesis that "workers are being treated as groups and not as individuals21" (Arrow, 1976: 234).

[22] Phelps is more definitive on this point whereas Arrow is still convinced that racism exists in crude forms. "What has been called racism – similar remarks apply to sexism – can be hypothesized to be the consequence of "scientific management" in the impersonal pursuit of maximum profit, not racial hostility or intolerance" (Phelps, 1972: 26).

[23] "'Tipping' is said to occur when a recognizable new minority enters a neighborhood in sufficient numbers to cause the earlier residents to begin evacuating" (Schelling, 2006: 302).

this ratio fits their requirement they stay, if not, they move to another neighborhood. Schelling assumes a rule of motion. From the left to the right, insatisfied individuals move to the nearest place where they can be satisfied with the color ratio of their neighborhood. They continue to move as long as they are not satisfied. Consequently, the equilibrium is reached when everybody is satisfied with his own neighborhood. Schelling first experiments this process with individuals placed on a line (cf. figure 1). Then he changes the distribution area with individuals placed within a square like a checkerboard (cf. figure 7). In each case he positions the two types of individuals randomly (blacks and whites are represented by "pluses" and "zeros"). He compares the possible outcomes with different initial distributions of "pluses" and "zeros", with equal and different numbers of "pluses" and "zeros", with different rules of motion, with different sizes of neighborhood, and with different preference regarding color ratios (for instance, one of the two types of population is endowed with more segregationnist preferences).

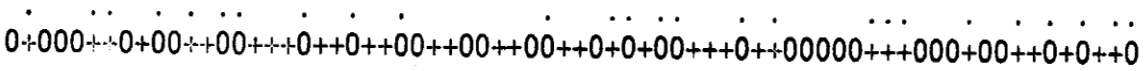

Figure 1

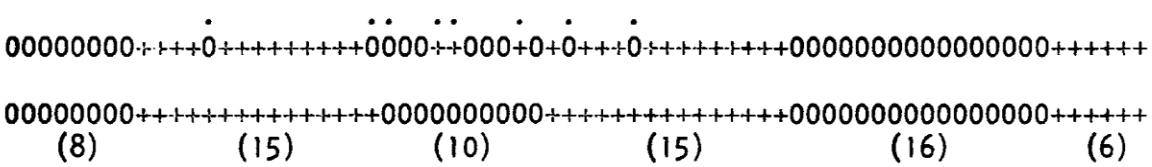

Figure 2

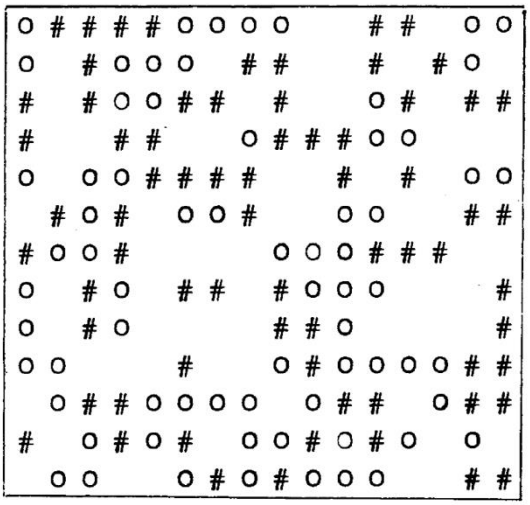

Figure 7

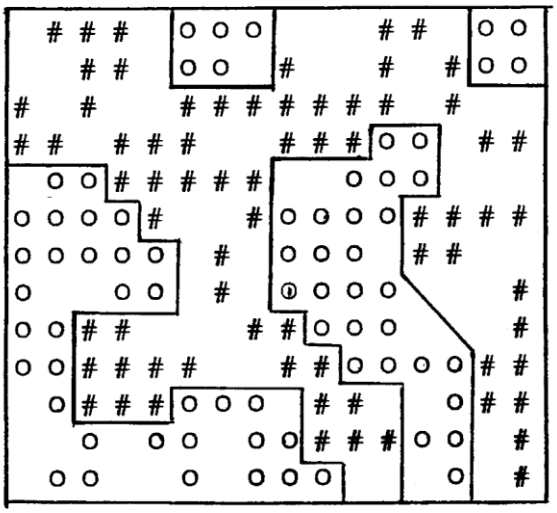

Figure 10

These figures (titled figure 1, 2 and 7 and 10) are taken from Schelling's RAND Memorandum RM-6014-RC (1969).

The conclusion is straightforward. A general pattern appears: the resulting distributions of pluses and zeros show a segregated area (cf. figures 2 and 10). This phenomenon is quite robust

respectively to different initial conditions, concerning either the individual, or the environnement[24]. There are always clusters of 'like-colors'[25] even if variations of the initial conditions have some effects on the resulting distribution. For instance, with individuals in line, reducing the size of the neighorhood induce more clusters of 'like-color' (*ibid;*, 265). At the opposite, "enlarging the area within which a person counts his neighbors attenuates the tendency to segregate, at least for moderate demands and near-equal numbers of the two colors" (*ibid.*, 281). If the initial number of the two populations is not equal, the minority tend to be less clustered than the majority (*ibid.*, 266-67). Even changing the rule of motion can lead to others distributions (265), nertheless as Schelling asserts that "the order of moves makes little difference" (*ibid.*, 265). Now, with individuals positionned within a square, changing the "intensity of demand for like Neighbors" (*ibid.*, 274) induce according to his experiments three results: (i) the number of initial discontent raises (*Ibidem.*) ; (ii) "it increases the like-color density that results from each movement" (*Ibidem.*) ; (iii) "the greater the demands the more movement is induced by those that move on the part of those that were originally content" (*Ibidem.*). When there are unequal numbers of pluses and zeros, but equal demands of like-color in their neighborhood, the minority tends to constitute "larger cluster" (*ibid.*, 277). Furthermore in this case "the minority tends to accumulate in denser neighborhood than the majority" (*ibid.*, 280). And "with equal numbers of the two colors but different demands, the more demanding color ended with a higher ratio of like to opposite neighbors" (*ibid.,* 279).

