"From warfare to welfare": Contextualising Arrow and Schelling's models of racial inequalities (1968–1972)*

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1. Introduction

The racial component of socio-economic inequalities appears as a structural element of American society.[1] From 1896 to 1964, racial segregation in housing, in public and private facilities and in companies was legally organised by the "Jim Crow" system. This set of laws, governed by the "separate but equal" principle, was challenged by the 1954 *Brown vs. Board of Education Act* (1954) which ended segregation in schools and was abolished by the 1964 *Civil Rights Act*, which outlawed racial and gender discrimination in all areas of life, especially in the labour market. The end of legal segregation did not, however, mean the vanishing of segregationist and discriminatory practices. The question of the relative efficiency of legislation and market mechanisms to reduce inequalities between groups became a central concern in the second half of the 1960s. The debates over the nature and causes of racial inequality involve theoretical arguments: systemic mechanisms of deprivation and exclusion, social domination, individual responsibility, etc. – challenges to public policy, about intervention itself and about priorities among "domains" in which to intervene: education or the labour

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* The first part of our title is borrowed from Jennifer S. Light (2005), which constitutes one of the inspirations of this work.

[1] We use the term "race" to refer to its meaning in the American context.

market or both? – and different actors: activists, policy-makers, intellectuals and academics. This article concentrates on the answers given to these issues in the late 1960s by Kenneth Arrow (1921–2017) and Thomas Schelling (1921–2016). Both are Nobel laureates (Arrow in 1972 and Schelling in 2005) with noted academic careers. Their involvement during World War II and the Cold War and their subsequent contribution to the transformation of economics made commentators see their recent death as the end of a generation.[2] Although their individual trajectories can be studied through the prism of generational "typical experiences", our concern is their work on racial inequalities and the conception of science that it reveals at a specific moment of history. Within the time span 1968–1972, Schelling and Arrow published separately what are now standard theoretical accounts of various kinds of racial inequality, namely, discrimination and segregation. The paper presents their theoretical contribution on racial inequalities within each author's research programme and within economics. In addition, the paper traces the origins of these two works from a common institutional context: the RAND Corporation.

In this paper, we do not claim that the RAND context *explains* the content of Arrow's and Schelling's works. We show that, despite important differences in their approach to racial issues, both works exemplify a common reshaping of the conceptualisation and formalisation of racial inequality, of which the "material origins" are found at RAND.[3] By "material origins" we mean the specific conditions behind the production of the models. However, the argument is not the same for the two authors. Arrow was asked to produce a reflection on the measurement of discrimination in the context of a RAND contract with the Office of Economic Opportunity (OEO) that eventually led him to build his model. Schelling materialised his model using the RAND's programming resources. The underlying narrative of this paper asks why two major theorists and major

2 Kenneth Arrow was a weather officer in the US Air Force during WWII. Thomas Schelling graduated during the war and joined the Marshall Plan administration at the Bureau of Budget immediately after the war ended. Both were involved in Cold War work (see infra). For biographical elements, see the Nobel Prize website. On Arrow, see Düppe and Weintraub (2014, Chapter 1) and Salles (2016). On Schelling, see Ayson (2004). They both also gave multiple interviews furnishing a retrospective view of their work and much information is collected in the long list of recent obituaries in the Press.

3 Asked if Arrow referred to Schelling's work and if they knew each other, Schelling emailed us that he could not remember discussing his or Arrow's work on racial issues with Arrow, whether at Harvard or at RAND. In fact, they both participated in "a group of RAND staff members and consultants assembled as part of the O[ffice of Economic Opportunity] effort over the summer of 1968" (Carroll and Pascal 1969, p. iii).

RAND contributors to military research became prominent for their models on racial issues.

The standard narrative of the emergence of an economic corpus on racial inequalities gives Gary Becker a central role (Prasch 2004). His taste-based model supposedly filled a void and a need for a theoretical framework; the field of racial relations being defined in the 1940s and 1950s by the quantitative domination of atheoretical empirical works.[4] Gary Becker defined discrimination as "the use of non-monetary considerations in deciding whether to hire, work with, or buy from an individual or a group" (Becker 1971, p. 11). These non-monetary considerations are formalised using taste-based preferences. After the second edition of *The Economics of Discrimination* (Becker [1957] 1971), Kenneth J. Arrow and Edmund S. Phelps separately published two models of "statistical discrimination" (Arrow 1972, Phelps 1972b).[5] Arrow's statistical theory of discrimination starts from the hypothesis that rational agents use cheap information about the average properties of groups to evaluate individuals' ability. Even if individuals are not racist, patterns of discriminatory behaviours occur because of the normal functioning of market forces. While Becker ([1957] 1971, pp. 57–8, 78–9) modelled segregation as a result of taste-based preferences, Schelling saw residential segregation as a result of the dynamics of individual decisions about where to live. Even when individuals want to live in a mixed area, their interactive decisions can induce segregation.

The apparent disdain of the issue of discrimination in economics between 1957 and the end of the 1960s is misleading. In fact, numerous empirical works seized upon the question in relation to the economics of education, human capital theory and the study of earnings differentials. Significant research took place in the Institute for Research on Poverty at the University of Wisconsin, at the Department of Economics at Chicago, within Princeton University's Industrial Relations Section and at the RAND Corporation.[6] What became Arrow's statistical theory of discrimination and Schelling's model of segregation were both circulated as "D" documents at RAND before being released as RAND Reports and were

4 Gunnar Myrdal's 1944 *An American Dilemma*, while providing an economic explanation of racial discrimination, is seen as a masterpiece of sociology; It went unnoticed as far as his theoretical contribution was concerned. On the reception of Myrdal's book, see Cohen (2004) and Cherrier (2009). On the economic analysis of discriminations before Becker's work, see Fleury (2012) and Chassonnery-Zaïgouche (2013).

5 Phelps coined the term "statistical discrimination" in his AER paper (Arrow 1976, p. 235).

6 For a review, see Cain (1986).

eventually published by RAND in a collective book (Pascal 1972).[7] The present paper focuses on this context.

In the second section, we start from the authors' own account of the origins of their work and how it relates to their other contributions to economics (2.1 and 2.2). In the third section, we locate the "material origin" of the models at RAND in the late 1960s (3.1) and how it relates to the transfer of the RAND tool-box to the study of welfare issues (3.2). In the fourth section, we describe how Arrow and Schelling amended some central hypotheses of (what they call) "neoclassical economics" (4.1) and how their modelling strategies are related to their conception of "science for action" inherited from their "warfare" work (4.2).

2. Two original contributions

Gary S. Becker's work on discrimination and segregation is the theoretical foundation that Arrow and Schelling start from. Both of these authors embedded their project within a theoretical discussion on the usefulness of Becker's work for studying racial inequalities and present their work as emerging from the troubled context of a racially segregated United States.

2.1 Applying "adverse selection" to racial discrimination

In 1968, Kenneth Arrow wrote a note on the difficulty of measuring discrimination that circulated internally at RAND. He then published a Report in 1971 and the formal exposition of his theory of statistical discrimination was presented the same year at a Princeton conference on market discrimination.[8] Arrow was unquestionably considered as "the" theorist of the conference (Oaxaca, email to the authors). The conference itself was perceived as a sign that racial and gender discrimination were becoming important topics within general economics. Before the publication of the conference proceedings, RAND published a volume in 1972, where Arrow's work appeared along with Schelling's "tipping model" and many other RAND Studies on "racial discrimination in economic life" (Pascal 1972). We first discuss the work from 1968 and 1971, where Arrow discusses how information should be accounted for; we then present the model as it appeared in 1972 and 1973.

