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Endogenous Maternity Allowances as Exemplified by Academic Promotion Standards

Abstract

I model the strategic interaction between scientists aiming for promotion and a research institution that seeks a highly productive faculty by setting a maternity allowance in the form of a minimum promotion standard. The model shows that maternity allowances need not derive from moral justice arguments but can emerge endogenously from efficiency considerations. The underlying mechanism rests on the assumption that exceptionally productive female professionals are also exceptionally productive if they choose to become mothers. Even though motherhood temporarily handicaps their productivity, it is exactly this cost of motherhood that signals the mothers' intrinsic high productivity. I explicitly refer to the academic labor market and use empirical evidence from academia to justify the model's specification, but the conclusions carry over to promotion decisions at the executive level in most professional lines of occupation.

JEL-Codes: C720, D820, J130, J160, M140, M510.

Keywords: maternity, job market signaling, fertility, research productivity, highly skilled labor, economics of science, scientometrics.

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1. Introduction

When evaluating candidates for executive positions, employers often amend the professional track record of mothers with a maternity allowance. Promotion guidelines usually rationalize these maternity allowances by claiming that motherhood not only constitutes a human right but raising children also provides considerable social benefits. As compared to other time consuming extra-professional activities which may also have adverse effects on job performance, the time constraint imposed by motherhood is thus viewed to have an altogether different significance that deserves to be taken into account when making promotion decisions. It is, of course, conceivable that this common justification of maternity allowances amounts to not much more than expressive rhetoric in the sense of Hillman (2010); but whatever the true reason for providing maternity allowances may be, considerations of fairness and moral justice dominate the public and professional discourse.

In this study, I explain the use of maternity allowances in meeting promotion standards without having recourse to arguments relating to fairness and moral justice. The basic idea rests on the assumption that productive people are not only productive on their jobs but also in many other activities. In particular, highly productive female professionals are, if they choose to have children, also exceptionally productive in their role as mothers. In academia, for example, highly proficient researchers are better able to keep their research ongoing while on maternity leave or when being burdened by raising young children. If productivity is comprehensive in this regard, female professionals can diminish the fuzziness that all measures of professional productivity suffer from, by having children. Having children is an informative and credible signal of productivity if less productive women find it impossible to combine their professional careers with motherhood.

My argument is closely related to the story line of the well-known labor-market signaling models in the tradition of Spence (1973, 1974) and Stiglitz (1975).[1] In these models, the signal is also costly and entails an activity that is potentially useless from a labor-market point of view (education providing edification as compared to human capital). The difference between my model and traditional labor-market screening models is that I consider two types of signals that determine the promotion decision: motherhood and an imprecise measure of professional productivity.[2] I show that by granting suitable maternity

[1] Surveys of the signaling literature in economics and management are to be found, respectively, in Riley (2001) and Connelly et al. (2011).

[2] My model thus belongs to the literature on dynamic signaling pioneered by Weiss (1983). This type of model continues to play an important role in education and labor economics (see, for example, Dilme and Li, 2014, and Kurlat and Scheuer, 2017). The model by Weiss (1983) assumes that pupils who have incomplete information about their ability sort themselves into a continuum of education levels. An accurate dichotomous (pass-fail) school-leaving exam attests the graduates a minimum (maximum) ability. On the basis of the education level and school-leaving exam, the employer offers a life-time income. My model has a similar structure. Junior

allowances, employers may enable highly productive professionals to signal their superiority by having children, whereas less productive professionals will remain childless. Even if highly productive professionals can send the fertility signal without maternity allowances, maternity allowances can still be introduced by the management because by doing so the likelihood of promoting lower ability candidates is reduced.

I base the structure of my model on stylized facts from the academic job marked because in academia evaluations and promotions follow especially transparent rules that rely to a large extent on readily available objective, but nevertheless fuzzy, bibliometric measures of research productivity. The Research Excellence Framework (REF) that evaluated the research productivity of British higher education institutions in the 2008–2013 period is a case in point. A maximum of four studies per researcher served as the basis of assessing the quality of their output. When a researcher submitted fewer studies, the missing studies were penalized by assigning them the lowest quality. An exception was however made for researchers who were constrained in their research production by individual circumstances, notably maternity. For each discrete period of statutory maternity leave, researchers could reduce the number of studies by one. The maternity allowance for each child born in the six-year assessment period thus amounted to 25% of the adopted standard.

Even though my model explicitly refers to the academic labor market, the conclusions carry over to other market settings because the model portrays the backdrop of promotion decisions at the executive level in any line of occupation. It does so by portraying employees who derive pleasure from successfully attending to their professional responsibilities, i.e. the employees pursue their professional careers not merely for a living. By succeeding professionally, they rather seek to confirm their identity and to gain self-fulfillment.

The interaction between employer and employees is portrayed from a decidedly managerial perspective; technically speaking, the interaction is reduced to a partial equilibrium setting that is common in personnel economics. The alternative would be to embed the described signaling mechanism in the entire labor market environment of, let's say, university graduates aspiring for identity-creating professions and to investigate the general equilibrium consequences of widely used maternity allowances. In such a model, female graduates would choose which firms or academic institutions they apply to by making their decision contingent on their heterogeneous profiles and the potential employers' career development programs in the form of maternity allowances. The employees would thus self-select themselves into specific career tracks, implying that the promotion decision rules become part of their choice set. Different firms or university departments would then face a different

professionals are also incompletely informed about their ability and choose to become mothers or remain childless (the choice set is thus not continuous but dichotomous). The subsequent record of professional accomplishments is however continuous (not dichotomous as in the Weiss model) and does not allow the observer to infer any assured information on the level of productivity.

ability composition of their junior faculty and chose their respective maternity allowances accordingly. Since incremental changes in the promotion policies have negligible effects on the junior faculty intake, a partial-equilibrium model, starting off at the stage when the promotion policies are changed, does not neglect a great deal of information that is essential from a managerial point of view.

Apart from the assumption that professional careers are to a substantial extent pursued for gaining self-fulfillment and the partial-equilibrium modelling strategy, four stylized facts of professional careers constitute the main structural elements of my model. In the following section, I introduce and substantiate these stylized facts by briefly describing some pertinent aspects of the relationship between research productivity and motherhood. I then proceed to present the model, derive its equilibrium behavior, and discuss some of its properties and implications.

2. Research productivity and parenthood: Four stylized facts

To specify my model, I rely on empirical findings that emerge from a questionnaire survey conducted by Krapf et al. (2017) to study the influence of parenthood on research productivity of academic economists. The questionnaire was sent to all economists registered with the RePEc Author Service (https://authors.repec.org/) in early 2012. The RePEc Author Service allows authors to build a portfolio of their research output published in outlets indexed by RePEc. In 2012, about 1500 publishers listed 1.3 million research items authored by 30,978 registered RePEc authors. The response rate of the survey amounted to 32.5%, which, after deleting non-active members, corresponds to 9,939 individuals whose response was linked to their RePEc publication records.[3]

It is well known that the compatibility of motherhood with pursuing a successful professional career depends, among other factors, largely on the age at first childbirth.[4] Figure 1 depicts the age distribution at first childbirth of the female economists in the sample collected by Krapf et al. (2017).

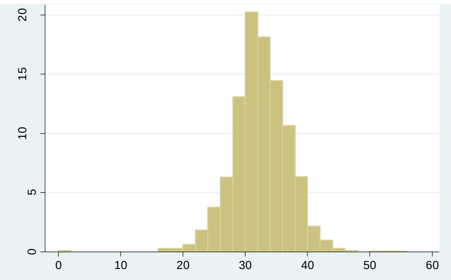

Figure 1a: Biological age at first birth

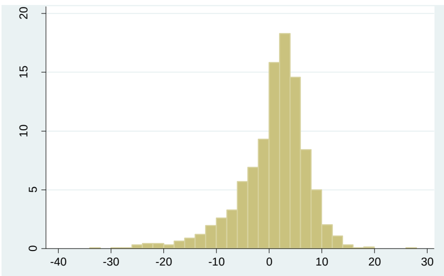

Figure 1b: Career age at first birth

[3] For a detailed discussion of the selection-bias issue, see Krapf et al. (2017), section 3.1.
[4] Cristia (2008) and Fitzenberger et al. (2013) estimate large negative effects of not delaying first birth on mothers' employment in the U.S. and Germany. Miller (2011) documents that the timing of first birth has a strong effect on future career outcomes in terms of wages for U.S. mothers and Wilde et al. (2010) find that the lifetime costs of early childbearing are particularly high for skilled women.

The first panel depicts the distribution of the *biological age* of female economists at first childbirth. The mean and median age is about 32. This is substantially higher than in the general population: in 2009, the mean age of women at the birth of their first child varied across OECD countries from 21.3 years in Mexico to 30.5 years in New Zealand. The second panel depicts the distribution of the *career age* of female economists at first childbirth, where career year 0 denotes the year in which the economists earned their PhD degree. The mean career age at first child birth is 0.4 and the median career age is 1.0 years. These findings are summarized as

> **Stylized fact 1**: Typical female economists with children gave birth to their first child about one year after receiving their PhD, i.e. in their early 30s.