In the "bounded neighborhood model", the definition of neighorhoood changes "instead of everyone's defining his neighborhood by reference to his own location, there is a common definition of the neighborhood and its boundaries" (*ibid.*, 284). Individuals are either 'in' or 'out' of a given neighborhood (*ibid.,* 260). Each individual in order to move either in or out, evaluates "the color ratio within the whole neighborhood" (*ibidem*). Each population is represented by a curve symbolizing the cumulative frequency distributions of the individual's tolerance[26]. This tolerance level is the upper limit of the color ratio an individual can tolerate. Beyond the tolerance threshold, the individual is dissatisfied, and either decides to move out or to stays outside the neighborhood. The purpose of this model is to experiment "what distribution of preferences or tolerances among the individuals of a given color may be compatible with dynamically stable mixture, what effect the initial conditions and the dynamics of movement will have on the outcome, and what kinds of numerical constraints may alter the results" (*ibid.*, 260). Again Schelling tests different initial conditions: with equal and unequal numbers of blacks and whites, and with different frequency distribution of individual's tolerance (*ibid.*, 285). The dynamic here has much more importance than previously. Even if initial conditions have an impact on the outcome, as Schelling claims "it is the dynamics of motion, though, that determine what color mix will ultimately occupy the area" (*ibid.*, 288).

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[24] When conclusions of models are *robust* under variations of explanatory variables, Gibbard and Varian (1978: 673-675) suggest that these models are a good "caricature" of reality, *examplifying* or *isolating* some features of that reality. They help us to understand the real world.

[25] See Aydinonat (2007: 441) for a presentation of the different theoretical and empirical tests made on Schelling's checkerboard model. Except for Bruch and Mare (2003, 2004) they all emphasizes that Schelling's results hold. Sugden (2000, 2009) too, recognizes that Schelling's results are robust, even if he adopts a very crictical assessment of Schelling's checkerboard model.

[26] More precisely: "the cumulative form measures, for any number of anticipated attendance, the number of poeple for whom that number is large enough" (Schelling, 2006 [1978]: 103).

A pervasive characteristic in the different configurations tested is that there are several possible outcomes or equilibria. Two types of equilibria generally compete: an equilibrium of all blacks or all whites, and a mixed equilibrium. Each intersection of the two populations' curves is a potential equilibrium, in which blacks and white can live together. Nevertheless, this kind of equilibrium is very sensitive to perturbations, and tightly relies on both the inital conditions and the process of interactions: "the occurrence of several mixed-color stable equilibria is usually sensitive, though, to smalll changes in the shapes and the positions of the curves. It is the extreme one-color equilibria that tend to be least disturbed by shifts in the tolerance schedules or changes in the aggregate numbers; and the occurrence of a single mixed stable equilibrium may be fairly immune to shifts in the curves" (*ibid.*, 296). For instance, in a situation where there are two possible equilibria (either all blacks or all whites), "which of the two will occur depends on how the process starts, and perhaps, the relative speeds of white and black movement. If initially one color predominates it will move toward complete occupancy. If initially some of both are present, in "statistically viable" numbers, relative speeds of black and white entry will determine which eventually becomes content with the ratio, reverses movement, and occupies the territory" (*ibid.,* 289). Now, if initial conditions allow a mixed equilibirum, "the difficulty is that any such mixture attracts outsiders, more of one color or both colors, eventually more of just one color, so that one color begins to dominate numerically. A few individuals of the opposite color then leave; as they do, they further reduce the numerical status of those of their own color who stay behind. A few more are dissatisfied, and they leave; the minority becomes even smaller, and cumulatively the process causes evacuation of them all" (*Ibidem.*). In other words, if the initial size of both populations is below the two curves, a mixture of blacks and whites could be an equilibirum.

Finally Schelling investigates what is called the "tipping" phenomenon, which is merely an application of his "bounded neighborhood model" – since tipping occurs when the entrance of a minority induces the evacuation of the former residents. Therefore, it is exactly a case that fits to the previous model, even if it is more complexe than the situations he tests in his "bounded neighborhood model". For him, "the process, if it occurs, is too complex be be treated comprehensively here. But evidently analysis of "tipping" phenomena wherever it occurs [...] and whether it involves black and whites, men and women [...], requires explicit attention to the dynamic relationship between individual behavior and collective results. Even to recognize it when it occurs requires knowing what it would look like in relation to the differential motives or décision rules of individuals" (*ibid.*, 308-9)[27].

In the different tests above mentionned, Schelling always postulates "segregationist preferences", but he affirms that the same experiments could be done with "integrationist preferences". It only implies to "postulate a preference for mixed living and simply reinterpret the same schedules of tolerance to denote the upper limits to the ratios at which people's preference for integrated residence is outweighed by their extreme minority status" (Schelling, 2006 [1978]: 165)[28]. Accordingly, for him, the same models can be applied to study the process

[27] For a detailed version of the tipping phenomenon, see Schelling in *Racial Discrimination in Economic Life* (Ed. by Pascal; 1972).

[28] In other words, stating "integrationist preferences" means to "assume that members of both colors have certain minimum demands for neighbors of like color, but no maximum demands" (Schelling, 2006: 282).

of interactions, and the same same kind of conlusions can be drawn: "[t]he same model fits both interpretations. The results are as pertinent to the study of preferences for integration as to the study of preferences for separation" (*Ibidem.*), "the same results flow from the two alternative hypotheses" (*Ibidem.*). It is merely the same kind of dynamic phenomenon.

To sum up the two types of models presented by Schelling are based on a set of variables with respect to individuals' decisions and their environment. In addition they encompass some variations of them, allowing different complex dynamics. Schelling experimented some of these variations, but much more could have be tested since "there is a wide variety of shapes of tolerance schedules that we could experiment with" (*ibid.*, 164). In fact, his models are conceived like experiments. Schelling (2006: 261) claims that the results are "experimental". Besides, his models present several limits. For instance, Schelling postulates that information is perfect. Every individual knows the color ratio within the neighborhood at the moment he makes his choice (*ibid.,* 285). Individuals do not anticipate the phenomenon of movement; they do not know the intentions of others (Schelling, 2006 [1978]: 156). If anticipations were allowed the segregation phenomenon would be even self-aggravated (Schelling, 2006: 307). For example, in the "bounded neighborhood model" postulating that it is absolute or relative numbers that count make a difference. As he claims, "one difference is that if absolute numbers are what matter, and if the influence is positive so that the more who do it the more will wish to, the activity is likely to be self-sustaining in a large group but not in a small one" (Schelling, 2006 [1978]: 109). For these reasons, Schelling's models are incomplete. They do not translate all the possible individuals' incentives and processes leading collectively to residential Segregation.