7 The "D" series are RAND Corporation's internal working papers usually written as a step in a continuing study within RAND; they could be expanded, modified, or withdrawn at any time. They were not peer-reviewed, and therefore not circulated outside of RAND without authorial permission.

8 The conference proceedings were published later by Ashenfelter and Rees (1973).

The short 1968 note is devoted to the theoretical aspect of market discrimination measurement. Rather than individual preferences, Arrow points to the social system to explain much of the observed discriminatory behaviours "in which the government may have considerable leverage for change" (Arrow 1968, p. 4). Instead of considering strong preferences to be sovereign, Arrow emphasises the opposite.

> It may well be that the discriminatory preferences are widespread but shallow. (Arrow 1968, p. 4)

> "Taste for discrimination" as expressed on the market may reflect not private attitudes but reactions to formal and informal social mechanisms. (Arrow 1968, p. 7)

Arrow then describes the persistence of discrimination despite the (partial) implementation of fair employment laws. His only empirical statement is that the ratio of non-white to white earnings decreases as educational level rises – a result he based upon data from Hanoch (1967). The question whether discrimination is possible when individuals have only a mild taste for discrimination or no taste at all, and the channels along which the "social system" impacts on the decisions of economic agents are the two research perspectives that he follows.

In the 1971 report, Arrow attacks more directly Becker's model. He points to the "lack of specificity" of the taste-based hypothesis (Arrow 1971, pp. 9–10). This lack of specificity concerns the nature of the taste (Becker does not explain differences in the distribution of tastes or difference in tastes; for example, dislike may depend on the nature of the association or physical distance) and the determinants of taste. Arrow is much more critical in his last paper on discrimination, characterising Becker's taste-based *ad hoc* hypothesis as tautological.[9] He adds: "Attributing taste to impersonal entities [large corporations] is a hypothesis of dubious usefulness" (Arrow 1998, p. 95). But his more important criticisms rest upon the predictions of the model. In a model using tastes, competition is supposed to rule out discrimination.

9 Arrow wrote several papers on discrimination from the late 1960s to the early 1970s and one paper in 1998. Published in a symposium on discrimination including three empirical papers and a methodological critique of field experiment by James Heckman, Arrow's paper is rather a comment than a theoretical paper. He adds nothing new from his previous work but the language (and criticism) seems less constrained. He seems not to have changed his mind in 27 years.

> 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, p. 12)

Yet, almost ten years after Becker's work, racial discrimination still pervaded every aspect of American life. Since the mid-1960s, major criticisms of Becker's model have pointed out the inconsistency of his model prediction with direct observational data showing the persistence of discrimination, even in competitive markets. Is racial discrimination costly – hence eliminated by market forces (as in Becker's narrative), or is racial discrimination profitable to the majority – hence reinforced by the more powerful agent of the market? Arrow's answer is straightforward: racial discrimination is an economising process – and therefore part of the market mechanism itself.

His subsequent model explains why employers rationally discriminate against certain individuals. The model is based on three hypotheses.[10] The first hypothesis of the model is that employers make a personal investment when hiring an individual. These fixed costs are the main costs of changing one's workforce and explain that, even if profitable differences in wages exist in a competitive environment, an employer will not change his entire workforce accordingly and instantly (Arrow 1971, pp. 19–20). Second, Arrow adds that employers and employees are in a strategic situation characterised by asymmetrical information.

> 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. (Arrow 1971, pp. 21–2)

Third, the employer does have some information: he knows the employee's gender or race and has *an idea* of the average productivity distribution between groups. What was only a "tentative hypothesis" (Arrow 1968, p. 16) then becomes the main assumption of the more formal model (Arrow 1972): because determining the productivity of an employee is costly, employers use race as a "proxy" for unobservable characteristics (Arrow 1972, p. 97). Hence, discrimination "can be thought of as reflecting not tastes but perception of reality" (Arrow 1973, p. 23). Discrimination implies the valuation in the market of "personal characteristics of the worker unrelated to productivity" such as race and gender (Arrow 1973, p. 3). According to Arrow, this valuation process is not perfect: average

10 Edmund Phelps developed a similar model published the same year in the *American Economic Review* (Phelps 1972b), based on "an exact statistical model", first exposed in *Inflation policy and unemployment theory* (Phelps 1972a, pp. 24–7).

knowledge of group characteristics can be derived from probability thinking based on data or previous experience or raw prejudices; valuation consists in applying average group characteristics to individuals with no certitude of their position within the distribution of these characteristics. Discrimination is a rational process of decision-making in an uncertain market environment where employers minimise their risk using the cheap information available to them. But "[o]nce we shift the explanation of discriminatory behaviour from unanalyzable (or at any rate unanalysed) tastes to beliefs" (Arrow 1973, p. 27), how can we explain the beliefs underlying what can be called "statistical beliefs"?

Arrow lists several explanations. The first one is based on Festinger's psychological work concerning "cognitive dissonance": estimations of a group's average productivity tend to be justified according to beliefs and previous (or current) experience.[11] Arrow then discusses the possibility of self-fulfilling prophecies, later explored in the literature (Lundberg and Startz 1983). In the case of gender discrimination, he formalises what he later calls a "model of perceptual equilibrium": "[r]ational adaptation by [minority members]" finally justifying an employer's attitudes toward the minority (Arrow 1976, p. 234). This rational adaptation to lower economic opportunity is based on the hypothesis that "workers are being treated as groups and not as individuals" (Arrow 1976, p. 234).

Where does this model come from? In Arrow's narrative, his work on racial discrimination is an application of adverse selection. He was first sensitised to the literature on adverse selection and moral hazard while preparing the examinations of the Actuarial Society and applied it in his seminal work on the welfare economics of medical care (Arrow 1974, p. 269; Arrow 2009, pp. 2, 9).[12] Arrow insists on the relevance of his model for general economics, just as his work on medicare was remembered for adverse selection rather than for its description of physicians' practice (Latsis and Repapis 2016, p. 96). What is relevant is the universalism of the mechanism described, observable in different contexts. His recollection of the evolution of his research interest centres on the incorporation of information (Arrow 1985, p. 89). He traces his familiarity with informational issues back to the application of Claude Shannon's theory of

11 Festinger's "perceptual illusion" was developed after the "principle of congruity" of Charles E. Osgood, the "Cold War psychologist" (Erickson *et al.* 2013, pp. 104–6). He spent some times at RAND in the 1950s working on game theory and experiments (Cot and Ferey 2015, pp. 5–6).

12 Both can be understood within a principal/agent relationship. Adverse selection concerns a situation with asymmetric information where the information on the *type* of products is not complete, whereas moral hazard describes a situation where a hidden *action* can occur after a transaction.

communication by Marchak and others at the Cowles Commission, his reading of George Stigler on the economics of information, and the role played by questions of "techniques" developed at RAND, such as linear programming (Arrow 2009). The influence of what he calls "probabilistic thinking" (Arrow 2009, p. 10) pervades all his later works. He took from Savage the idea that beliefs could be derived "in the form of probability distributions as part of rational behaviour under uncertainty" and part of his research question was to determine whether uncertainty was exogenous or endogenous to the economic system (Arrow 2009, p. 9).