Since female economists are relatively old at first childbirth, the question arises as to whether they wait with their fertility decision until they are able to assess their professional prospects in a reliable manner. In academia, the road to success is paved with publications. Figure 2 therefore depicts the distribution of the cumulated research output at the end of the second career year of women who were at the time of the survey at least 40 years old.[5] This restriction is necessary because differentiating between women who either are or eventually become mothers and women who remain childless requires a sample of women who, at the time of the survey (in our case in in 2012) are already at an age at which becoming pregnant is unlikely. Furthermore, notice, that the employed measure of research productivity (the RW index) dates output at the time it first appears as a working paper. This measure has the advantage of dating research effort more precisely than measures that make do with the date of publication in a journal. The quality weights used in both types of measures corresponds to the quality of the journal in which the output is (eventually) published which could be several years after the publication of the working paper.

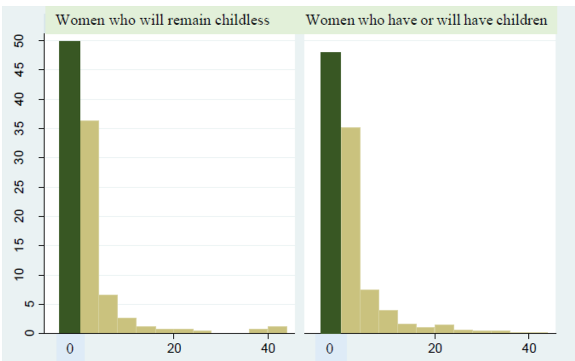

Figure 2: Cumulated research output at the end of
The second career year

[5] The data is again taken from the survey by Krapf et al. (2014). I use the research output at the end of the second career year instead of the output at the end of the median career year at first childbirth, i.e. career year 1, in order to allow for a publishing lag that may escape the RW measure of research productivity.

The two distributions depicted in Figure 2 indicate that at the age when female economists typically have their first child, the research records of economists who will remain childless do not differ from those who are already mothers or eventually will have children. At the end of the second career year the mean research output as measured by the RW indicator amounts to 2.15 (SD 6.3) for female economists who remain childless, and 2.49 (SD 6.2) for female economists who were already mothers or had children afterwards. Indeed, according to the Kolmogorov-Smirnov (KS) test for equality of distributions, we cannot reject the hypothesis that the two distributions are drawn from the same populations: the p-statistic of the KS test amounts to 31.5%. Restricting the sample to serious contenders for tenured positions, i.e. female economists who had at the end of their sixth career year at least 2 RW points to their credit, the respective means (standard distributions) for the second career year are 5.71 (9.5) and 5.83 (8.6). Up to the end of the fourth career year, the distributions of research productivity are actually very similar for the two groups.[6] Only beginning from the fifth year, the p-values of the KS tests begin to drop. This empirical evidence strongly suggests that even if female economists who are or will become mothers are indeed inherently more productive than female economists who will never have children, these differences are far from obvious at the end of the second career year. When junior scientists critically assess their professional skills by comparing, for example, their skills with the skills of their peers, this self-assessment thus mainly draws on limited information and unreliable insights.

> **Stylized fact 2**: At the age when typical female academic economists decide whether to have children or to remain childless, the self-assessment of their research prowess is liable to be fraught with substantial uncertainty.

The information provided in Figure 2 is replicated in Figure 3a for the research accomplishments achieved by the end of the 6th career year. Even though the KS test for equality of distributions still does not reject the hypothesis that the two distributions are drawn from the same population (the p-value is 18%), it is evident that the distributions have become more dissimilar: mothers and scientists who eventually will become mothers now appear to do better than women who will remain childless. The distributions in Figure 2 and 3a also nicely illustrate Lotka's law that predicts an exponential distribution of research output, implying in particular that low research outputs are very common. It is therefore not surprising that almost one half of the female academic economists have not yet produced any countable research output by the end of the second postdoc year (see Figure 2). Perhaps more surprising is that at the end of the 6th postdoc year over a quarter of all female economists still have nothing countable to show. This is, however, not a finding that is restricted to women. The research production patterns of male economists are not much different from the patterns shown here for females, even though male economists are, on average, more productive than female economists.[7]

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[6] The p-values of the KS-tests are also close to 30% for the distributions at the end of the third and fourth year.

[7] More detailed results for male and female economists are to be found in Krapf et al. (2017).

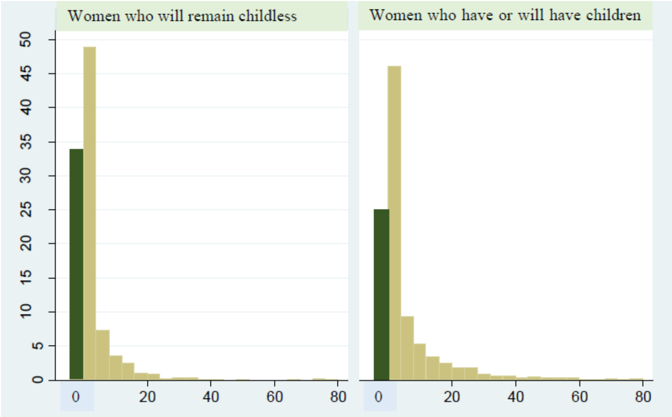

Figure 3a: Cumulated research output at the end of the sixth career year

One should however not jump to the conclusion that this paucity of research achievements necessarily indicates low ability. The scatter diagram depicted in Figure 3b shows how the research output of the female economists in the sample collected by Krapf et al. (2017) develops in the long run. It transpires that the cumulated research output at the end of the 24th career year when the economists usually are in their early 50s does not strongly correlate with the cumulated research output at the end of their sixth career year. The average research oeuvre of female economists at the end of her sixth career year amounts to about 5 RW points, and increases until the end of the 24th career year to about 9 RW points. Figure 3b indicates that many young scientists who appear to be underachievers manage to embark over the long haul on above average academic careers. Low research output at the beginning of an academic career thus does not necessarily reflect low ability, it rather documents that research is a business associated with a great deal of uncertainty. The third stylized fact summarizes this result.

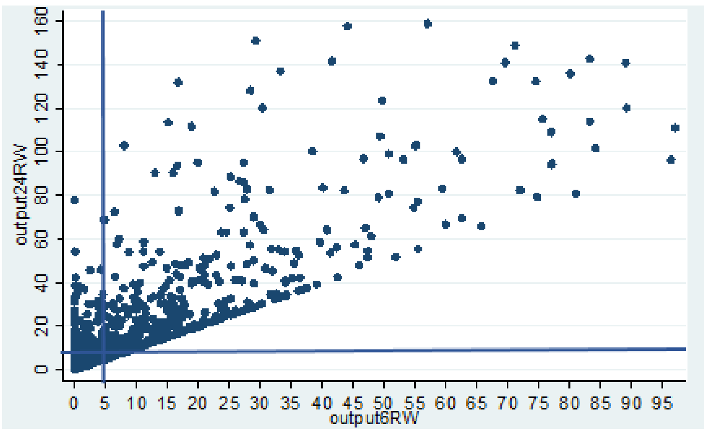

Figure 3b: Research output, end of career years 6 and 24 (female economists)

Stylized fact 3: Research productivity indicators are fuzzy measures of inherent research skills: low output does not necessarily indicate low skills and zero countable research output even after 6 career years is not uncommon.

One of the most striking results of merging the survey-gathered information about motherhood with the research records of the female respondents indicates that female economists with strong publication records are more often mothers than are female economists with weaker publication records. Figure 4 depicts the research productivity patterns across career time for female economists with no children, one child, and two or more children. Notice, that the sample is again restricted to women who received their PhD before 1990; we thus deal here with the sample of academic survivors that also underlies Figure 2.

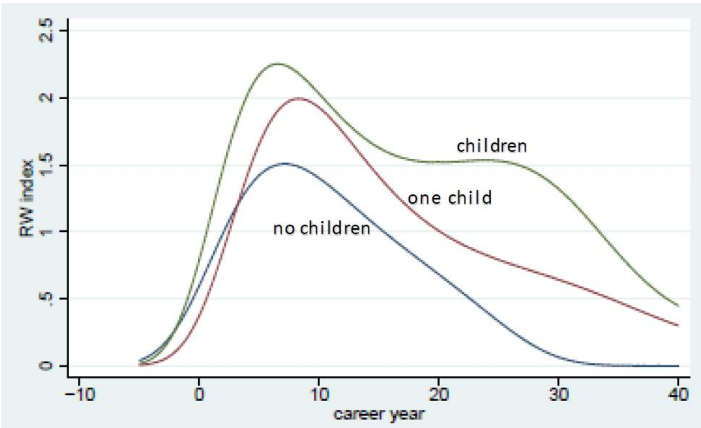

Figure 4: Average patterns of life-cycle productivity of female economists with no, one, and two or more children

Figure 4 indicates that mothers of two or more children are, on average, more productive than mothers of a single child, who, in turn, are more productive that female economists without children.[8] Joecks et al. (2014) find similar results for researchers in economics and business administration affiliated with Austrian, German, and Swiss universities.[9] At the first glance, this piece of empirical evidence, i.e. the fourth stylized fact to be used in designing the model, appears to go against the grain, perhaps because motherhood is immediately associated with an additional burden that is liable to reduce research productivity. Motherhood is however not exogenous. Women rather base their fertility decision on a cost-benefit calculus that includes strategic considerations relating to their job-market prospects.