Hence, Schelling (2006: 268) recognizes that "this is too abstract and artificial to be a motion picture of whites and blacks [...] but it is suggestive of a segregating process and illustrates some of the dynamics that could be present in individually motivated segregation". The need to abstract is partly due to the fact that "there are many different incentives or criteria by which blacks and whites [...] become separated" (Schelling, 2006 [1978]: 142). He acknowledges that in reality "it is not easy to tell from the aggregate phenomenon just what the motives are behind the individual decisions, or how strong they are [...] the dynamics are not always transparent. There are chain reactions, exaggerated perceptions, lagged responses, speculation on the future, and organized efforts that may succeed or fail" (*ibid.*, 146). This complexity is explained phenomenon studied, the kind of "poeple responding to an environment that consists of people who are responding to each other. As people respond they change the environments of the people they associate with, and cause further responses. Everybody's presence affects, if only slightly, the environment of everybody else" (*ibid.*, 169). Accordingly these situations are too complexes (i) to accurately characterize all possible explanatory variables, and (ii) to predict the outcomes of these individuals' interactions – or interdependent decisions.

These two contributions amend the neoclassical theory on racial and segregation issues and rely on the same methodological conception of economics as a science.

THE METHODOLOGICAL NECESSITY TO MODIFY STANDARD HYPOTHESIS OF NEOCLASSICAL MICROECONOMICS

The two contributions are (relatively neglected in historiography) game theory's applications to social issues. Schelling's models of segregation are a clear methodological and analytical break with standard game theory. The use of game theory is rather implicit in Arrow's model and was probably influenced by his encounter with Harsanyi and a reapropriation of the concept of "unobservables types[29]". It nevertheless breaks with the previous approach to discrimination.

To understand how Schelling's models of residential segregation necessitate some modifications of neoclassical microeconomics, we should compare how they differ from what was standard game theory[30]. First, the dynamics of interactions matters and influences outcomes, at the opposite of standard game theory. For instance, Schelling (1984: 239) underlines how game theory "is concerned with outcomes, not intermediate processes". In standard game theory the outcome is predictible – since it directly relies on individuals' preferences. To the contrary, in the dynamic models of segregation there are different possible equilibria that can be drawned from the same intial conditions. Accordingly, it is difficult, even impossible to predict which one of the competing equilibria will be reached as the outcome primarily relies on the dynamic.

In Arrow's work, this idea translates first in the break from Becker's taste-based explanation of discrimination. If he asserts that a part of discrimination is clearly due to preferences for discrimination as an expression of crude racism (Arrow, 1971, 1972), he progressively moves towards his statistical theory, insisting on the non-intentional aspect of discrimination. When insisting on the possibility of self-fulfilling prophecies, Arrow explicitly recognizes the impact of social dynamics and history over outcomes – i.e. present and future discrimination. Discrimination is not simply the result of preference but also the result of social interactions that make emerge unvoluntary outcomes. The mechanism is based on the existence of costly informations.

Second, Schelling's conception of equilbrium is extremely different from standard game theory for several reasons. Equilibria in the dynamic models of segregation are not (i) optimal, and (ii) mere agregation of individuals' preferences (since the dynamic of interactions count). Nevertheless, for Schelling (2006 [1978]: 176), his models are "an example of "equilibrium analysis"". He emphasizes how in cases of social interactions "there is no presumption that the self-serving behavior of individuals should usually lead to collectively satisfactory results" (*ibid.*, 25); "an equilibrium division is not likely to have any optimal properties" (*ibid.*, 182). Furthermore equilibria are more interpreted in terms of stable pattern of behavior. His idea is to show how different configurations can lead to regular general patterns which are presently segregated area. And, again, instead of having a static conception of stability like in game theory,

[29] This hypothesis was suggested by Ali Khan during a discussion at the 2013 Summer Institute for the Preservation of Economic Thought held in the University of Richmond.

[30] Besides Schelling argues in the preface of *Micromotives and Macrobehavior* (2006: 4) that dynamic models of segregation are *n*-players games. He says: "I do appreciate that it is easily construed as multi-person game theory".

there is a dynamic conception of it (Ayson, 2004: 186)[31]. Thus, the conception of the link between individual and collective in Schelling's models, in which social patterns are not the simple summation of individual characteristics[32] – i.e. individual preferences – differs from standard game theory.

In the same perspective, Arrow's conception of equilibrium is different from Becker's one. The central contribution of Arrow is the incorporation of information in a general equilibrium model of discrimination. It radically changes the informational basis of the standard model in the analytical approach to Labor Economics at that time, essentially developed at Chicago (Kaufman, 2006). This depart from partial equilibrium model (Becker's) is also an illustration of the existence of a sub-optimal situation. Discrimination is no more a transitional state that market forces will make disappear, but an empirically consistent and stable phenomena, reinforced by statistical discrimination and self-fulfilling prophecies. Equilibrium here is not optimal. In Arrow's perspective, there is an explicit account of emergence that contradicts standard aggregation argumentation. Even if Arrow's commitment to methodological individualism is pregnant, he recognizes the necessity of explaining unintended phenomenon via social interaction outcomes.
Third, because individuals' decisions are based on the environment they contribute to modify by acting, rational choice theory cannot be a tool for individuals' decisions. Indeed, Schelling asserts that "the person has a *preference* about [a] statistic, and the person *contributes* something to that statistics" (2006 [1978]: 186). Consequently, the hypothesis of "context-independency" falls. The standard conception of individual rationality in terms of consistency of choices cannot prevail. Besides, as Schelling claims (2006: 215) standard game theory is "a deductive theory about the conditions that [players'] decisions would have to meet in order to be considered "rational", "consistent", or "noncontradictory"". Here again we understand the shift between game theory and the models of segregation. Schelling's aim is to show how interdependent individuals acting intentionaly – and furthermore rationally according to their preferences – can cause unintentional consequences. Schelling (1980 [1960], 1984, 2006) militates for the importance of postulating rational agents even if he has a broad conception of rationality. We understand clearly that he adopts a much more realistic approach than game theory. He does not search for conditions allowing individuals to make "rational", "consistent" or "non-contradictory"" choices (*Ibidem.*), but aims at showing how rational individuals can cause an unintended phenomenon.