Arrow applied the concept of adverse selection essentially because "it fits" the analysis of discrimination – the specific structure of the subject. By doing so, he produces a criticism of current theories of discrimination, essentially Becker and a "common sense" version of the Marxist argument, which eventually forms a basis for political action. Indeed, contrary to Becker's model, the market does not clear discrimination. If discrimination were a problem of information about personal characteristics, government or management rules could modify the "perceptual equilibrium."

2.2 From a "pencil-and-paper experiment" to a model of segregation

In a comparable way to Arrow, Schelling (in Steelman 2005, p. 40) refers to the US context of race relations and denounces Becker's treatment of segregation and his *ad hoc* explanation by adding a "taste for discrimination." When he looked back on it, Schelling 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. (Schelling in Swedberg 1990, p. 194)

As a multi-faceted socio-economic phenomenon, segregation requires a new conceptual inception. Like Arrow, Schelling resorts to interactional systems and to psychological factors such as perceptions as explanatory factors of segregation in a complex, uncertain and evolving world.

In the late 1960s, in three RAND documents and four published contributions (1968a, 1968b, 1969a, 1969b, 1971a, 1971b, 1972b), Schelling developed two models of residential segregation and tipping. Tipping occurs when the entrance of a minority induces the evacuation of the former residents of a district (Schelling 2006a, p. 302).

In several interviews after the Nobel Prize and in a six-page reminiscence piece published in the *Handbook of Computational Economics*, Schelling tells the story of the conception of his dynamic models of

segregation. The paper plays down the importance of the RAND context in making the idea, but does emphasise the role of its programmers in the "materialisation" of the model (Schelling 2006b).

> I was at RAND in the summer of 1967. I wrote a chapter called "the process of neighbourhood 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. (Schelling in Aydinonat 2005, p. 4)

The exercise was first intended to "teach [his] classes how people's interactions could lead to results that were neither intended nor expected" (Schelling 2006b, p. 1641). Schelling tried to confirm his "strong intuitions" that "fairly extreme segregation" can emerge from "the dynamics of movement" (Schelling in Aydinonat 2005, p. 4) by looking at the literature in RAND's library. He searched in sociological journals but found nothing (Schelling in Aydinonat 2005, p. 4), before deciding to build something himself.

> One afternoon, settling into an airplane seat, I had nothing to read. To amuse myself I experimented with pencil and paper. (Schelling 2006b, p. 1641)

"Rampant racism" – what Becker assimilates to tastes for racial discrimination – is not the basis of his analysis of residential segregation (Schelling in Steelman 2005, p. 40). He considered that each individual wants to live in a mixed area, but without being in a minority. Therefore, in order to choose where to live, everyone evaluates the ratio of colour between the two populations that compose a neighbourhood. The main difference with Becker's treatment of segregation and the standard static treatment of the late 1960s is also, and mainly that Schelling focused, on the dynamics of individual decisions and the *processes of interactions* leading to the collective consequence of residential segregation. He attempted to demonstrate that without any will to favour residential segregation, the process of the individuals' decision nevertheless collectively induces this consequence, which is mainly the consequence of such a dynamic of interactive individual decisions. Schelling tried to verify this hypothesis with two different definitions of neighbourhood: a first subjective definition of neighbourhood, according to which "everybody defines his neighbourhood by reference to his own location" (Schelling 2006a, p. 260), and a second objective definition of neighbourhood, such as a specific district, which means that everybody agrees on the location and delimitation of this neighbourhood. The former account of neighbourhood corresponds

to what Schelling called the "spatial proximity model" while the latter corresponds to the "bounded neighbourhood model" or "tipping phenomenon."

The hypotheses of the "spatial proximity model" are threefold. First, the population of individuals is twofold ("blacks" and "whites", but it can be applied to distinctions between men and women, young and old, etc.). Schelling has a very broad application of his first intuitions: neighbourhoods, clubs, ballparks or dining tables (Schelling 2006b, p. 1641). Second, each individual evaluates his/her location according to a colour ratio of the population composing the neighbourhood. If the colour ratio fits the individual's requirement (e.g. a ratio of 1/2 of the same colour), he/she stays; if not, he/she moves to another location. Schelling first experimented with this process by imagining individuals associated with 'o' or 'x', placed on a line. In the original "pencil-and-paper experiment", it was "a line of x's and o's that [he] somehow randomized" (Schelling 2006b, p. 1641).[13] Then, in the 1969 paper, he changed the distribution area to individuals placed within a square like a checkerboard. Third, the rule of motion is that unsatisfied individuals move, from the left to the right, to the nearest place where they can be satisfied with the colour ratio of their neighbourhood and they continue to move until they are satisfied. The equilibrium of the model is reached when people are all satisfied with their own location. The conclusion of this model is straightforward: whatever the initial conditions tested with respect to the initial random distribution of two populations, to the number of each colour within the global population, or to the value of the colour ratio that each individual wants in her neighbourhood, etc., there are always clusters of 'like-colours'. While this was not the purpose of each individual motion, together they induce a segregated area. This type of equilibrium is the only solution that this model induces even if some variations of the clusters of like-colours within the segregated area exist (there may be more or fewer clusters, more or less density, etc.).

The hypotheses of the "bounded neighbourhood model" are again threefold. There is a twofold population. Each individual of each population evaluates the colour ratio within the district that she considers, and more specifically each population is represented by a curve symbolising the cumulative frequency distributions of the individual's tolerance threshold. This tolerance level is the upper limit of the colour ratio that an individual can tolerate in order to live in the district. The rule of

13 The constraint of having no eraser was slightly eased when he decided to use his son's coin collection, both the copper and the grey zinc pennies "we had all used during the war" (Schelling 2006b, p. 1641).

motion is the following: if the ratio of two colours is lower than their tolerance threshold, people stay in the district in which they live; if it is above their threshold, they move. Similarly, if they are outside the district and the ratio is lower than their threshold, they move in, and if it is higher, they stay outside. The equilibrium of the model is reached when the distribution is stable, i.e. when there are no more moves. Two kinds of equilibrium in this model generally compete: (i) an equilibrium of all "blacks" or all "whites", i.e. the district under scrutiny is completely peopled either by "blacks" or by "whites" and (ii) a mixed equilibrium. The latter kind of equilibrium is nevertheless very sensitive to perturbations which is why it is the former kind that tend to be stable (Schelling 2006a, p. 296). Again, Schelling tests different initial conditions regarding, for instance, the tolerance threshold of each population, the aggregate number of individuals of both populations, and the aggregate within each population. Whatever these initial conditions, it is the "extreme one-colour equilibrium" that is stable. The tipping phenomenon is therefore a specific application of this model.

3. The late war on poverty and the RAND Corporation context

Analysis of the various drafts of Arrow's and Schelling's contributions to racial issues and their own narratives provide internal explanations of the development of their theories. We insist that their modelling strategies of racial inequalities have a clear link to the RAND Corporation – it was part of a broader project in the case of Arrow (3.1) and it relied heavily on tools developed at RAND in the case of Schelling's model (3.2). There is no contradiction between the recollection of Arrow and Schelling and the emphasis we put on the RAND context. Actors' own narratives often differ from historians' narratives (Weintraub 2005). It is true that Arrow and Schelling wrote "thought papers" rather than running projects or engaging in policy work. Unlike some of their previous RAND works, in the case of racial issues, Arrow and Schelling did not produce concrete policy recommendation or specific cost calculations. However, their work provided new narratives to trace the link between racism (a belief) and discrimination and segregation (actions). Both works were acknowledged to be linked only to a broad political context. In fact, both papers were written and later discussed at RAND in the context of the late "War on Poverty" (WoP) programmes. We argue in this section that this context matters for an understanding of the *origin* of Arrow's work and of the *form* that Schelling's models of segregation took.