[8] Using other measures of research productivity does not substantially change this stylized fact (see Krapf et al., 2014, section 4.2).

[9] These results are reminiscent of the study by Amuedo-Dorantes and Kimmel (2005) that finds that college-educated mothers do not experience a motherhood wage penalty at all but rather enjoy a wage boost when compared to college-educated childless women. Other studies report no motherhood effects (Datta Gupta and Smith, 2002) or motherhood wage penalties that decrease with the skill level (for example Budig and Hodges, 2010). All of these findings are however not uncontroversial (Killewalda and Bearak, 2010; Wilde et al., 2010, Betrand et al. 2010).

Stylized fact 4: Female economists with children are, on average, more productive researchers than are female economists who have no children.

I now proceed to piece stylized facts 1-4 together to arrive at a model that portrays the strategic interaction between junior professionals seeking promotion and an employer that aims at hiring highly skilled senior staff members. The model will then be used to investigate how maternity allowances can influence the female scientists' fertility decisions and how the department, taking the endogenous fertility decisions into account, determines the promotion standards and the maternity allowance. As will become apparent, the modeled interaction will, under realistic conditions, give rise to the endogenous, i.e. managerially induced, emergence of maternity allowances.

3. The Model

I consider a university department that requires a senior faculty of a given size.[10] At the first stage of the game, the department frames the rules that govern its promotion decisions. In the academic job market, the decisive promotion may best be taken to mean granting tenure. I will therefore use this term when referring to academic promotion. At the second stage, the members of the junior faculty react to these rules and at the end of the game the tenure policy is implement. The model thus portrays a single early career step that often plays a momentous role in the progression of a candidate's professional career. This kind of momentous promotion is also common in the corporate sector and in public administration.

To focus on the motherhood issue, I blind out the more comprehensive gender issue and assume that the department reserves for each cohort a given number of senior-position slots for female candidates. Departments may do that for diversity reasons or to neutralize a possible gender bias caused by women being, ceteris paribus, less inclined to participate in contests (Bosquet et al., 2013).[11] Explicitly (and perhaps counterfactually) assuming that the gender issue is resolved, allows however above all to concentrate the study on the issue of maternity allowances. Admittedly, I adopt this modelling strategy also because of its clear advantages in terms of analytical convenience. Dropping the quota would result in three types of junior faculty: members who signal in the separating equilibrium their self-perceived high ability (mothers), members who, by default, signal self-perceived low ability (childless women), and members who cannot signal their self-perceived ability (men). Since the natural assumption when doing away with the gender quota would be that men are evaluated according to the standard applied to

[10] The Job market for junior faculty in economics is described in Coles et al. (2010) and the self-selection of graduates into basic, applied and industrial research in Agarwal and Ohyama (2013).

[11] Notice, that gender quotas need not derive from an attempt to neutralize discrimination. As a matter of fact, I prefer to assume here that the assumed quota derives from other reasons because I do not want to taint my claim that maternity allowances can emerge endogenously with any subargument referring to moral justice. For a survey of gender equality measures aimed at promoting women to senior positions in European public research, see European Commission (2008).

childless women, mothers would outperform men in the longer run.[12] This is, however, not what we observe. All bibliometric studies including Krapf et al. (2017) show that the research productivity of men is, on average, higher than the research productivity of women. A realistic portrait of the academic labor market that explicitly includes the male junior faculty would thus require a richer model, i.e. a model that takes into account more refined signaling techniques that allow all candidates to send informative ability signals. Several possibilities of doing so spring to mind, for example a continuous range of candidate abilities or, as introduced by the pioneering study by Kurlat and Scheuer (2017), employers with heterogeneous expertise in evaluating the candidates' abilities.

The number of quota slots is given by assumption and the number of eligible candidates is usually also known. The probability P^t that a randomly chosen female candidate is actually promoted (tenured) is therefore given: $P^t = k$. The department aims at maximizing the research prowess of the newly recruited senior faculty. For that purpose, the department can set two tenure standards. The first one, $\bar{x}^c > 0$, defines the minimum research output (measured, for example, by quality weighted journal publications) for candidates who have children; the second one, $\bar{x} \geq \bar{x}^c$, defines the minimum research output for the childless female candidates. The difference $\bar{x} - \bar{x}^c$ is the maternity allowance.[13]

There are two types of scientists: high-ability and low-ability scientists. With probability ρ a scientist has high ability H, and with probability $1 - \rho$ low ability L.[14] This is common knowledge. The crucial relationship portrayed in this model runs from ability to fertility. Since, according to the first stylized fact, (female) academic economists have their first child typically not much later than the year after receiving their PhD, they make their fertility decision at a stage of their academic career when they have not much more information at their disposal than their experience gained in graduate school. At that stage, their research experience and the associated research output is still rather small. The self-assessment of their research abilities is therefore fraught with substantial uncertainty and subject to misjudgment. I model this uncertainty as follows: before deciding whether to have children or not, the scientists receive a private signal about their ability. The signal is, however, not perfect: with probability $\theta > 1/2$ the signal indicates the true ability level, and with probability $1 - \theta$ the signal indicates the wrong ability level. The fuzziness of the private ability signal corresponds to the second stylized fact

[12] Here an interesting issue with respect to anti-discrimination laws arises. In a model with three different groups of candidates in which men are treated like childless women, men would suffer from *indirect discrimination* because they have no opportunity to signal their superior ability apart from producing more research output than less able candidates. Since employers are better able to identify the productivity of women, they might, even in the absence of anti-discrimination laws, favor women when hiring junior staff. This argument goes against the general presumption that employers avoid hiring women because of the pregnancy risk. On unintended consequences of gender-neutral promotion policies in academia, see also Antecol et al. (2018).

[13] Notice, that this tenure rule does not induce competition between candidates for tenure. Matching of heterogeneous candidates to heterogeneous firms (here departments) with the help of a tournament mechanism is modeled in, for example, Hopkins (2012).

[14] In reality, ability is, of course, a continuous variable. Distinguishing only two ability classes is due to analytical convenience and the norm in this type of literature (see, for example, Kurlat and Scheuer 2017 for a recent study).

identified in the previous section.

After having received the ability signal, the scientists use Bayes' rule to update their a priori belief of being of high or low ability. The probability of being of type H, conditional on having received the high-ability signal (s=H), is

$$P(H|s = H) = \frac{\theta\rho}{\theta\rho+(1-\theta)(1-\rho)}.$$

Without unduly jeopardizing the generality of the qualitative results, let the unconditional probability ρ of a scientist being of high ability be one half, so that $P(H|s = H) = P(L|s = L) = \theta$ and $P(H|s = L) = P(L|s = H) = 1 - \theta$. Based on the posterior, the scientists decide whether to have a child or not. Afterwards the research output begins to accumulate in earnest.

Research output is assumed to be stochastic. Producing no countable output is always possible as indicated by the third stylized fact. The probability that a high ability scientist (H) with no children (nc) will produce zero countable output amounts to $z_{nc}^{H} \in (0,1)$. With probability $1 - z_{nc}^{H}$ the output will be positive. In this case, the output x_{nc}^{H} is drawn from a uniform distribution over the support $(0, 1]$; i.e. unity denotes the maximum possible output. An analogous "production technology" applies to the output of high ability scientists with children (x_{c}^{H}) and low ability scientists with and without children (x_{c}^{L}, x_{nc}^{L}). Figure 5 illustrates the assumed "technology."

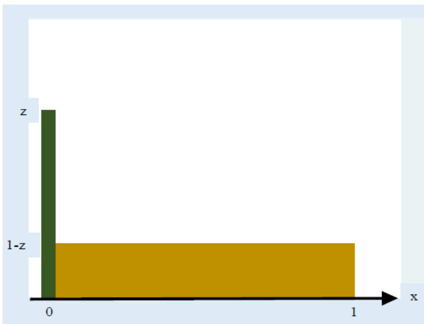

Figure 5: Probability distribution of individual research output

It goes without saying that this simplistic specification does not reflect all properties of realistic research production. For example, if a low-ability scientist produces some countable research output at all, the probability of her output being of high quality is identical to the probability of a high-ability scientist to produce output of the same quality. Even though Oswald (2007) finds that many articles published in highly reputable journals remain often uncited (which might well indicate low quality delivered by scientists with limited abilities), the employed specification was clearly guided by considerations of analytic convenience. Since I do not intend to draw any normative conclusions from my model but rather attempt to explain some observed phenomena, this crude specification, which is reminiscent of Lotka's Law, is permissible.