In Arrow's model of statistical discrimination, economic agents are rational. The objective of his argumentation is to justify the rationality of discriminatory behavior, which is *a priori* an irrational behavior essentially because it is founded on non-economically relevant criteria. There is no need for additional hypothesis on taste and preference to explain discrimination. As in Schelling's models of segregation, even with an extended version of rational behavior –

[31] For a discussion about the pervasiveness of Schelling's concept of stability and its evolutions throughout his work, see Ayson (2004)

[32] For Schelling (2006 [1978]: 14) segregation is about the kind of situations "[...] that usually don't permit any simple summation or extrapolation to the aggregates" since the "aggregate results [...] sometimes have no recognizable counterpart at the level of the individual" (Schelling, 2006: 256).

more context dependent in a less perfect environment – Arrow maintains the necessity of rational agents.

How the concepts and mechanism Arrow and Schelling produced have modified the type of results and policy recommendations. What does it tell us on their respective conceptions of the role of science? This section will first insist on Schelling's conception of modelling as a tool for action and second on Arrow's prayer to go beyond market-based explaination, both perspectives aiming at producing credible policy recommendations.

ABSTRACT MODELLING AND SCIENCE FOR ACTION

Schelling's models are rooted both on *idealization* and *abstraction*[33]. Since Schelling eliminates some variables (with respect to individual choices) he considers to be relevant in the explanation of residential segregation, he states on a *ceteris neglectis* clause (Rol, 2008: 70)[34] which is an instrument of idealization (see Rol, 2008), or of "vertical isolation" (Mäki, 1992, 1993, 1994)[35]. Two statements allow us to assert that Schelling's models are abstract. His representations of neighborhoods are highly simplified (Sugden, 2000, 2009; Aydinonat, 2007), and, again, he only focuses on individual decisions and does not incorporate other factors (Aydinonat, 2007). For this last reason Schelling recognizes that his models are highly abstract (Schelling, 2006: 268). Thus, he offers what Aydinonat (2007) calls a "partial potential (theoretical) explanation".

Accordingly, it weakens the possible actions in order to prevent from residential segregation. Acting either on the process or on the initial condition, does not warrant avoiding segregation. Moreover reality is complexe and the fact that the *underlying mechanism* leading to segregation identified in the models seems operative, is not a proof.

Nevertheless developping models like his is helpful (2006 [1978]: 182). Schelling explicitely justifies his models' usefulness for two reasons. First the problem investigated matters. As developped in the first part of the paper, poverty and discrimination became of major concern in the United States meanwhile Schelling writes. Besides Schelling (2006: 302-03) grounds on empirical researchs of Grodzins (1957), Duncan and Duncan (1957), Mayer (1960), which testify the generalization of residential segregation and tipping in American cities. The second reason, which is explicitely Schelling's primary concern, implies that:

> "The systematic consequences of individual behaviors must not be so transparent that we can treat the aggregate as though it were a collective individual, and do without the model [...]. In such cases, studies of aggregates will not permit inferences about individual motives, without the help of a mediating model. And

[33] On this point we disagree with Sugden (2000, 2009). In his analysis of Schelling's models, Sugden claims that they are neither idealized nor abstract worlds.

[34] More peculiarly, the *ceteris neglectis* clause means that some explanatory variables in a phenomenon are excluded from its explanation (Rol, 2008: 70) because the relation between the variables considered is sufficiently invariant to erase other possible causal factors (*ibid.*, 70-71).

[35] Again, Sugden (2009) does not recognize "vertical isolation" in Schelling's models.

> knowledge of individual behaviors will not by itself lead either to predictions of aggregate outcomes or to be paid to the macro phenomena that are the object of policy" (Schelling, 2006 [1978]: 182-83).

Because the dynamic of individual interactions matter, having an insight into residential segregation requires modelization. However, the relationship between real phenomena and models is not univocal for Schelling. To understand this assertion, we stress how Schelling defines a model and then its functions.

A clear-cut definition of models is given in the following quotation:

> "By "model" I mean either two things. A model can be a precise and economical statement of a set of relationships that are sufficient to produce the phenomenon in question. Or, a model can be an actual biological, mechanical, or social system that embodies the relationships in an especially transparent way, producing the phenomenon as an obvious consequence of those relationships" (*ibid.,* 87).

Schelling's models can potentially belong to the two categories he identifies. Nevertheless, in some relevant aspects we can argue that the latter is convenient to approximate his models. In this case, we can argue that Schelling's vision of modelization coincide with those of Mc Closkey (1983), Gibbard and Varian (1978) and Hausman (1992). This statement, again contradicts with Sugden's position[36]. Accordingly Schelling's methodology is both justifiable and relevant in the field of economics (Hausman, 1992)[37].

Now, considering this definition, Schelling purports two functions to models. Either they are used as "basic models", that is, "approximations that can be elaborated to simulate with higher fidelity the real situations we want to examine" (*ibid.,* 183) or they "constitute a "starting set" on which better approximations can be built, they illustrate the kind of analysis that is needed, some of the phenomena to be anticipated, and some of the questions worth asking" (*Ibidem.*).

We suggest in this paper, that Schelling sways between these two functions of models. We highlight for the moment that his models, as experiments, are basically a "starting set" to have an insight into the *underlying mechanism* of residential segregation. Though, Schelling intends to build a "basic model". Moreover, his models are rooted on a "basic model" which can translate a wide range of socio-economic phenomena (Schelling, 2006: chap. 17)[38], that is, which can be easily mannipulated to be as close as possible to reality. A social mechanism is defined as follow:

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[36] More peculiarly, for McCloskey (1983) models need only to be like the real world in "some significant respect". Along those lines, Gibbard and Varian (1978) explain that the purpose of models is to "illuminate" certain aspects of the real world by exaggerating or isolating some of its features.

[37] See, among others, Sugden (2000, 2009), Aydinonat (2007) and Rol (2008) for a discussion on the similarities and differences among the authors mentioned with respect to the epistemic and methodological status of models in economics, their link with reality and theory.

[38] Schelling refers to Marchetti, Meyer and Ausubel (1996:25) who assert that the « logistic curve » can model lots of population dynamics. Residential segregation exhibits a dynamic of populations. In addition in *Micromotives and Macrobehavior* (2006 [1978]) Schelling applies the "logistic curve" to a wide range of populations dynamics.

> "I propose [...] that a social mechanism is a plausible hypothesis, or set of plausible hypotheses, that could be the explanation of some social phenomenon, the explanation being in terms of interactions between individuals and other individuals, or between individuals and some social aggregate" (Schelling, 2006: 236)[39].