3.1 The "material origins" of the models at RAND

Arrow's work on racial discrimination is part of "a study on the measurement of racial discrimination" (1971, iii), started in 1967. The contribution was primarily drafted as a RAND Report to be later included in the forthcoming RAND book, first entitled "The American Economy in Black and White: Essays on Race Discrimination in Economic Life", and eventually published as *Discrimination in Economic Life* (Pascal 1972). The 1968 note and the 1971 Report were written while Arrow was under contract with the Office of Economic Opportunity – as shown by the identification number. The contract itself does not include the insertion of the work within a specific project but aimed to cover Arrow's expenses while working at RAND in the summers of 1967 and 1968. It was supplemented by Ford Foundation funding.

To understand the origin of Arrow's work, one has to understand the role of the OEO during the "unconditional War on Poverty" declared by Lyndon Johnson in 1964 (Huret 2010, Patterson 2000). Various arguments and intellectual communities were looking for ways of fighting poverty. The OEO initially developed a somewhat radical programme of decentralised policies. Led by Sargent Shriver with a team of radical social theorists, hundreds of local anti-poverty programmes were funded under the banner of the decentralised Community Action Programs (CAP). The basic idea that individuals ("poor people" themselves) can change their condition through community development and themselves determine the type of policy required were among the main hypotheses of the early programmes in the "War on Poverty." Beginning in 1965 and amplified in the following years, the "urban crisis" and the new direction of the Civil Rights movement urged the need to evaluate the major programs and legislation of the WoP. In 1967, Johnson called in a National Advisory Commission on Civil Disorders to study the origins of the troubles, and especially the massive riots. The report suggests the prominence of white racism to explain the continuing processes of segregation in American society. The reconsideration of the role of racism as an explanation of racial inequalities and the need to measure and to evaluate the impact of anti-discrimination laws are at the heart of Arrow and Schelling's modelling strategies.

In 1965, to analyse the situation, the OEO decided to issue grants for research on the WoP and an evaluation of its success. Among other projects, it funded the collection of new data sets to supplement the decennial Census: the *Survey of Economic Opportunity* (SEO).[14] The existence of data

14 The SEO was later transferred to the Institute for Research on Poverty (IRP) at the University of Michigan and became the Panel Study of Income Dynamics (PSID) in 1968. The IRP was also created with funds from the OEO.

and the political demand for quantified evaluation fostered the entry of economists to the debate. In 1967, political imperatives among liberals were characterised by new uncertainties about the causes of racial inequalities and divisions regarding the priorities in the allocation of Government funding between the Vietnam War abroad and the WoP at home. Politicians, including Johnson, were looking for new narratives and a new management of poverty issues (Huret 2004). Arrow's work constitutes precisely one of these new narratives.

The specific type of evaluation proposed by RAND to the OEO was based on the constitution of models to be tested against empirical data (Pascal and McCall 1967). If we replace Arrow's work in the network of reports completed from 1967 to 1972, many works including those of Arrow and Schelling can be interpreted as coping theoretically with the problem of uncertainty in dynamic processes, when agents face limited data and limited computation availability – e.g. stochastic processes, especially Markov chains and search models. This was exactly the type of metaphor that was transferred, followed by the analytical tools to study them. Urban riots and racial tensions were analysed as strategic games, labour relations as stochastic processes, etc. These tools were not innovative in themselves but it was an innovation for the social scientists involved to apply them to relatively new areas of investigation: domestic issues.

Many OEO projects were coordinated by Anthony Pascal (Pascal 1965, Pascal and McCall 1967), who edited the RAND book on racial discrimination in 1972, in which works by both Arrow and Schelling were published. Pascal does not mention whether Arrow's (1968) was sponsored by OEO, but he makes it clear that RAND, *and not the OEO*, sponsored the 1971 report, although the research was relevant to the OEO (Pascal 1971, p. 35). At RAND, two types of research coexisted: targeted research (for example, to evaluate the Women's Job Corps of Los Angeles and other specific programmes) and basic research. Clients usually funded directly targeted research but a considerable part of the grant was dedicated to basic research with no precise agenda. It was this type of non-constrained funding, coupled with the relaxed south Californian interdisciplinary working environment, that was seen as the source of success for innovation at RAND during the Cold War. Arrow's work was funded by OEO as basic research, while Schelling was funded by RAND as part of the general reflection on urban issues and poverty. In the coordination meeting on urban issues in summer 1967, summer consultants with no precise agenda (such as Arrow and Schelling) were put together with RAND staff (such as Pascal and McCall) who work on

the evaluation of specific issues for the OEO (Carroll and Pascal 1969).[15]

In the late 1960s, many intellectuals and activists questioned the idea that "dismantling the legal edifice of segregation and discrimination would ensure" [the end of racial in equality, though many liberals of the 1950s had thought it would (Geary 2011, p. 54). A solution was to ask the RAND experts *within* the Defense administration and the OEO for new explanations and research directions; their answer was to ask experts at the RAND Corporation itself, experts they knew as former colleagues.[16] One of the solutions was to transfer the management of the management and research tools developed during WWII and deployed during the Cold War to fight the WoP.

3.2 Transferring the tool-box

In our exchanges with Thomas Schelling, when he spoke of the origins of his model, he expressed a distance specifically from the RAND context, while clearly linking it to his engagement in a battle of ideas in the course of teaching economics.[17] Schelling's segregation model was also included in the 1972 RAND book, though it was not part of any formal contract with the OEO. His work was funded as basic research under a RAND research project in the newly created "domestic programs section." It was discussed in the context of the RAND Studies for the WoP that was planned in the summer of 1967. The RAND context allows us to understand the *form* of the model in Schelling's work, i.e. his resort to programming, as opposed to understanding the model's origin.

It is well known that the RAND Corporation is for many scholars a "pure Cold War institution" (Hounshell 1997, p. 240). In the mid-1960s, many RAND "defense intellectuals" – i.e. "civilian experts who participated in defense planning" (Light 2005, p. 239) – began to work on the

15 The group also included James Coleman, Robert Dorfman, Thomas Glennan, Seymour Lipset, and Albert Wohlstetter from RAND; Thomas Tomlisson, Barabara and Walter Williams from the OEO.

16 The number of contracts signed during the late 1960s while ex-RANDites were in the Administration (whether at the DoD or other department and agencies such as the OEO) was the subject of scandal and inquiries. Current RAND consultants and staff were instrumental in shaping the demand and the supply side of the "poverty–academic-complex".

17 Contextualisation within Schelling's teaching and academic activities is not the subject of this paper, yet it is a hypothesis for testing that it is where the influence of his work mainly lies.

war at home.[18] The diversification at RAND, first related to civilian defense in the early 1960s, expanded rapidly after 1966 following the official decision of the RAND Board of Trustees to redirect research beyond military contracts (Jardini 2000). This diversification meant a transfer of tools.