The research production technology employed by the four types of scientists (high and low ability, with and without children) thus differs only by the zero-output probabilities. By definition

$$z_c^L > z_c^H \text{ and } z_{nc}^L > z_{nc}^H. \quad \text{(Z1)}$$

Moreover, because pregnancy and rearing children is costly in terms of professional activities,[15] we have for some years following childbirth

$$z_c^L > z_{nc}^L \text{ and } z_c^H > z_{nc}^H. \quad \text{(Z2)}$$

The crucial ingredient of the model is that highly productive researchers are assumed to be also more efficient in managing their family life than less productive researchers, i.e. the reduction in research productivity induced by parenthood is larger for L-type than for H-type scientists. Measuring research productivity by the probability density 1-z of non-zero output, one arrives at the constraint

$$(1 - z_{nc}^H) - (1 - z_c^H) < (1 - z_{nc}^L) - (1 - z_c^L) \quad (1)$$

which is equivalent to

$$0 < \Delta z^H \equiv (z_c^H - z_{nc}^H) < \Delta z^L \equiv (z_c^L - z_{nc}^L). \quad \text{(Z3)}$$

This constraint gives rise to the outcome that in a separating equilibrium mothers are more likely to be of high ability than childless women, thereby rendering the model's behavior compatible with the fourth stylized fact. The absolute advantage of the H-type scientists imposed by (Z3) implies, of course, also a relative advantage:[16]

$$\frac{1-z_c^L}{1-z_{nc}^L} < \frac{1-z_c^H}{1-z_{nc}^H}. \quad \text{(Z3')}$$

The scientists maximize their expected payoff deriving from the utility function

$$V = \alpha x + \beta t + c,$$

where x denotes research output, the dummy variable t assumes the value t=1 if the scientist is granted tenure (and zero otherwise), and the dummy variable c assumes the value c=1 if the scientist has a child (and zero otherwise). Research output x is valued ($\alpha > 0$) for intrinsic reasons; the model thus portrays jobs that provide opportunities for self-realization. Tenure is however also valued ($\beta > 0$) because it comes with job security, a higher income, and may, in addition, provide an ego rent. As

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[15] Combining motherhood with professional obligations may, of course, also cause other types of costs, such as increased stress (Buddelmeyer at al., 2015).

[16] Dividing the first inequality in (1) by $1 - z_{nc}^L$ and rearranging yields $\frac{1-z_c^L}{1-z_{nc}^L} < 1 + \frac{z_{nc}^H - z_c^H}{1-z_{nc}^L}$. Subtracting on both sides $\frac{1-z_c^H}{1-z_{nc}^H}$ yields $\frac{1-z_c^L}{1-z_{nc}^L} - \frac{1-z_c^H}{1-z_{nc}^H} < \frac{(z_{nc}^H - z_c^H)(z_{nc}^L - z_{nc}^H)}{(1-z_{nc}^H)(1-z_{nc}^L)} < 0$ because $(z_{nc}^H - z_c^H)$ is the only negative term.

long as any heterogeneity in tastes (particularly in children) is not correlated with ability, the assumption of identical preferences is innocuous.[17]

The department finally observes the scientists' research output and family status. The family status is informative for the department because the productivity signal received by the individual scientists is not observable by outsiders and the observed research output is still too small to provide conclusive evidence (as indicated by the third stylized fact). The model's chief point is that the scientists can transform their beliefs about their scientific prowess into a credible productivity signal by becoming mothers. Based on this observation and the documented research portfolio, the department now makes the tenure decision according to the rules determined at the beginning of the game. The objective of the department (to retain high ability scientists) can thus be restated formally as follows: subject to the constraint $P^t = k$, the department maximizes the probability $P(H|\, t)$ of choosing a high-ability scientist when granting tenure.[18]

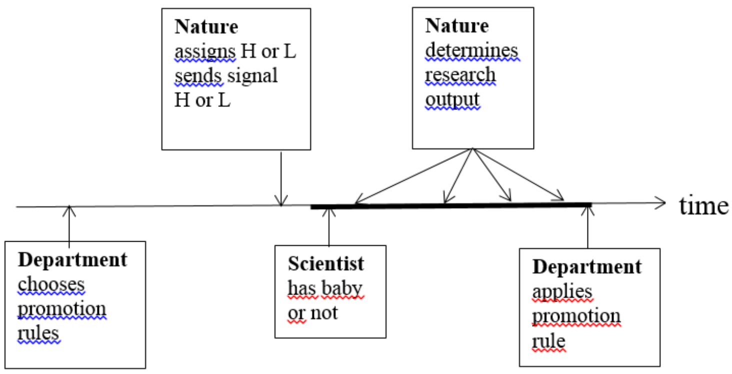

Figure 6: The structure of the game

Figure 6 depicts the structure of the entire game. Without unduly restricting the generality of the model, I assume that the time at which the tenure decision takes place is given. This assumption allows to frame the tenure rules $(\bar{x}^c, \bar{x})$ independent of career age. The important restriction is not the timing of the tenure decision as such, but rather that the decision is taken not too late in the career, i.e. not at a career time when the record of accomplishments has already completely revealed the scientist's inherent ability. In the context of academia, the model thus portrays a "European"-type tenure rule, i.e. a rule

[17] If the characteristics of the scientist's partner (father) are not correlated with ability, the implicit assumption that utility V does not depend on these characteristics is also innocuous. In the very narrowly defined professional segment (academic scientist), one can safely assume that partner choice and productivity are uncorrelated.

[18] An alternative objective of the department could be maximization of research output. Since, however, the visibility and reputation of a research institution depends much more on high-quality research than on the quantity of research output, maximizing the staff's research prowess appears to capture this objective much better.

with a prespecified time of tenure (usually six years after having received the PhD). “American”-type rules which set $\bar{x} = \bar{x}^c$ but grant mothers extra time on the tenure track could, in principle, also be portrayed by a similar model setup. Instead of identifying an optimal maternity allowance, one would arrive at an optimal tenure clock, i.e. a tenure clock that is sufficiently generous to let high ability women have children, but not low-ability women. But this way of modelling the promotion or tenure process would come at the price of a much narrower scope because in most non-academic professions promotions are usually not deferred in such a manner.

Furthermore, notice, that the first move of the department is not followed by the second move commonly modeled in fully fledged principal-agent games: the scientist’s participation decision is omitted. As pointed out in the Introduction, this is not to mean that the chosen tenure rules do not influence the number and possibly also the gender and ability composition of the recruited junior faculty. Refraining from explicitly modelling the participation decision rather reflects the presumption that departments know from experience what their intake of new junior faculty on average looks like. Since the tenure rules are rarely changed and, if so, incrementally, the tenure rules and the junior faculty intake can be assumed to be in equilibrium, implying that the interaction between the two need not be modeled explicitly in the partial equilibrium context of managerial decisions.

4. Equilibrium analysis

Since the department can commit to applying the codified tenure procedure, the game features the familiar Stackelberg structure. I therefore begin the equilibrium analysis by deriving the action of the Stackelberg follower, i.e. by establishing the fertility decision for a given tenure policy characterized by the state-contingent minimum tenure requirements $\bar{x}^c$ and $\bar{x}$.

4.1 The fertility decision

Consider a scientist who has received the high-ability signal s=H indicating. Her expected utility from having children amounts to

$$EV(s = H, c = 1) = 1 + \alpha[P(H|s = H)E(x|H) + P(L|s = H)E(x|L)] +$$

$$\beta[P(H|s = H)P(x \geq \bar{x}^c \,|\, H) + P(L|s = H)P(x \geq \bar{x}^c \,|\, L)]$$

$$= 1 + \left(\frac{\alpha}{2} + \beta(1 - \bar{x}^c)\right)(1 - \theta z_c^H - (1 - \theta)z_c^L).$$

Similarly, the expected utility of a scientist who has received the signal s=H from having no children amounts to

$$EV(s = H, \mathrm{c} = 0) = \left(\frac{\alpha}{2} + \beta(1 - \bar{x})\right)(1 - \theta z_{nc}^{H} - (1 - \theta)z_{nc}^{L}).$$

A scientist who has received the high-ability signal s=H thus decides to have children if and only if $\Delta V^{H} = EV(s = H, c = 1) - EV(s = H, c = 0)$ is non-negative. She is indifferent between having children and having no children if $\Delta V^{H} = 0$. A scientist who has received the low-ability signal s=L is indifferent when $\Delta V^{L} = 0$.