In other words, a social mechanism is a kind *stylized fact*. It purports to mimic and then to explain a real social phenomenon – like presently residential segregation is. The difficulty to clearly justify that such a mechanism is *the* explanation stems from the fact that no ambiguity should remain concerning its plausibility (*ibid.,* 236-37). In Sugden's words (2000, 2009), the social mechanism must be a *credible* hypothesis. Even so, we argue that Schelling's models have an epistemological status more complexe than Sugden's "credible worlds"[40] (2000, 2009).

Schelling's model could fit with this definition, however it does not account Schelling's purpose and Schelling's own vision of models. Besides, we will stress in the remainder of this paper that *in fine*, Schelling's ambition is to elaborate *a theory* to account for segregation in its overall. It partly means for him requiring to a set a models sufficiently accurate to explain each aspect of such phenomenon but at the same time wide enough to be applied to other social phenomena. In view of that, Schelling is close to Giere's conception of theories (1988).

We will show how this vision underscores a complexe relationship between models, theories and political action especially because the investigation (explanation and the eventual issuing prediction) is about a *social phenomenon*. In fact, because the mechanism underlying Schelling's model is a social mechanism, the dichotomization between positivism and normativism tends to erase. It explains why Schelling's models are so disputable in the afferent literature (Aydinonat, 2007; Innocenti, 2007; Rivzi, 2007; Sugden, 2000, 2009).

Actually, what we have to keep in mind is the fact that models are merely tools for Schelling. Whatever the step to which our scientific knowledge of a socio-economic phenomenon has progressed: "a model is a tool; to be useful, it has to be adjustable or to consist of a set from which we can select the appropriate member" (2006 [1978]: 90). In this perspective, we can assert that Schelling shares the same vision of models as Morgan and Morrison (1999), Morgan (1999) and Cartwright (1998, 1999, 2000). The need to focus his interest either on basic models or on more peculiar models depends on the existing amount of scientific knowledge. For instance, "after a certain amount of heuristic experiments with building blocks, it becomes more productive to identify the actual characteristics of the phenomena we want to study, rather than to explore general properties" (*ibid.,* 183-84).

How to conciliate Schelling's conception of modelization in economics, economic theories and public intervention?

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[39] In *Strategies of Commitment* (2006: 236) Schelling ascribes this definition to Hëdstrom and Swedberg in the introduction of *Social mechanisms: An Analytical Approach to Social Theory* (1998).

[40] [A] credible world may be constructed around general empirical regularities – we might say, empirical laws – that are merely postulated. For all we know, these regularities may not be part of how the world really works. All that is required is that, in the current state of knowledge, they are credible *candidates* for truth" (Sugden, 2009: 18).

Because the dynamic of interactions count and because individual decisions are interdependent, the aggregate pattern is not directly explained by individual decisions[41]. Consequently, there is for economists a *black box*. Schelling attempts to have an insight into this black boxe and he justifies it with three other reasons.

> "I want to advert the discussion of what one can do with social mechanisms that one cannot do whith "mere correlations", or, perhaps more aptly, "curve fitting". A distinction is often made between *prediction* as the goal of science (and as the "test" of a theory), and *explanation* (i.e., a better understanding of what is going on, a more satisfying place to stop). I think there are at least three other advantages of having a grasp of the social mechanism that lies behind the regularity in behavior" (2006: 239-40).

The first avantage implies that: "knowing about the mechanism lets us know what to look for [...] to explain the differences and verify the mechanism itself" (*ibid.*, 240). The second advantage, presently of particular interest, involves "the possibility of intervention" (*ibid.*, 240). Even if Schelling assumes that models are "a metaphor for social mechanism that display the same underlying generative process, there may be varieties of interventions to consider once we have the underlying mechanism and some appreciation of the most influential parameters" (2006: 240). The third advantage entails "that once we see the mechanism, how it works, and maybe its mathematical shape, we have a kind of template that may fit other phenomena" (2006: 240).

Schelling emphasizes the usual dichotomie between prediction and explanation. The difficulty in residential segregation – again, because it is about a social phenomenon –, is to draw the frontier between theory and reality. And in fact, we argue that this line blurred in Schelling's work:

> "The logistic shape will necessarily be only an approximation of the empirical data, and there may be other differential equations that can generate approximations to the data. The *fact* of a good fit does not alone confirm the conjectured underlying mechanism, and there may be a family of mechanisms of which the conjectured underlying mechanisms" (2006: 239).

That is why Schelling explains that:

[41] "Social mechanism could be contrasted with theories, laws, correlations, and black boxes. There is near consensus on a hierarchy that has "mere" correlations at the bottom, with laws higher up. Laws that are black boxes (*i.e.*, opaque as to how they work) are, even if fully reliable like the law of gravity, less helpful than laws that work transparently. Theories have less status than laws if the laws are well established and the theories not; theories built on established laws, like the theory of planetary motion, are the summit. A pervasive question for social phenomena is the role, or the exclusive role, of "methodological individualism", the notion that the ultimate analysis is a rational, or at least a purposive, individual. Some believe that any social phenomenon that cannot be reduced to the behavior (choices) of individuals is a black box and therefore unsatisfactory. There is some notion that what is inside a black box must be social mechanism, or several social mechanisms" (Schelling, 2006 : 235).

> "On the relation of social mechanisms to theories, I propose that a theory may comprise many social mechanisms, but also that a social mechanism may comprise many theories" (Schelling, 2006: 235).

We found in this quotation the third purpose presented above. So theorizing requires formalization and eventually mathematization. To frame a theory, the solution is accordingly: modelling, testing, modelling again, testing, then abtracting – *i.e.* generalizing –, theorizing, etc. In a way Schelling's models have a certain independency from both reality and theory. Such recursive feedbacks between reality, models and theory, attempt to assert in some way or another, truthfulness [42] ; and accordingly, well-specified recommandations for public interventions. That is why Schelling's models should not be judge independently of its overall project. It partly explains why we disagree with Sugden (2000, 2009).

We would like to point out that Schelling's methodology is largely explained by his starting point: game theory.

> "Game theorists, and social scientists who deal with the subject of which game theory is the mathematical frontier, are out of touch with each other in a way that, say, economists and economic theorists are not, for a number of reasons including, often, the absence of a sufficient common interest to keep them in touch. The mathematical barrier is not the only one. There is an unusual dichotomy between the subtle, elegant, mathematical accomplishments of game theorists and the interest of social scientists" (Schelling, 1984: 241).