What was first transferred to the WoP was the RAND research management tool, the Planning–Programming–Budgeting System (PPBS).[19] A first explanation of this shift is the political demand to extend RAND's successes in planning and management to the WoP's administration at a time when Johnson was trying to regain control over decentralised programmes (Breslau 1997, O'Connor 2001, Chapter 6). The transfer of RAND experts to the Department of Defense (DoD) under the McNamara regime was the model for the reorganisation of the WoP after 1965 (Jardini 1996, Chapters 6 and 7, Forget 2011). The Johnson administration was looking for a "more politically neutral kind of poverty knowledge" (O'Connor 2001, p. 173). The OEO office of Research, Planning, Programs and Evaluation (RPP&E) created in 1965 took shape as a clone of the DoD Office of Systems Analysis.[20] A second (joint) explanation is the intensification of Cold War confrontation: segregation and racial discrimination at home were analysed by the Soviets as an illustration of American imperialism at a domestic level (Rosser 1962). In this regard, it explains why large parts of Arrow's 1968 and 1971 reports are devoted to arguing against Marxian analyses of discrimination while major radical theories were being produced (Marshall 1974).

PPBS reformulates the way that research should be conducted. The persons in charge of its implementation at OEO were former RAND consultants. They were instrumental in securing the new contract for RAND. These contracts entail the evaluation of programmes, the production of

18 This historical "shift" is documented for the areas of urban planning (Light 2005), general welfare administration (Jardini 1996), the OEO (Forget 2011) and the Department of Health, Education and Welfare (Huret 2004).

19 The PPBS methodology is an integrated management system developed in the mid-1960s within the DoD under McNamara's rule. The principle is to establish techniques to identify priorities and strategies in an organisational framework aiming at controlling operations and costs. See DonVito (1969).

20 Robert Levine, a former RAND consultant, was the main planner of the WoP as head of the RPP&E. He later went back to RAND to head the Domestic Programs division. He was one of the press' targets over the financial stakes between RAND and the OEO. See e.g. "Many Consultants Get Poverty Funds" (*The New York Times*, 8 November 1970), "Millions to Consultants. The Rich Rewards of Poverty" (*The San Francisco Examiner*, 8 November 1970) and "Fat Contracts Follow Former OEO Employees Into Ranks of Private Consultants" (*The Sacramento Bee*, 8 November 1970).

data and the production of evaluative models. The types of model were supposed to fit the idea of basic research that could later be useful for policy recommendations. The direct result was a cluster of research studies using research management techniques and conceptual tools such as systems analysis. This shift also fostered new research by academics at RAND, now applying the tool widely beyond military issues.[21] This trend is well illustrated by the individual trajectories of prominent RAND consultants. For example, we can mention the RAND analyst Robert Levine and his application of simulation models to the urban crisis. Outside the Government departments themselves, we can add John Kain's shift from military transportation to the study of the "American Negro" and Wohlstetter's move from the analysis of deterrent force to racial differences in wages (Wohlstetter and Coleman 1970).[22] We argue that this transfer of knowledge within the Administration that was translated into a shift in the production of knowledge at RAND had an impact on the modelling strategy deployed by Arrow and Schelling. Arrow's (1968) document is a reflection of the data availability that echoes Wohlstetter and Coleman's work; all of them discussed poverty and urban issues in the 1967 summer workshop.

Both Arrow's and Schelling's RAND studies before those on racial discrimination and segregation concern mainly war issues, Arrow writing on optimisation under uncertainty and Schelling on the strategic analysis of conflict.[23] Their "science of warfare" (Hounshell 1997) developed at RAND was also characterised by cross-disciplinary exchanges (Heims 1991, Fortun and Schweber 1993, Jardini 1996, Galison 1998, Mirowski 1999, 2002, Isaac 2010, pp. 136–8). Not only did Arrow's and Schelling transfer mathematical tools in their work on racial discrimination and segregation but also the methodology of research and of scientific production that

21 This "shift" of research interests, financial resources and military contracts, occurred also in other "Cold War" companies such as the Systems Development Corporation (software), Lockheed and McDonnell (aerospace), and Litton Industries (communication systems) and considerably enlarged the research scope of the "military–industrial–academic complex" (Leslie 1993).

22 Kain went on to join the Harvard Kennedy School faculty just when the Ford Foundation was funding the Urban Issues programme in the context of the WoP.

23 Arrow's famous *Collective Choice and Individual Values* originated in a RAND command to build a welfare function for the Soviet Union (Arrow 1948). He worked on "airframe cost–performance", mathematical models of air transportation systems, applications of linear programming and gradient methods for optimisation, etc. At the end of the 1950s, the RAND commissioned Schelling to apply game theory to the strategic analysis of conflicts. He became a staff member of RAND in 1958–1959 and worked with Herman Kahn and Albert Wohlstetter on "new strategic thinking" for the nuclear war (Sent 2007, p. 456).

had been the hallmark of RAND since its creation in 1946. Since the very beginning, RAND has been characterised by an "interdisciplinary approach to identifying, evaluating, and applying technology" (Campbell 2004, p. 52).

In Schelling's case, this transfer of tools directly concerns the application of the technology of programming.[24] In an essay wrote in 1972 (republished in Hegselmann 2012), studying the dynamics of his model, Schelling produced a "guided tour through a computer program" (Schelling 1972a, p. 1) and arguments *against* the use of computer simulation.[25] He actually implemented the two-dimensional version (checkerboard) of his model with RAND computers. The computers that he used, like most computers at the time, "did not have an output device that could display and visualise an ongoing dynamics" (Hegselmann 2012, § 3.2–3.3). With no screen, but with a tele-typewriter, Schelling was arguing for a manipulation of the model "by hand" to visualise the dynamics. This limitation completely disappeared in the 1980s. The computerisation of Schelling's model occurred at RAND where "John Casti has been preparing a versatile computer program" for this purpose (Schelling 1969a, p. iv). But the cooperation did not work well (Hegselmann 2012, p. 5). He finally asked for help from his student, James Vaupel, who had trained in mathematical statistics at Harvard and was then a PhD candidate at RAND. Vaupel "completely disassembled [Schelling's] 'model' into its smallest components and reassembled it before [his] eyes as a set of instructions that a computer could follow" (Schelling 1972a, p. 1). He next trained Schelling, in three hours, how to program with BASIC, the famous programming language. According to Hegselmann, this experience helped Schelling produce a generalised version of his model (2012, § 4.1–4.4) and refine it in the production of alternative hypotheses.

The sharing and dissemination of tools was a prerequisite of the proper functioning of system analysis. These tools range from material artefacts such as computer programming, to management tools such as PPBS, and stochastic modelling (Markov Process). Arrow's model uses the Markov property as well as other formal ways of dealing with uncertainty in a

24 For a history of linear programming and RAND, see for instance Dantzig's RAND memorandum (1963), Dantzig (2002), and Augenstein's RAND draft (1993). For a history of the development of computer science and RAND, see Ware (2008). On the "computerisation" of economics after 1970, see Backhouse and Cherrier (2016).

25 This essay is a teaching document for a lecture at the Kennedy School of Government (Harvard University). Schelling was teaching there at the beginning of the 1970s. Unfortunately, we lack access to the name and characteristics of the course it was written for.

dynamic model. In this regard, Isaacs (2010, p. 138) speaks of the "war-induced regime of toolmaking and tool sharing." He also emphasises how the social scientists at RAND "were convinced by their experiences of war work that toolmaking and tool dissemination held the key to scientific advances in concrete problem areas" (Isaac 2010, p. 138). We indeed argue that both Arrow and Schelling are particular examples of this kind of epistemological position with respect to the use of mathematical tools that gained relevance in postwar era economics.