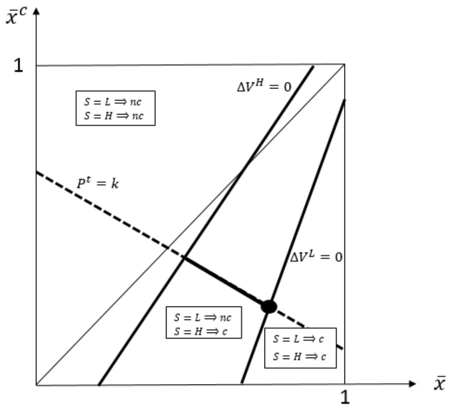

Figure 7: indifference loci in the tenure-policy space

Figure 7 depicts the two indifference loci $\Delta V^{H} = 0$ and $\Delta V^{L} = 0$ in the tenure-policy space. Tenure thresholds $(\bar{x}, \bar{x}^{c})$ above the indifference loci induce the respective scientists to remain childless, i.e. for tenure policies $(\bar{x}, \bar{x}^{c})$ above the $\Delta V^{H} = 0$ line, nobody will have children, and for policies below the $\Delta V^{L} = 0$ line, all scientists will have children. For policies between the two lines, only scientists who receive the high-productivity signal will have children. The following Lemma describes the location of the two indifference loci (the proof is in the Appendix).

Lemma

Given assumptions Z1-Z3, the following holds:

(a) The slopes of the indifference loci $\Delta V^{H} = 0$ and $\Delta V^{L} = 0$ are larger than unity.

(b) The slope of the $\Delta V^{H} = 0$ locus is smaller than the slope of the $\Delta V^{L} = 0$ locus.

(c) For α sufficiently large, the $\Delta V^{H} = 0$ locus lies above the $\Delta V^{L} = 0$ locus and the $\Delta V^{L} = 0$ locus lies below the 45^{0}-line.

The configuration of the indifference loci depicted in Figure 7 thus presumes that parameter α measuring the scientist's intrinsic valuation of her research output is sufficiently large. If this condition is satisfied, separation always implies that receivers of the signal s=H do have children, whereas receivers of the s=L signal remain childless.

The information summarized in Figure 7 thus yields

> **Proposition 1**
> Given assumptions Z1-Z3 and suitable values of the parameters α and β, tenure policies $(\bar{x}, \bar{x}^c)$ that separate signal-H from signal-L receivers, such that signal-H receivers have children, whereas signal-L receivers remain childless, are feasible.

Under separation, scientists with children are, on average, of higher ability than childless scientists because the signal is informative ($\theta > 1/2$). If the productivity of high-ability scientists with children is higher than the productivity of childless low-ability scientist, i.e. if $z_c^H > z_{nc}^L$, separation thus gives immediately rise to our fourth stylized fact. However, even if $z_c^H < z_{nc}^L$, the high-ability mothers will eventually, when their children become youngsters, outperform childless scientists of low ability.

4.2 The optimal separating equilibrium

I now turn to the calculus of the first mover, i.e. the department. To obtain more information about the ability of the candidates eligible for tenure, the department prefers a policy $(\bar{x}, \bar{x}^c)$ that separates candidates who received the s=*H* signal from candidates who received the s=*L* signal. According to Proposition 1, such a separation can be induced by any tupel $(\bar{x}, \bar{x}^c)$ of tenure thresholds between the two indifference loci in Figure 7.

To identify the optimal tenure policy $(\bar{x}, \bar{x}^c)$, the department needs to consider the constraint $P^t = k$ that guarantees that, over time, all vacancies are filled. To nail down this constraint, notice that in a separating equilibrium the probability of a type-H candidate being promoted (tenured) amounts to

$$P(t|H) = P(H|s = H)P(t|c = 1, H) + P(H|s = L)P(t|c = 0, H)$$

$$= \theta(1 - z_c^H)(1 - \bar{x}^c) + (1 - \theta)(1 - z_{nc}^H)(1 - \bar{x}) \quad (2)$$

and similarly for a type-L candidate.[19] The probability of an arbitrarily chosen candidate being promoted therefore amounts to

$$P^t = \frac{1}{2}\, P(t|\, H) + \frac{1}{2} P(t|\, L)$$

$$= \frac{1-\bar{x}^c}{2}\{\theta(1 - z_c^H\,) + (1 - \theta)(1 - z_c^L\,)\} + \frac{1-\bar{x}}{2}[(1 - \theta)(1 - z_{nc}^H) + \theta(1 - z_{nc}^L)] \quad (3)$$

[19] $P(t|L) = (1 - \theta)(1 - z_c^L)(1 - \bar{x}^c) + \theta(1 - z_{nc}^L)(1 - \bar{x})$

which needs to be equal to the demand k of new faculty members. The slope of the $P^t = k$ line in the tenure-policy space $(\bar{x}, \bar{x}^c)$ turns out to be negative and shifts downwards in the tenure-policy space as demand *k* for tenured faculty increases (see Appendix).

Since the department attempts to select those candidates who are most likely of type *H*, the department chooses that tupel $(\bar{x}, \bar{x}^c)$ of tenure thresholds on the $P^t = k$ line between the two indifference loci $\Delta V^H = 0$ and $\Delta V^L = 0$ that maximizes $\text{P(H}|t) = \frac{P(t|\,H)P(H)}{P^t} = \frac{P(t|\,H)}{2k}$. The department thus maximizes $P(t|\,H)$ as given in equation (2) subject to $P^t = k$. It turns out that $\frac{dP(t|H)}{d\bar{x}}(P^t = k)$ is positive (see Appendix), i.e. the share of high-ability scientists among the promoted scientists increases as the tenure threshold $\bar{x}$ is increased on the $P^t = k$ line, which, in turn, implies that the tenure threshold $\bar{x}^c$ is decreased. Since corner solutions which either prohibit childless women from being promoted $(\bar{x} = 1)$ or grant tenure to all mothers if they have any countable research output at all $(\bar{x}^c \longrightarrow 0)$ are not realistic, we seek interior solutions which are described in

Proposition 2

The optimal interior separation-inducing tenure policy $(\bar{x}, \bar{x}^c)$ is characterized by the intersection of the $P^t = k$ line with the indifference locus $\Delta V^L = 0$.

Among the tenure policies that satisfy the market constraint $P^t = k$, the optimal tenure policy thus maximizes the maternity allowance $\bar{x} - \bar{x}^c$.[20]

4.2 Pooling equilibria

The question remains as to whether the optimal tenure policy inducing separation is superior to tenure policies that induce pooling. Under a tenure policy that induces *pooling on children* the probability that a promoted scientist is actually of high-ability is

$$P(H|t)^c = \frac{1}{2}\frac{P(t|H)}{P^t} = \frac{1-z_c^H}{(1-z_c^H)+(1-z_c^L)}.$$[21]

The probability that a promoted scientist is actually of high ability when the tenure policy induces *pooling on no children* is

$$P(H|t)^{nc} = \frac{1-z_{nc}^H}{(1-z_{nc}^H)+(1-z_{nc}^L)}.$$

[20] As is usual in this literature, I assume that indifferent agents behave the way that pleases the author.
[21] The probability of promoting a high-ability scientist is $P(t|H) = P(x \geq \bar{x}^c|H, c = 1) = (1 - z_c^H)(1 - \bar{x}^c)$ and the probability of promoting a low-ability scientist is $P(t|L) = (1 - z_c^L)(1 - \bar{x}^c)$. The probability of a randomly chosen candidate being tenured is therefore $P^t = \frac{1}{2}\big((1 - z_c^H) + (1 - z_c^L)\big)(1 - \bar{x}^c)$.

Notice, that under tenure policies inducing pooling, the probability of a promoted candidate having high ability is independent of the demand for newly tenured faculty members as measured by k and is thus independent of the tenure standard $\bar{x}$ in the case of *pooling on no children* and on $\bar{x}^c$ in the case of *pooling on children*.

Given the assumed constraints on the productivity parameters, it turns out that $P(H|t)^c > P(H|t)^{nc}$ (see Appendix). We thus have

Proposition 3

A tenure policy that induces pooling on children yields a higher ability faculty than a tenure policy inducing pooling on no children.

The mechanism underlying this result is simple. Children reduce productivity (assumption Z2). In an environment in which all junior faculty members have children, the tenure standard needs to be smaller than in an environment in which everybody is childless, otherwise not all senior faculty slots can be filled. The lower tenure standard is however not to the advantage of low-ability scientists because children increase the disadvantage of low-ability scientists in the rat race: when everybody is handicapped with children, high-ability scientists outperform their low-ability peers even more than in a situation in which nobody has children.

This result is perhaps not surprising, but it is packed with social explosives. If granting no maternity allowances induces all female employees to remain childless, a policy that induces all women to become mothers will improve the employers' ability to distinguish between high and low ability female employees. The introduction of maternity allowances is then clearly in the interest of the employer. In this case, motherhood allowances emerge endogenously and thus do not need to be imposed on indignant employers by any outside upholders of moral standards.