Highly mathematical accounts of game theory entails important limits for social scientists, that is, for political action but "how much a limitation this is depends, as in any theory, on whether an abstract, somewhat perfectionist bench mark can be helpful, and whether we can keep in mind that the result is only an abstract and perfectionist bench mark" (Schelling, 1984: 240). Therefore, Schelling who developped and theoretized the concept of interdependence of decisions and actions within standard game theory, pulls out this concept and incorporate it in his dynamic models of segregation and tipping. He just grasped a concept of game theory and apply it to his field of research: residential segregation. Indeed, only game theoretic rudiments are worthiness for him[43].

If analists, economists or social scientists focus on the abstract and mathematical aspects of game theory, the ultimate risk is to forget that they remain in an abstract theory, which is necessarily distinct from the real world.

> "Game theory run the same danger as any theory in being too abstract, even in the propensity of theorist to forget, when they try to predict or to prescribe, that all their theory was based on some abstract premises whose relevance needs to be confirmed" (Schelling, 1984: 240).

[42] "[A] 'model', in order to make us learn about the world and about a theory, must have a partial independence from both the world and this theory" (Morrison and Morgan, 1999: 81).

[43] "Game theory is more than a "theory", more than a set of theorems and solutions; it is a framework for analysis. And for a social scientist the framework can be useful in the developmnent of his own theory" (Schelling, 1984: 221-22).

Considering Schelling's sharp critic of a too mathematical and abstract account of game theory in order to intervene, we understand his specific methodology in the dynamic models of segregation. Indeed, they remain idealized and abstract. Nevertheless, they are just a step in the process described by Schelling[44] and leading to recommandations for policymaking. Besides, idealization and abstraction are both justifiable (Hausman, 1992) and necessary (Mäki, 1992, 1994, 1996) in social sciences and a fortiori in economics. As Rol (2008: 86) argues: "[t]o bear relevance for policy recommendations, an economic theorem must be weak enough to be true, and strong enough to have a bite".

> "If the world we want to intervene in is full of 'disturbances' and if we have no determinate or precise clauses to deal with these, we feel the lack of sufficient information to explain what makes the real world so different from our models. We can only hope there is some theory capable of dealing with the multiplicity of phenomena that disturb our simpler theoretically established regularities. This additional theory may already exist as part of another discipline, so that it does not make part of the existing background knowledge of the economist. It may also be completely absent. It seems that interfield theorizing is needed to deal with policy relevant phenomena that escape our explanatory hypotheses and their clauses that serve to hedge them" (*ibid.*, 90-91).

It is exactly what Schelling propounds in his dynamic models of segregation, and it perfectly matches with his vision of modelization and theorization we emphasized in this paper.

BEYOND MARKET-BASED EXPLANATIONS?

As Schelling (2006 [1978]: 35) claims, some social phenomena like residential segregation or tipping, are "in the borderline of "market arrangements"". Arrow and Schelling draw their works on this statement. They both militate for a "comprehensive treatment of socioeconomic differentials between whites and nonwhites" (Schelling, 2006: 309)[45]. Nevertheless, they also acknowledge that racial discrimination is an economic phenomenon, though its scope bypasses economics frontiers – and even more neoclassical economics frontiers. They ground their work on the use of economic tools, and at the same time, are open to other social sciences like sociology, psychology, and, as for Schelling, to communication theory and theories of group processes (see Ayson, 2004, chapter 6).

Schelling draws his models of residential segregation on a "mechanism that translates *unorganized individual behavior* into collective results" (2006: 256). Though, residential segregation has much more possible causes generally intertwined, yielding to more complex dynamics than Schelling's "abstract exploration of some of the quantitative dynamics of segregating behavior" (*ibid.*, 260).

In reality:

[44] We can draw a parallel between Schelling and Holland (1995) on this point.
[45] Schelling (1969: 3 ; 2006: 309) recommands Pascal's book *Racial Discrimination in Economic Life* (1972), for such approach.

> "Some segregation results from the practice of organization; some is deliberately organized; and some results from the interplay of individuals that discrimininates. Some of it results from specialized communication systems, like different languages. And some segregation is a corollary of other modes of segregation." (*ibid.*, 253).

Accordingly:

> "It is not easy [...] to draw the lines separating « individually motivated » segregation, the more organized kind, and the economically induced kind [...]. The economically induced separation is also intermixed with discrimination. To choose a neighborhood is to choose neighbors. To pick a neighborhood with good schools is to pick a neighborhood of poeple who appreciate schools [...]. Poeple may furthermore rely, even in making economic choices, on information that is itself color-discriminating; believing that darker-skinned poeple are on the average poorer than lighter-skinned, one may consciously or unconsciously rely on color as an index of poverty" (*ibid.*, 255-56).

For these reasons it is hard to figure out the *real* explanations of segregation, but even more to isolate one *real* explanatory factor. Three consequences follow from this state of affairs.

First, it appeals for a *beyond market comprehension* of the factors leading to residential segregation. Residential segregation is not only grounded onto economic differentials. It necessitates investigating this phenomenon through other frameworks in social science.

Second, Schelling has isolated only one possible cause: individual behaviors; but even the explanatory variables of individual behaviors are limited. Consequently, Schelling is extremely cautious in his recommandation in terms of Policymaking. He lists some of the possible actions to avoid complete segregated area, but at the same time he clearly emphasizes how they may be inoperative[46].

Accordingly, the eventual policies and operational instruments are considerably limited in their power. In the following example, Schelling highlights how a possible intervention might prove to be useless in practice:

> "Economic segregation might statistically explain some initial degree of segregation; if that degree were enough to cause color-consciouness, a superstructure of pure discrimination could complete the job. Eliminating the economic differentials entirely might not cause the collapse of the segregated system that it had already generated" (*ibid.*, 256).

Since mixed equilibria compete with "extreme mono-colored stable equilibria" (*ibid.,* 301), "getting "over the hump" from one stable aquilibrium to another often requires either a large perturbation or concerted action. Acting in concert, people can achieve an alternative stable equilibrium" (*ibid.,* 302). Thus, in case in which residential segregation is explained by

[46] "Limiting the ratio of black to white or white to black that may be present, by restricting the further entry of the color that exceeds the limiting ratio, may or may not provide a stable equilibrium according to the shapes and positions of the two curves. Furthermore, limiting the ratio may exclude one or more stable equilibria and thus bring about the particular color combination corresponding to a particular stable equilibrium" (ibid., 298).

individual decisions and behaviors, and only in this case, concerted actions can prevent from complete segregation and can be more efficient than regulatory policies in terms of quotas.