4. Science for action

The contributions of Arrow and Schelling have the same purpose: to produce theoretical models to understand and to serve as a basis to intervene in real world issues. We call this conception of science in relation to the objective it serves "science for action." "Science for action" therefore refers to the articulation between abstract modelisation and political action. This is not to say that Arrow and Schelling were asked to produce policy recommendations of a precise nature. It was hoped they would produce basic research that would foster applied research which in turn could combat current burning issues. Consciousness of policy objectives goes with a high degree of abstraction that expresses their concept of science and their use of modelisation, inherited from the earlier development of economic theory at RAND.

4.1 Amending the "neoclassical" framework?

By "neoclassical" economics and "standard microeconomics", Arrow and Schelling refer mainly to the way in which these terms were defined at the University of Chicago after WWII.[26] From Arrow's perspective, racial discrimination analysis works as a test for "neoclassical price theory" (1971, p. v). From Schelling's perspective, segregation allows him to extend his amendment of standard game theory. Commonality does not mean similarity: while producing different types of model, Arrow and Schelling nevertheless opposed what they both saw as the dominant economic paradigm applied to racial inequalities at the time, namely Becker's work. 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. For Schelling, some modification of standard game theory was necessary to

26 On the different perspectives in postwar microeconomics, see Mirowski and Hands (1998).

cope with real-world issues. Although it is more often emphasised that RAND played an important role in the rise and spread of a new mainstream form of postwar economics, we would emphasise the plurality of microeconomic perspectives that both Arrow's and Schelling's works illustrate. Far from representing "the move in economics towards monism about beliefs, ideology, theories, models and policy advice" that characterises postwar economics (Sent 2007, p. 458; for a comparative claim, see also Morgan and Rutherford 1998, p. 19), they opened and amended what were then considered standard narratives.

According to Giocoli, the 1960s saw changes in the way that the economic world was characterised. Instead of a "system of forces", it became an explanation in terms of "relations" (Giocoli 2003, p. 4). In the "system of forces" account of economics, the explanans is the markets – i.e. the forces of supply and demand on such markets – while in the "system of relations," the explanans becomes the individual's choice and rationality, where rationality is understood as a consistency between individual choices. After WWII, in what is considered standard decision theory under certainty and uncertainty, rationality in consumer theory and game theory (i.e., Samuelson 1938, von Neumann and Morgenstern 1944, Nash 1950, 1951, Savage 1954, Harsanyi 1967/1968) is indeed characterised in terms of consistency of individual choices. Becker's tastes-based model of discrimination represents the "system of forces" account of economics: he adds a parameter in the individuals' utility function but it is market forces that explain the equilibrium. In his account, the link between micro-foundations (individual's choices) and macro-behaviours is entirely explained by the market. We argue that Schelling's and Arrow's works correspond to neither of these accounts.[27] It is individuals' choices *and* interactions (potentially within markets) that explain the social outcomes, i.e. explain the translation from the micro-foundations to the macro-behaviours, but this process is not based on any conception of rationality as consistency of choice.

Contrary to Becker's work, in which "the analysis should start from an exact specification of the particular utility function valid for the case under scrutiny [and preferences] should then be taken as given and stable" (Giocoli 2003, p. 113), preferences in Schelling's and Arrow's work are far from standard and stable. The inadequacy of Becker's use of 'a taste for discrimination' is the problem. If markets in the long run eliminate discrimination, it is not clear whether agents with a "taste for discrimination"

27 In this paper, we focus on Arrow's works developed outside the framework of his work on General Equilibrium. Hence, we break with his treatment of preferences in earlier works (see Salles 2016, pp. 695–6).

will disappear or will modify their preferences. Hence, preferences are no longer independent from the context and the sovereignty of individuals' preferences is not respected.[28] For both Arrow and Schelling, individuals evolve in a complex environment and thus it is far from possible that individual choices will reflect stable and coherent preferences. In Schelling's theory of strategy for the Nuclear War, the proof that players can go against what might be in their interest, i.e. what might be their individual preferences, was one of its main contributions (e.g. see Sent 2007). In Arrow's modelisation of discrimination, the feedback effect of discriminatory behaviours and segregation can in the long run modify preferences.

Under conditions of uncertainty, rationality as consistency (Savage 1954, Harsanyi 1967/1968) entails that people must handle rational beliefs, i.e. that people must be able to form correct expectations regarding all the possible consequences of their choices. As we saw (Section 2), Arrow and Schelling integrate individuals' perceptions that prevent consistent choices and behaviour, for instance, because it induces a break with the hypothesis of context independence (see Tversky and Kahneman 1981). In Schelling's models, the perception that people have of their neighbours and of their neighbourhood impinges on their decision about where to live and individuals' decisions are based on the environment that they help to modify by their actions (Schelling [1978] 2006, p. 169). The behaviours adopted by the individuals in his models are more like rules of behaviour than rational decisions. Rules of behaviour are characteristic of bounded rationality (e.g. see Kirman 2011). In Arrow's later account of the labour market, "rules" become screening devices used by agents in discriminating against or selecting individuals (see his "filter theory" in Arrow 1973).

Furthermore, for both Schelling and Arrow, it is impossible for individuals to predict all of the possible consequences of their choice. They indeed show in their work on discrimination and segregation that interdependent individual choices induce emergent collective patterns that the individuals have not foreseen, even when individually adopting rational behaviour, because of their information (for Arrow) or following their (supposedly) individual preference (for Schelling). Schelling's aim is to show how interdependent individuals acting intentionally can cause unintentional consequences. The objective of

28 Gautié (2007, p. 929) points out this ambiguity regarding the status of the hypothesis of rationality based on utility maximisation in Becker's work: the hypothesis is methodological (individuals act *as if* they are utility maximising); this behaviour is also presented as a result of the selection process by the market (rational agents are more competitive).

Arrow's argumentation is to justify the rationality of discriminatory behaviour, without making any hypotheses on preferences. This conception of rationality as rules in a context of uncertainty, which allows for both feedback effects and emergence, is highly congruent with the conception of rationality that emerged from the Cold War context (Erickson *et al.* 2013, Chapter 1), which descended from the omnipotence of perfect calculation to bounded rationality.

The "neoclassical" account of equilibrium that comes with the 'rationality as consistency' view is that equilibrium is conceived in a static manner (Giocoli 2003, p. 138). It corresponds to a steady state, i.e. "a state of no motion" (Weintraub 1991, p. 18). Nothing can explain the process that leads to such a situation, i.e. how and why a specific equilibrium occurs (Giocoli 2003, p. 208); it is only supposed that the plan of every individual who composes the society is congruent with all the others – everybody has maximised his/her expected utility – and no one has an interest in changing his/her plan. This is the underlying premise for the Nash equilibrium and more generally for standard game theory. Besides, in standard game theory, the outcome is predictable, since it directly relies on individuals' preferences and utility function.