4.3 Comparing separation with pooling on children

Proposition 3 shows that in order to identify the best tenure policy for the department, one only needs to compare the optimal separation policy as described in Proposition 2 with the policy that induces pooling on children. To do so, observe from (2) and (3) that when the department uses a separation-inducing policy, the probability of a promoted scientist being of high ability equals

$$P(H|t)^s = \frac{P(t|H)}{2P(t)} = \frac{\theta(1-z_c^H)(1-\bar{x}^c)+(1-\theta)(1-z_{nc}^H)(1-\bar{x})}{(1-\bar{x}^c)[\theta(1-z_c^H)+(1-\theta)(1-z_c^L)]+(1-\bar{x})[(1-\theta)(1-z_{nc}^H)+\theta(1-z_{nc}^L)]}.$$

Notice, that in a separation equilibrium the probability $P(H|t)$ depends on the demand for newly promoted faculty as measured by $P^t = k$ and therefore also on the tenure standards $\bar{x}$ and $\bar{x}^c$.

Separation is superior to pooling if $P(H|t)^s > P(H|t)^c$. The following Proposition describes when this is the case. The proof is in the Appendix.

Proposition 4

If the ability signal is sufficiently informative, i.e. if θ is sufficiently large, then (for suitable values of the parameters α, β, and k) the optimal tenure policy is the interior separation-inducing tupel $(\bar{x}, \bar{x}^c)$ as characterized by Proposition 2.

5. Discussion

The main result summarized in Proposition 4 shows that maternity allowances can emerge endogenously from the strategic interaction of self-interested employers and employees. Maternity allowances thus need not reflect concerns for fairness and moral justice, which does, of course, not imply that these concerns actually do not, or should not, play any role in designing tenure policies. Unsurprisingly, maternity-allowance policies that separate candidates on the basis of the imperfect ability signal only pay if the ability signal is sufficiently informative. Notice, in particular, that separation does not require maternity allowances: one may well observe separation, i.e. motherhood of scientist who receive the high-ability signal, if no maternity allowances are granted. This can happen if the tenure policy $(\bar{x}_0, \bar{x}_0^c = \bar{x}_0)$ lies below the $\Delta V^H = 0$ locus and on the tenure constraint $P^t = k$.[22] Not granting a maternity allowance under these circumstances, i.e. neglecting the information provided by separation, would however be detrimental to the objectives of the employer.

Instituting management-imposed maternity allowances creates, of course, gainers and losers. The employer profits almost by definition: if he did not profit, the employer would not institute the allowance scheme. But the interest of the employer may not suffice to successfully implement the maternity-allowance scheme if it is not supported by other stakeholders. On the part of the employees, only the junior staff (faculty) members are directly affected. I therefore focus on the stake of the directly affected junior staff, i.e. the junior staff members who will be subjected to the new rules.

A plausible, but by no means the only conceivable sequence of tenure policy changes might be the following. Assume the starting point to be an unique minimum tenure standard that induces pooling on no children, i.e. a point $(\bar{x}_0, \bar{x}_0^c = \bar{x}_0)$ on the 45^0-degree line in Figure 8 above the $\Delta V^H = 0$ locus. In the initial situation, all junior female professionals are thus childless and, since the tenure constraint needs to be satisfied, the tenure standard is set at $\bar{x}_0 = \bar{x}_0^c = 1 - \frac{2k}{2 - z_{nc}^H - z_{nc}^L}$.[23] The assumed initial situation is supposed to reflect that successful female professionals foregoing a family was not

[22] In this case $\bar{x}_0^c = \bar{x}_0 = 1 - \frac{2k}{2 - \theta(z_c^H + z_{nc}^L) - (1-\theta)(z_c^L + z_{nc}^H)}$.

[23] Notice, that the point $(\bar{x}_0, \bar{x}_0^c = \bar{x}_0)$ does not lie on the $P(t) = k$ line; this line only indicates the tenure constraint under separation.

uncommon before employers began to introduce family friendly policies.[24] The employer now decides to introduce a maternity allowance by specifying a lower minimum tenure standard $\bar{x}_1^c$ for mothers: $\bar{x}_1^c < \bar{x}_0$. To induce separation, i.e. to induce receivers of the H-signal to become mothers, the maternity allowance $\bar{x}_0 - \bar{x}_1^c$ needs to be sufficiently large, i.e. the tenure scheme $(\bar{x}_0, \bar{x}_1^c)$ needs to lie below the $\Delta V^H = 0$ locus (see Figure 8). For those candidates who receive the L-signal, nothing changes; they continue to have no children, the tenure standard $\bar{x}_0$ still applies to them, and, since their productivity does not change, their chance of being promoted also remains unchanged. The productivity of the receivers of the H-signal, on the other hand, decreases when they become mothers. The associated utility loss is however overcompensated by the utility of motherhood.[25] Since the employer has a given tenure target, the employer needs to set the tenure standard $\bar{x}_1^c$ such that the probability of a receiver of the H-signal being promoted remains also unaltered. This constraint implies that the policy scheme $(\bar{x}_0, \bar{x}_1^c)$ needs to lie on the $P(t) = k$ line.

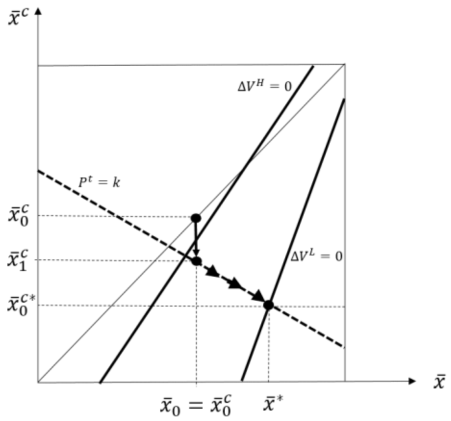

Figure 8: Sequence of changes in tenure policy

[24] My narrative of the emergence of maternity allowances thus presumed that the initial situation is characterized by all female professionals having no children. One could, however, just as well presume an initial situation in which no maternity allowance is granted and receivers of the high-ability signal nevertheless become mothers. In this case the initial situation would be indicated by the intersection of the $P(t) = k$ line with the 45°-line below the $\Delta V^H = 0$ locus and the introduction of a maternity allowance that is compatible with the tenure constraint would require a decrease in the tenure standard $\bar{x}^c$ for mothers and an increase in the tenure standard $\bar{x}$ for childless women. This scenario corresponds in my narrative to the second step in increasing the maternity allowance discussed below.

[25] In line with the first stylized fact reported in Section 2, the model assumes that the fertility decision is made before the research oeuvre begins to accumulate. Some female economists do however have their first child much later in their career when they are already in a position to guesstimate the size of their research oeuvre at the time when the promotion decision will be made. In this case it is possible that women who would otherwise not have children might be induced to have a child to meet the tenure criterion. To avoid this kind of gaming the system, motherhood allowances should in 'real world' organizations be conditioned on how long the candidates were burdened in the trial period by motherhood and by how many children. Krapf et al. (2017) provide an evidence-based estimate of the cost of motherhood in terms of foregone research output.

In this scenario, introducing a maternity allowance of the type $(\bar{x}_0, \bar{x}_1^c)$ is thus not controversial: both the employer and the receivers of the H-signal gain,[26] and the receivers of the L-signal are not affected. In academia, the department can easily absorb the decrease in productivity on the part of the young mothers because the department is not the final claimant of the research output; by assumption the department is only interested in the inherent ability of its senior faculty. In a commercial enterprise, the productivity loss can possibly be offset by reducing the remuneration of the entire junior staff.

After the first step, the introduction of the uncontroversial tenure policy $(\bar{x}_0, \bar{x}_1^c)$, the employer is led to advocate further changes in a second step. To exploit the newly gained informational advantage of being able to distinguish between receivers of the H and L-signal, he will suggest a further increase of the maternity allowance. Since increasing the maternity allowance by decreasing $\bar{x}^c$ without changing $\bar{x}$ would entail hiring too many new senior staff members, the increase of the maternity allowance can only be accomplished by increasing the tenure standard $\bar{x}$ for childless contenders. The employer will thus push for changes in the tenure policy that correspond to a sliding down on the $P(t) = k$ line. These changes will be more difficult to implement because the gainers, i.e. the employer and the (prospective) mothers, will now face opposition from the junior staff members who plan to remain childless because they received the low-ability signal. The optimal policy for the gainers is the policy described in Proposition 4, i.e. the intersection $(\bar{x}^*, \bar{x}^{c*})$ of the $P(t) = k$ line with the $\Delta V^L = 0$ locus. Notice, that in the course of moving from $(\bar{x}_0, \bar{x}_1^c)$ to $(\bar{x}^*, \bar{x}^{c*})$ the ability composition of the tenured faculty improves because more mothers, i.e. scientist who receive the high-ability signal, become senior faculty members. It is this change in ability or research productivity that represents the underlying objective of employers in introducing *endogenous* maternity allowances.