Even if Schelling gives very few advises for policy recommandations, it does not mean that his models are not conceived for acting upon segregation problems. We will demonstrate how his models fit with a conception of *science for action*. Recognizing the limits of his models and their conclusions does not imply for Schelling their worthlessness. In fact, like Arrow, he merely tackles the economic imperialism by showing (i) how economics and economic tools are limited to formalize social phenomena and (ii) how theories and models as mere idealization and abstraction of reality should prevent economists to have faith in the omnipotence of their science[47]. Schelling's conception of *science for action* requires for him the awareness of (i) the complexity of social phenomena and more generally of social reality, and (ii) the limits of the conclusions of economic theories and models. It implies, accordingly, to be cautious with policy recommandations only based on theories and models' conclusions, especially when they deal with social phenomena.

Both authors have the same use of abstract model and the same definition of science. Arrow also emphasizes that economics is not sufficient to study the multiple causes of racial discrimination, and explicitly calls for analysis to go beyond market-based explanations (Arrow, 1976, 1998). Arrow, as Schelling, perfectly assumes the lack of complexity of the theory *vis-à-vis* the reality of American racial issues. According to Arrow, "economic theories can say something about the effects" but is not in a position "to explain why the phenomenon occured in the first place" (Arrow, 1976: 236). Causal explanations are limited. He explicitly accepts the limitation of any scientific research and especially, of the clause *ceteris paribus*:

> "The fact that you are not explaining everything is no excuse for not explaining whatever you can explain on the basis of something taken as given. Science always does that[48]. Nevertheless, it would obviously be useful, especially for policy purpose, to go beyond that" (Arrow, 1976: 234).

As a central and multi-faceted phenomenon, Arrow argues that discrimination has been analysed only in a special field of economics[49]. But more deeply, he asks, in his last paper on the topic: "[c]an a phenomenon whose manifestations are everywhere in the social world really be

[47] "The important thing is then not to put too much confidence in our prediction or exaggerated emphasis on the elements that we happen to comprise in our analysis" (Schelling, 1984: 206).

[48] When answering a criticism "that neoclassical theory has to bring in *ad hoc* hypotheses in order to draw any inferences relating either to differential unemployment, sexual segregation, or wage differences", Arrow states that this criticism actually apply to all school of thought: "[t]he statement is correct, but actually the same *ad hoc* hypotheses are needed by the internal labor market theory. In fact, this is part of a large set of cases in which all competing theories thrown by economists fail – Marxist and institutional theories, as well as neoclassical. The basic root is outside the economic realm" (Arrow, 1976: 235-236). He adds: "Economic arguments of all schools deal with anonymous individuals. The characteristics of sex, race, and nation are not incorporated. It may not be totatlly surprising that economic theories have nothing to say about the causes of sexual, racial, or national differences" (Arrow, 1976: 236).

[49] "Racial discrimination pervades every aspects of a society in which it is found. It is found above all in attitudes of both races, but also in social relations, in intermarriage, in residential location, and, frequently, in legal barriers. It is also found in levels of economic accomplishment; that is, income, wages, prices paid, and credit extended. This economic dimension hardly appears in general treatments of economics, outside of the specialized literature devoted to it" (Arrow, 1998: 91).

understood, even in only one aspect, by the tools of a single discipline?" (Arrow, 1998: 91). As in his last paper on the topic as in the previous one, the objectives are to explore discrimination as a phenomenon and to assess the "scope and limits of ordinary economic analysis[50]": essentially because "[studying discrimination] is important not only in itself but as a test of standard theories" (Arrow, 1998: 91). Using the others papers of the symposium[51] and his own memory from the 1950's and 1960's, Arrow argues that the first constraint on theory is reality – this is coherent with the "credible hypothesis": models have to be consistent with the evidence of wide-spread discrimination:

> "There is clear evidence of just plain discrimination against women that could not be explained by actual or perceived behavior by them. I find myself in a rare agreement with our chair [Barbara B. Reagan?], that the basic explanation must lie outside the economic field. There is a certain amount of discriminatory behavior which is not going to be eliminated even when it is obviously not in the economic interest of the employer" (Arrow, 1976: 235).

He then "suggest[s] that market-based explanations will tend to predict that racial discrimination will be eliminated and [...] since they are not, we must seek elsewhere for non-market factors influencing economic behavior" (Arrow, 1998: 93). Economics has limits essentially based on the conception of exchange as impersonnal:

> "Enough has been said to suggest that market-based theories give an inadequate account of the effects of racial discrimination on economic magnitudes and the effects of racial discrimination. It is increasingly recognized that many social interactions with economic implications are not mediated through a depersonalized market, but rather through the cumulative effect of individual choices. (Arrow, 1998: 97).

He gives Schelling model of segregation as an exemple of new way to model emerging effects – that do not correspond to representative individual or simple aggregation (Schelling, 1971). But he does go even further:

> "The hypothesis that prices do not reflect every kind of social interaction, even those of economic importance, is used in many contexts. [Its] an illustration of a more general principle – that beliefs and preferences may themselves be the product of social interactions unmediated by prices and markets" (Arrow, 1998: 97).

[50] "By economic theory, we mean that in some sense, markets are the central institution in which individual actions interact and that other institutions are of negligible importance'" (Arrow, 1998: 94).

[51] In 1998, an important symposium in the Journal of Economic Perspectives displayed three papers on "evidence" of discrimination on three particular markets. Yinger's paper used audit testing data to study discrimination on consumer market. Darity and Mason's paper displayed a wide range of evidences of discrimination in labor market (statistical evidence, regression evidence, and "direct evidence", i.e. audit testing and court cases). Ladd proposed a multi-regression analysis and audit testing data analysis to study discrimination in mortgage lending. Three other papers were presented as comments: a contribution by James J. Heckman which is a major critic of audit testing studies; a review of economic progress of black people on an historical perspective, and the paper by Arrow (JEP, 1998, 12, 2).

Market is a special type of network, transaction is a "social event" (Arrow, 1998: 99). He abundantly quotes economic sociology contributions (Granovetter, 1974, 1988; White, 1995) and concludes:

> "Clearly, the anonymous market, in which in effect every seller is connected with every buyer, is one extreme of a network. [...] The main point is that personal interactions occur thoughout this process, and therefore there is plenty of room for discrimiantory beliefs and preferences to play a role which would be much less likely in a market subject to competitive pressures. The network model seems most appropriate for the labor market, and perhaps less so for the housing, automobile, and credit markets. But in all of these, each transction is a social event" (Arrow, 1998: 98-99).