Schelling and Arrow had different conceptions of the notion of equilibrium. For both of them, contrary to the static neoclassical analysis, the dynamics of interactions matter and influence outcomes. From this perspective, Schelling (1984, p. 239) underlines how standard game theory "is concerned with outcomes, not intermediate processes." In the dynamic models of segregation, there are different possible equilibria that can be derived from the same initial conditions; they are first and foremost the result of the 'processes' of individual interactive decisions. The outcomes of Schelling's model – i.e. the equilibria of the models – are not the result of consistent choices or of individual preference and represent the players' maximisation of their expected utility. Equilibria are not mere aggregations of individuals' preferences, as in each kind of game theory, whether from von Neumann and Morgenstern, from Nash or from Harsanyi (Schelling [1978] 2006, pp. 25, 182). Furthermore, equilibria are interpreted in terms of stable patterns of behaviour, i.e. in dynamic and not static accounts.

Arrow steadily moves towards his statistical theory, insisting on the non-intentional aspect of discrimination. While insisting on the possibility of self-fulfilling prophecies, he explicitly recognises the impact of social dynamics and history on outcomes – i.e. present and future discrimination. Discrimination is not simply the result of preferences but also the result of social interactions that impel unexpected outcomes. In both Arrow's and Schelling's work, it is therefore the dynamic of

interactive individual decisions that provides the how and why of a particular equilibrium. Arrow's conception of equilibrium also emphasises the non-optimal aspect, and, of course, the aggregation problems (Arrow 1951). The departure from the static equilibrium model illustrates the existence of a sub-optimal situation: a consequence of the incorporation of information in a general equilibrium model of discrimination, opposing a partial equilibrium model based on two societies trading. Discrimination is no longer a transitional state that market forces will make disappear, but an empirically consistent and stable phenomenon, reinforced by statistical discrimination and self-fulfilling prophecies.

4.2 Abstract modelling for science for action

The complexity, volatility and uncertainty of the world impose specific conditions but do not preclude intervention in the market. Those conditions are related to the fact that "the world is full of disturbances" (Schelling 2006a, p. 90) and that many self-aggravating factors exist. The prediction of Becker's tastes-based model supports the view that non-intervention markets will clear racial discrimination; the more competitive a market is, the less discrimination it generates. On the basis of Becker's model, Milton Friedman inveighed against anti-discrimination legislation (Friedman 1962, Chapter 5). The "lucky consistency" of Friedman's science and politics (Cherrier 2011) relies, in this case, on the status he gave to sovereign preferences: government should not try to impose its preferences on individuals, even if they have racist preferences. According to both Arrow and Schelling, this position is methodologically and ideologically wrong. Throughout their respective careers, Arrow and Schelling have been involved as experts on various public and national councils; they are well known for their governmental links and much of their work has been very policy-oriented (Schelling 2005, p. 41).[29] The way that they

29 Influenced by Harold Hotteling's market socialism, Arrow defines himself as a "democratic socialist" or a "mild socialist" (Klein and Daza 2013). He was a member of the Council of Economic Advisers during the Kennedy administration. A member of several committees (against political discrimination, for Affirmative Action in the Universities), he also chaired the AEA Committee on the Status of Women in the Economic Profession. Schelling worked for the Bureau of Budget (from 1945 to 1946) and for the Economic Cooperation Administration, which negotiated the Marshall Plan. He served for two years at the Executive Office of the President (1951–1953). Schelling produced numerous studies for the State Department in the 1950s and 1960s (at the Pentagon and then Camp David, for the Defense Secretary, McNamara, in 1962).

modelled dynamics, equilibrium and what is rational behaviour was very much in line with "Cold War liberalism." This expression refers to "the campaign to reassert the tenets of governmental rule legitimised by popular consent, but not susceptible to fascist or authoritarian perversions" (Amadae 2003, p. 13). Markets were becoming complex systems, systems on which one (the government) could act. The emphasis on control – what variables are available to control the system or act on it – is reinforced by the search for analytical "tools" that will serve as tools for action.

Their conception of science is embedded in their conception of the use of abstract models and the recognition of their limitations. Models are discovery tools based on the formalisation of abstract "mechanisms." Acting on the real world means resorting to modelling, and the prime purpose of modelling is to discover some mechanisms linking microfoundations with macrobehaviours that operate in the real world. A formal model then must expose the underlying real-world mechanisms to understand how to conceive some eventual action on the phenomena. Only mechanism can be the basis of the explanation. In the case of his work on residential segregation, Schelling thought of modelisation as a discovery tool rather than an evidence-making one; it had to "show" possibilities and mechanisms. In fact, to Schelling's mind, whatever the stage 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" (Schelling [1978] 2006, p. 90). From this perspective, he conceives his models as mere simulations that are first intended to exhibit a mechanism that he has intuited.[30] The underlying mechanism is the interaction of individuals under uncertainty. The thinner the scientific knowledge of a phenomenon is, the greater is the need to abstract. In the case of segregation, such a general framework was the dynamic of individual interdependent decisions and use of the dynamic system formalism. Schelling's models are rooted in both idealisation and abstraction.[31] Even if it is not a definitive proof, the *mechanism* leading to

30 It is regularly considered that Schelling's models of residential segregation are among the precursors of Agent-Based Modelling, and that ABM is seen as a form of experiments, as a new way to generate and collect data (see Epstein and Axtell 1996, Epstein 2006). We, however, think his segregation model is more a simulation device than an experiment. On this distinction, see Guala (2002, pp. 59–74). Experiment and simulation differ with respect to their level of abstraction. While experiments allow inferences to be made between systems on the basis of soundly established facts, simulations remain too abstract to permit such strong inferences.

31 Since in explaining residential segregation he eliminates some variables (with respect to individual choices), which he considers to be relevant, he includes a *ceteris neglectis* clause (see Rol 2008, p. 70).

segregation identified in the models seems operative; it models "credible worlds" (Sugden 2000).

Contrary to Becker, who makes the phenomena to be explained disappear, Arrow tries to build an explanation of its persistence despite competition. Complexity is also tackled in the way they both explain the possible relation between segregation and discrimination. In the long run, Arrow's model is compatible with wage differences coupled with tendencies to segregation, geographical separation and also segregation by occupation (Arrow 1971, pp. 19–20). These tendencies reinforce the cumulative effects of perceptions of the increasing inequalities because no learning of the "real" productivities or capacities of individuals can occur in the absence of contact. In Schelling's model, the preference structure could be modified (Hegselmann 2012, § 4.2) to complicate even more the relationship between segregation and discrimination.

In addition to the influence of RAND that we see in the need for abstraction and modelling that translates into Arrow's and Schelling's work (though, again, the type of modelling they propose is very different), we identify interdisciplinarity as another possible influence of RAND of the same kind on their modelling strategy. Recall that interdisciplinarity was indissolubly linked at RAND with systems analysis (see Section 3). Embracing all the aspects or determinants of a phenomenon such as racial discrimination and segregation cannot be done without the help of other social sciences. For Schelling, residential segregation is "on the borderline of 'market arrangements'" which entails looking "outside economics" (Schelling [1978] 2006, p. 35) and bypasses the economic sphere: the causes of segregation are multifactorial (Schelling 2006a, pp. 255–6). For these reasons, he grounds his work in the use of economic tools, and, at the same time, is open to sociology, psychology,[32] communication theory and theories of group processes (see Ayson 2004, Chapter 6). The conditions for conceiving interventions rely on such interdisciplinarity (Schelling 2006a, pp. 90–1). From such a perspective, Schelling attacked Becker's monism with regard to methodology (Schelling in Swedberg 1990, p. 194). Schelling and Arrow's conception of the relation between social sciences is very different from the defence of economic imperialism advocated by Becker (see Chassonnery-Zaïgouche 2018).