A further increase of the maternity allowance by increasing $\bar{x}^*$ or decreasing $\bar{x}^{c*}$ would destroy the separation equilibrium. Since this is, according to Proposition 4, not in the interest of the employer, the employer would not go along with such a proposal. Employers' resistance towards maternity allowances is therefore not to expected at the introduction stage but possibly when some stakeholders attempt to extend substantial existing allowances.

By identifying the gainers and losers from maternity allowances, one arrives at the conclusion that the introduction of a modest maternity allowance may be achieved uncontested. Further increases of the maternity allowance will however always cause resistance of the junior staff who believe to be professionally less qualified than their more self-confident peers. In equilibrium, which will probably be arrived at after a lengthy discovery process, the informational advantage of separation is exploited to the hilt and the motherhood allowance, given the constraint of separation, is maximized. Since two of

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[26] The employer gains because he can now better discriminate between high and low ability candidates and perhaps also because he can sell the new tenure policy as reflecting family friendliness and high social standards.

the three main stakeholders continually gain in the course of this discovery process, backsliding is unlikely, i.e. a ratchet effect is a work which stabilizes the equilibrium.

To empirically test the predicted attitudes of the directly affected groups towards the introduction or extension of maternity allowances is not a simple matter because corporate policy disputes take place behind the stage. Moreover, empirical analyses have to contend with the aggravating circumstance that maternity allowances are often communicated implicitly and are therefore not directly observable by outsiders. This problem also impedes empirical tests of the model's comparative-static properties.

Empirically meaningful comparative-static properties (of interior equilibria) can be easily derived. Consider the benefits of professional success that transcend the benefits deriving from seniority; confirming identity and self-esteem may serve as examples. In the model, professional success is portrayed by the variable x and the valuation of professional success by parameter α. An increase in α shifts the $\Delta V^L = 0$ line down which results in a reduction of the tenure threshold $\bar{x}^c$, an increase of the tenure threshold $\bar{x}$, and thereby an increase of the maternity allowance. The model thus predicts that endogenous maternity allowances are especially large in professions that provide ample scope for self-realization.

Returning to the groves of academe, one observes that some universities or departments are more selective in granting tenure than others. When elite institutions and less reputed institutions hire the same number of senior faculty members, the elite institutions can usually choose from a much larger pool of candidates than the less reputed institutions. The model can portray this the selectivity by the probability $P^t = k$ of an arbitrary candidate being hired. Selectivity thus varies negatively with the parameter k that affects the location of the $P^t = k$ line but not the location of the $\Delta V^L = 0$ locus. An increase in selectivity s shifts the $P^t = k$ line upwards. The comparative static result therefore predicts that elite institutions have higher tenure standards and, more surprisingly, provide lower maternity allowances.[27]

These examples show that the theory of endogenous maternity allowances provides many hypotheses that can, in principle, be empirically tested. But there is the rub: as long as maternity allowances are not disclosed, one has to make do with prima facie evidence.

6. Conclusion

I present a model that explains why maternity allowances for highly skilled professionals need not derive from moral justice arguments but can emerge endogenously from efficiency considerations. The basic underlying mechanism rests on the assumption that if exceptionally productive female professionals

[27] This follow directly from the fact that the ΔV^L=0-line is steeper than unity (see Lemma (a)).

choose to have children, they are also exceptionally productive in their role as mothers. Even though motherhood temporarily handicaps their productivity, it is exactly this cost of motherhood that signals their intrinsic high productivity because self-handicapping oneself by motherhood is not a feasible strategy for career-concerned low-productivity women. In this respect, the model not only resembles the familiar labor-market signaling models in the tradition of Spence and Stiglitz, but also Zahavi's "handicap principle" that proposes that animals of high intrinsic biological fitness may signal this status by sending a viability-reducing signal (see, for example, Nöldeke and Samuelson, 2003). If, in biology, the peacock tail is the classic example of a handicapping signal of male quality, somebody with a penchant for exaggerated formulations might say that for postmodern humans, babies are the equivalent for female quality.

Maternity allowances may arise endogenously because they allow employers to make better informed promotion decisions. The reason is that the maternity allowances can be fine-tuned in such a way as to minimize the probability of promoting low-ability female employees by advantaging mothers who are more likely to be highly productive. Optimal maternity allowances therefore increase the share of mothers and, at the same time, increase the average productivity among the female staff.

Even though the specification of the model explicitly refers to the academic labor market, the model is designed to portray some crucial common aspects of all labor markets for executives. This focus on general aspects of executive-level labor market settings inevitably blanks out certain aspects that only apply to specific professions. The academic labor market may, for example, especially attract women with children because academic jobs allow more flexibility regarding working hours than most other professions. Tenure is therefore likely to be more valuable for mothers who, as a consequence, may exert, from a welfare point of view, too much effort to reach this objective. Maternity allowances would in this case increase efficiency not only via the signaling mechanism, but also directly.

Apart from showing that maternity allowances may emerge endogenously from managerial efficiency considerations, the model gives rise to a host of comparative static implications that can, in principle, be subjected to empirical testing. Unfortunately, extensive information about the incidence and design of maternity allowances is still largely unavailable. Such information is however indispensable for making progress in the exploration of the design and mode of operation of maternity allowances. It is to be hoped that purely theoretical models, such as the one presented here, may help in pointing out which information is required for conducting theory-guided empirical research on the actual operation of maternity allowances.

My model makes not claim to providing normative insights. It rather describes the signaling-by-fertility mechanism and explains how maternity allowances can be used by the management to exploit the opportunities offered by this mechanism. This purely positive approach allowed me to use a rather coarsely specified model which, however, gives rise to a host of empirically testable hypotheses.

Nevertheless, coarse models take shortcuts that blind out mechanisms that may also impinge on the portrayed phenomenon. In my model two such shortcuts may serve as a starting point for models aimed at providing a broader view of the operation of maternity allowances. The first one is the partial equilibrium setting, the second one the gender issue at large. How do endogenously introduced maternity allowances influence the gender balance in specific labor markets? To answer this question, the assumed quota guaranteeing a gender-balanced senior staff needs to be dropped, especially since in a world in which maternity and other impediments women may face in the labor market are taken care of with appropriate allowances, quotas can no longer be justified.

Maternity allowances are a relatively new type of labor market instrument. Research on their prevalence, design, and mode of operation is therefore only about to emerge. Theoretical studies are helpful tools in throwing light on the expected effects of these instruments. Perhaps even more importantly, theoretical insights may also serve as guidelines for data collection and for designing suitable empirical strategies. Because what counts in the end is to learn something about how maternity allowances actually change the efficiency of labor markets and the wellbeing of its participants. This can only be achieved by well-conceived empirical research.

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Appendix

Proof of the Lemma

$\Delta V^H = 0$ yields $\bar{x}_H^c = \frac{1-(\frac{\alpha}{2}+\beta)[\theta(z_c^H - z_{nc}^H)+(1-\theta)(z_c^L - z_{nc}^L)]}{\beta(1-\theta z_c^H-(1-\theta)z_c^L)} + \frac{1-\theta z_{nc}^H-(1-\theta)z_{nc}^L}{1-\theta z_c^H-(1-\theta)z_c^L}\bar{x}$ and

$\Delta V^L = 0$ yields $\bar{x}_L^c = \frac{1-(\frac{\alpha}{2}+\beta)[(1-\theta)(z_c^H - z_{nc}^H)+\theta(z_c^L - z_{nc}^L)]}{\beta(1-(1-\theta)z_c^H-\theta z_c^L)} + \frac{1-(1-\theta)z_{nc}^H-\theta z_{nc}^L}{1-(1-\theta)z_c^H-\theta z_c^L}\bar{x}$.

(a) This follows immediately from Z2:

$s^H = \frac{1-\theta z_{nc}^H-(1-\theta)z_{nc}^L}{1-\theta z_c^H-(1-\theta)z_c^L} > \frac{1-\theta z_{nc}^H-(1-\theta)z_{nc}^L}{1-\theta z_{nc}^H-(1-\theta)z_{nc}^L} = 1$, and similarly for $s^L = \frac{1-(1-\theta)z_{nc}^H-\theta z_{nc}^L}{1-(1-\theta)z_c^H-\theta z_c^L}$.

(b) $s^H - s^L = \frac{2\theta-1}{D_H D_L}(1-z_{nc}^L)(1-z_{nc}^H)\left[\frac{1-z_c^L}{1-z_{nc}^L} - \frac{1-z_c^H}{1-z_{nc}^H}\right] < 0$,

where D_H and D_L denote the denominators of s^H and s^L, respectively. D_H and D_L are positive: $D_H = 1-\theta z_c^H-(1-\theta)z_c^L > 1-\theta z_c^L-(1-\theta)z_c^L = 1-z_c^L > 0$, because of Z1, and similarly for D_L. θ>1/2 by assumption, and the expression in the square bracket is negative according to Z3.