In his 1998's paper, Arrow retrospectively made his critics harsher on Becker's model and pointed up the problem of the isolation of a market-based explanation for discrimination. In doing so, he clearly states that economics is limited by its tools and have to use other social sciences results for the analysis of the causes of discrimininton. The essential reason is the ambiguity of discrimination as a phenomenon that is linked to intentional inequal treatment (discrimination *per se*) and to the existence of productivity differences correlated with group affiliation (human capital differentials investments and differentials return to investments) but also to retroaction phenomena and self-fulfilling prophecies. More generally, this paper conveys a view on what economics is about:

> "There is no way of separeting completely the study of racial discrimination (or indeed many other aspects of economics) from moral feelings. There are many modern varieties of liberalism, which draw the boundaries between social and individual action in different places, but all agree in rejecting racial discrimination, by which is meant allowing racial identification to have a place in an individual's life chances. It is, of course, important to be analytic; moral feelings without analysis can easily lead to unconstructive policies" (Arrow, 1998: 91).

This is the very subject of his Tanner Lecture – "The Unknow Other" – introduced by a first speech on "Extended Sympathy and Individual Differences[52]".

CONCLUSION

> "The need to do interdisciplinary research has been stressed by many economists of heterodox breed. Those who feel that theoretical economics leaves too many aspects of the social world unexplained tend to be the same scientists who also look out for alternative intellectual sources" (Rol, 2008: 90).

The specificity of both Arrow and Schelling is precisely to be at the same time players and challengers of orthodox economics.

In this conclusion, we would like to draw the attention on Arrow and Schelling's legacy. We would like to underscore how progressively their methodologies - which were at the threshold

[52] According to Arrow's archives, this lecture should have taken place at Harvard in 1985 (Box 7) but, except for an incomplete draft, I do not find any track of the actual lecture in the Tanner Archives records.

of orthodox and heterodox economics - became progressively anchored in the core of orthodox economics.

For instance, Schelling is considered to be one of the precursors of behavioral economics (Carvalho, 2007) and the pioneer of Agent Based Modeling – ABM – (Epstein and Axtell, 1996; among others), as well. With his experiments on focal points (in Schelling, 1960), he opened up to the use of experiments in economics. Moreover ABM are currently use as experiments (Aydinonat, 2007; Drogoul and Ferber, 1994; Liebrand, 1998; Liebrand et *al.*, 1998) or as theory building (Epstein, 2007, 2008)[53].

> "The engineers of social science are the policymakers (or their advisers.) And social reality generally presents difficult cases of intervention. The mere fact that economic policy exists reflects that we believe it is necessary to have at least some economic knowledge of what is economically possible and what is impossible. Even if our economic theorems are idealizational, we think that these are true enough. We also think that their external validity is such that, on these theorems, we can reasonably base decisions to intervene in economic processes" (Rol, 2008: 93).

Schelling's insight in residential segregation should be accordingly understood as part of a broad project enhancing deeper scientific knowledge on complexe social phenomena, and improve economists' capacity to propose public intervention in the real world.

From a theoretical point of view, Arrow is considered as a major contributor to the economics of information, and his theory of statistical discrimination is the basis of modern economics of discrimination, as well as empirical works.

Beside his major theoretical contribution, Arrow has been actively involved in expert assessement on discrimination. For examples among others, Arrow testifies for trials concerning class action on discrimination in seniority practice against African-Americans (*John R. Williams, et al. vs. E.I. du Pont De Nemours & Co.*, 1993) along with Paul Samuelson, for class action on sex discrimination (*Anna Penk, et al. vs. Oregon State Board of Higher Education*, 1983) along with Barbara Bergmann. He was also chairperson of the *American Economic Association Committee Against Political Discrimination*, a member of the *National Advisory Committee of the Comprehensive Regional Center for the Minorities* at The City College (New York), and of the *Committee for Affirmative Action in the Universities*[54]. Finally, he discusses the role of economics, especially the role of neoclassical theory, in understanding discrimination. In his last paper devoted to discrimination, Arrow clearly stands, in contradiction with Becker's claim, that economics (and especially neoclassical theory) is not "good enough" to analyse fully discrimination.

Along those lines Schelling was and remains involved in public and governmental councils. For instance Schelling was lastly committed in the policy proposals for the Copenhagen Consensus. He was, among others, member of: the US Budget Bureau (from 1945 to 1946), the Economic

[53] Even Schelling (in Carvalho, 2007) asserts that one of the purposes of ABM is theory building.
[54] In this latter committee, he argues in favor of transitory quotas for women's against Abba Lerner's position; he was supported by Wassily Leontieff. Kenneth J. Arrow Papers 1939-2011, Duke University. David M. Rubenstein Rare Book & Manuscript Library, Accession (2000-0222) 1077-1980, Box 2.

Cooperation Administration in Europe (1948-1950), the White House and Executive Office of the President (1951-1953). His participation in national or international councils constitutes the seeding grounds for his theoretic production throughout his carrier while at the same time his theoretical developments try to propose well-shape policies. As he emphasizes in an interview in 2005 "much of my work is very policy-oriented".

Thomas Schelling and Kenneth Arrow supervised Spence's Ph.D Thesis, defended in 1972[55]. As a conclusion, we quote how he regarded his advisors's work:

> "My thesis advisors are very different and very gifted. Kenneth Arrow taught me (and many others) mathematical economics and general equilibrium theory. When I took his course in general equilibrium theory, the take-home exam that I produced was lost. After a frightening phone call and a successful search for a copy, I rushed it in and waited while Ken read it, which he did (all twelve pages) at a rate of about 2 seconds a page. Now I have to say that there was a lot of mathematics on those pages. I just assumed that he wasn't really reading it, until he finished and then started asking me some detailed questions about the assumptions and analysis on page five. Describing Ken Arrow's contributions to economics in the second half of the 20th century would come quite close to just describing the evolution of economics during that period.
>
> Tom Schelling, as all who studied with him knew, had an extraordinarily original mind. Unique in our experience was his capacity to analyze using carefully constructed analogies, with just the right number of similarities and differences. Many of my younger colleagues were motivated in the best possible way by normative and policy questions. I think I tended more to being just fascinated by how markets and mechanisms like them worked. A great deal of that interest and motivation came from hours spent with Tom Schelling. It could be tipping points, focal points, sorting out congestion on a beach with surfers and swimmers, deterrence. Schelling's curiosity seemed endless and his capacity to shed light remarkable".

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