32 For instance, Schelling (1980 [1960]) often refers to the sociological concept of 'social role' as one important determinant of individual decisions in interactions. He also emphasises the role that experimental psychology can play for delineating the extent of the influence of individual perceptions on decision-making.

Arrow also emphasises that economics is not sufficient to trace the multiple causes of racial discrimination and explicitly calls for analysis going beyond market-based explanations (Arrow 1976, 1998). According to Arrow, "economic theories can say something about the effects" but are not in a position "to explain why the phenomenon occurred in the first place" (Arrow 1976, p. 236). Arrow asks, in his last paper on the topic: "[c]an a phenomenon whose manifestations are everywhere in the social world really be understood, even in only one aspect, by the tools of a single discipline?" (Arrow 1998, p. 91). When assessing the "scope and limits of ordinary economic analysis", Arrow argues that "the basic explanation [of discrimination] must lie outside the economic field." (1976, p. 235). Economics has limits essentially because of the impersonal conception of exchange (Arrow 1998, p. 97). He gives Schelling's model of segregation as an example of a new way to model emerging effects, which do not correspond to representative individuals or simple aggregation (Schelling 1971a, 1971b). But he goes further:

> The hypothesis that prices do not reflect every kind of social interaction, even those of economic importance, is used in many contexts. [It is] 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, p. 97)

The market is a special type of network, one which in earlier years he would have called a system. A transaction is a "social event" (Arrow 1998, p. 99). He abundantly quotes contributions from economic sociology (Granovetter 1973, 1988, White 1995). In his 1998 paper, Arrow retrospectively intensifies his criticism of Becker's model and points up the problem of isolating a market-based explanation for discrimination. In doing so, he clearly states that economics is limited by its tools and has to use results from other social sciences to analyse the causes of discrimination.[33]

Policy recommendations are possible once the underlying mechanisms have been formalised. Schelling (2006a, p. 240) insists on the fact that "there may be varieties of interventions to consider once we have the underlying mechanism and some appreciation of the most influential parameters." In manipulating his models manually instead of directly with a computer, he "saw" that, when imposing a strict limit on movement, everyone becomes satisfied "with less travel and more integration" (Schelling 2006a, p. 240). This could be one of the potential policy recommendations to make in the light of Schelling's models. But Schelling is extremely

33 Arrow advocates something he did not do himself, and this openness can be seen as the view of a man reflecting on the past and current state of the discipline at no pragmatic cost.

cautious in making recommendations that could count as policy-making. He lists some of the actions that might prevent areas from becoming completely segregated, but at the same time he clearly emphasises that these may be inoperative.

Like Arrow, he insists that (i) economics and economic tools are useful but limited; and (ii) that theories and models, as mere idealisations and abstractions of the world, should prevent economists from putting faith in the omnipotence of their science. Their conception of *science for action* requires an awareness of (i) the complexity of social phenomena and more generally of social conditions, and (ii) the limits to the conclusions from economic theory and modelling. This conception, accordingly, implies the need for caution with policy recommendations based on theory alone and conclusions drawn from models, especially when they deal with social phenomena. However, in analysing the relationship of their model with the external world, they both reassert the universalism of their concepts and methods and the need for openness to other social sciences.

"Science for action" is a style of research that we identified in Arrow and Schelling's conception of the use of their model: it is abstract but useful. The type and the actual policy recommendations to be extracted from these works are not as clear-cut as from other RAND studies. However, these works clearly contradict the Beckerian narrative, which consists of letting the market works.

5. Conclusion

At the turn of the 1970s, new "dissenting times" started with feminist, radical and Marxist theories of discrimination opposing Gary Becker's seminal contribution. Both Arrow and Schelling were contesting Becker's views, too, but they were at the same time players and challengers of what was not yet "mainstream" or "standard" economics, but no longer "neoclassical" economics. They sometimes played the game at the same place, during the "long and hot summers" of the late 1960s, at the RAND Corporation.

Their works criticises the conception of economics exemplified by Chicago economics and produce a very different account of modelling the determinants of action. In Schelling's and Arrow's work, despite different strategies, the social system furnishes a mechanism that goes beyond market-based explanations. We decided not to read Arrow's and Schelling's contribution in the context of the history of specific fields (welfare economics, urban economics, labour economics), methods (game theory, topography) but instead to focus on narratives within the debates on racial inequalities in the 1960s in relation to one institutional context. We argue

that this context hints why Arrow wrote on racial discrimination (he had never done so before and he did it in the context of a RAND contract with the OEO) and explains the form that Schelling's model took (programming done at RAND). We put the emphasis on the commonality of their contribution, i.e. the political context and a shared conception of "science for action." Was the development of an alternative framework to Becker's model policy-oriented or theory-oriented? We have argued in this paper that it was both, by describing the "material origins" of the two models in the RAND context and the two authors' underlying common vision of "science for action".

However, a policy impact does not follow from the fact that models are policy-oriented (Hirschman and Popp Berman 2014). Arrow's and Schelling's methodological views and the relative autonomy provided by such an environment as the RAND Corp display this particular way of seeing abstract individualistic modelisation as answering the "big problems of the day" while not clearly deriving from it clear-cut policy recommendations. The immediate impact of Arrow's and Schelling's papers was to circulate new conceptual definitions of discrimination and segregation. This new body of work opposed Gary Becker's previous analysis and in the 1970s and 1980s became central to applied microeconomics. Hence, as an epilogue but not the focus of the paper, we can mention a perspective on what they did change: not policies themselves but academic techniques via the development of the "signalling paradigm." [34] While at Harvard, Arrow and Schelling supervised Michael Spence's PhD dissertation on signalling and screening models, defended in 1972. The model was very close to McCall's (1968, 1970), developed at RAND as a major perspective from which to oppose "human capital orthodoxy" (Arrow 1973, p.193) as derived from Becker and Mincer's works. In this regard, Arrow's work plays an important role in the development of the economics of information applied to labour economics and microeconomics in general (Stiglitz 2002). In this regard, too, the influence that Schelling has with respect to his work on bargaining, negotiation and strategy is very important in political science (see Riker 1997). In economics, his innovative vision of game theory is widely recognised; his concept of focal points and its intuitive power is well known, even though very few game theorists integrate it in their theory. The dynamic models of residential segregation, for their

34 Signalling refers to the classical work by Michael Spence on the labour market: when workers hold private information about their own productivity, they will signal their ability by choosing the level of education that signals their productivity. Employers use screening procedures for the purpose of selecting individuals. See Hörner (2008).

part, have an enduring impact on economics because they opened a new research area: agent-based modelling (Epstein 2006, pp. 65–6, Kirman 2011, pp. 186–213, Hegselmann 2012, § 1.1). Therefore, the impact of the models was not so much on the policy side as on the formal development of the social sciences.

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Abstract

This paper focuses on Arrow and Schelling's contributions to the study of racial inequality in the late 1960s. We start from the authors' account of the origin of their work. Then, we locate the "material origin" of the models at the RAND Corporation in the late 1960s and show how it relates to the transfer of the RAND tool-box to the study of welfare issues. Finally, we describe how Arrow's and Schelling's modelling strategies relate to their conception of "science for action," inherited from their "warfare" work.

Keywords

Discrimination, segregation, Arrow (Kenneth J.), Schelling (Thomas C.), RAND Corporation