(c) $\bar{x}_H^c(\bar{x}=1) - \bar{x}_L^c(\bar{x}=1) =$

$$\left\{\frac{2\theta-1}{\beta D_H D_L}\right\}\left[(z_c^H - z_c^L) + \frac{\alpha}{2}(1-z_{nc}^L)(1-z_{nc}^H)\left(\frac{1-z_c^H}{1-z_{nc}^H} - \frac{1-z_c^L}{1-z_{nc}^L}\right)\right] > 0$$

The term in the curly bracket is positive ($see\ (b)$), the first term in the square bracket is negative (Z1), and the second term is positive according to Z3'. For α sufficiently large, the difference $\bar{x}_H^c(\bar{x}=1) - \bar{x}_L^c(\bar{x}=1)$ is therefore positive. Since the $\Delta V^H = 0$ locus is flatter that the $\Delta V^L = 0$ locus, the $\Delta V^H = 0$ locus lies above the $\Delta V^L = 0$ locus. The second part follows immediately from

$$\bar{x}_L^c(\bar{x}=1) = \frac{1}{\beta(1-(1-\theta)z_c^H-\theta z_c^L)}\left(1-\left(\frac{\alpha}{2}+\beta\right)\left((1-\theta)\Delta z^H+\theta\Delta z^L\right) \quad + \beta(1-(1-\theta)z_{nc}^H-\theta z_{nc}^L)\right)$$

$$= \frac{1}{\beta(1-(1-\theta)z_c^H-\theta z_c^L)}\left(1-\frac{\alpha}{2}\left((1-\theta)\Delta z^H+\theta\Delta z^L\right)\right)+1$$

$\bar{x}_L^c(\bar{x}=1)$ is thus smaller than unity iff $\alpha > \hat{\alpha} \equiv \frac{2}{(1-\theta)\Delta z^H+\theta\Delta z^L}$.

The shape of the $P^t = k$ line

$P^t = \frac{1}{2}P(t|H) + \frac{1}{2}P(t|L) = \frac{1-\bar{x}^c}{2}\{\theta(1-z_c^H) + (1-\theta)(1-z_c^L)\} + \frac{1-\bar{x}}{2}[(1-\theta)(1-z_{nc}^H) + \theta(1-z_{nc}^L)]$ (3)

Since the expressions in the curly and squared bracket in the above equation are positive, the slope of the $P^t = k$ line in the tenure-policy space $(\bar{x}, \bar{x}^c)$ is negative:

$$\frac{d\bar{x}^c}{d\bar{x}}(P^t = k) = -\frac{[(1-\theta)(1-z_{nc}^H)+\theta(1-z_{nc}^L)]}{\{\theta(1-z_c^H)+(1-\theta)(1-z_c^L)\}}. \quad \text{(A1)}$$

The $\bar{x}^c$-intercept of the $P^t = k$ line $\bar{x}_k^c = \frac{\theta(2-z_C^H-z_{nc}^L)+(1-\theta)(2-z_c^L-z_{nc}^H)-2k}{\theta(1-z_c^H)+(1-\theta)(1-z_c^L)}$ indicates that the $P^t = k$ line shifts downwards in the tenure-policy space $(\bar{x}, \bar{x}^c)$ as (relative) demand k for tenured faculty increases.

Proof of Proposition 2

$\mathrm{dP(t|H)} = \frac{\partial P(\mathrm{t|H})}{\partial \bar{\mathrm{x}}}\mathrm{d\bar{x}} + \frac{\partial P(\mathrm{t|H})}{\partial \bar{x}^c}\frac{\partial \bar{\mathrm{x}}^{\mathrm{c}}}{\partial \bar{\mathrm{x}}}\mathrm{d\bar{x}}$, where $\frac{\partial \bar{\mathrm{x}}^{\mathrm{c}}}{\partial \bar{\mathrm{x}}}$ denotes the slope of the constraint $P^t(\bar{x}^c, \bar{x}) = k$ (equation A1).

$$\frac{dP(\mathrm{t|H})}{\mathrm{d\bar{x}}} = -(1-\theta)(1-z_{\mathrm{H}}^{\mathrm{nc}}) - \theta(1-z_{\mathrm{H}}^{\mathrm{c}})\frac{\partial \bar{\mathrm{x}}^{\mathrm{c}}}{\partial \bar{\mathrm{x}}} =$$

$$-(1-\theta)(1-z_{\mathrm{H}}^{\mathrm{nc}}) + \theta(1-z_{\mathrm{H}}^{\mathrm{c}})\frac{[(1-\theta)(1-z_H^{nc})+\theta(1-z_L^{nc})]}{\{\theta(1-z_H^c)+(1-\theta)(1-z_L^c)\}} =$$

$$\frac{\theta^2\frac{1-z_H^c}{1-z_H^{nc}}-(1-\theta)^2\frac{1-z_L^c}{1-z_L^{nc}}}{\{\theta(1-z_H^c)+(1-\theta)(1-z_L^c)\}}(1-z_H^{nc})(1-z_L^{nc}) > 0$$

because $\frac{1-z_c^H}{1-z_{nc}^H} > \frac{1-z_c^L}{1-z_{nc}^L}$ (assumption Z3) and $\theta^2 > (1-\theta)^2$ by assumption.

Proof of Proposition 3

$$P(H|t)^c - P(H|t)^{nc} = \frac{(1-z_c^H)(1-z_{nc}^L)}{((1-z_c^H)+(1-z_c^L))((1-z_{nc}^H)+(1-z_{nc}^L))}\left[\frac{1-z_c^H}{1-z_{nc}^H} - \frac{1-z_c^L}{1-z_{nc}^L}\right] > 0 \text{ by assumption Z3}$$

Proof of Proposition 4

The proof follows the argument sketched in Figure 9. Figure 9 depicts the $\Delta V^L(\theta = 1) = 0$ locus for suitable values of α and β (see proposition 1) and for a perfectly revealing signal ($\theta = 1$). For suitable values of k, the $P^t(\theta = 1) = k$ line intersects the $\Delta V^L(\theta = 1) = 0$ locus in the interior of the tenure policy space $(\bar{x}, \bar{x}^c)$. This intersection represents a separating equilibrium if it provides the department with more high-ability scientists than pooling on children, i.e. if $P(H|t)^s > P(H|t)^c$. To check whether this constraint is satisfied, Figure 9 also depicts the $\Delta P = P(H|t)^s - P(H|t)^c = 0$ line that goes through the point $(\bar{x}, \bar{x}^c) = (1, 1)$ and is, for $\theta = 1$, parallel to the $\Delta V^L(\theta = 1) = 0$ locus. Tenure policies $(\bar{x}, \bar{x}^c)$ below the $\Delta P = 0$ line satisfy the constraint $P(H|t)^s > P(H|t)^c$. For any k associated with a

$P^t(\theta = 1) = k$ line that intersects the $\Delta V^L(\theta = 1) = 0$ locus in the interior of the tenure policy space, the intersection of the two lines thus represents an interior separating equilibrium.

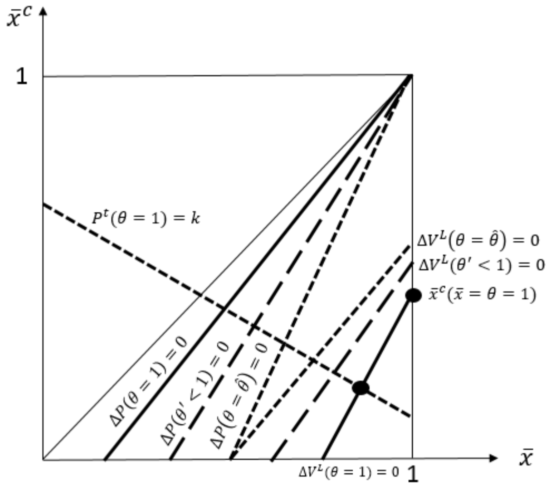

Figure 9: Comparing separation with pooling on children

At a first glance, it might be surprising that the equilibrium value of $\bar{x}$ can be smaller than unity if the ability signal is perfect. After all, this implies that childless scientists are tenured even though the department is aware that they are less able than mothers. For a tenure policy that needs to be determined exclusively by the two thresholds $\bar{x}^c$ and $\bar{x}$, the department can, however, not set $\bar{x} = 1$ and fill the slots vacated by the not hired childless scientists by hiring additional mothers because that is only possible by decreasing the standard $\bar{x}^c$ and thereby increasing the maternity allowance $\bar{x} - \bar{x}^c$. Increasing the maternity allowance, however, destroys the separation equilibrium because now all scientists would become mothers. The allowance scheme portrayed by the model is thus not an optimal mechanism; but it is the scheme that is usually applied – and the purpose of this study is to show that the observed type of allowance schemes can emerge endogenously.

Starting from $\theta = 1$, the discriminatory power of the signal is now decreased. The reduction in θ causes the two crucial lines to shift in the indicated manner: the $\Delta V^L = 0$ locus shifts upwards, the $\Delta P^s = 0$ line turns counterclockwise around $(\bar{x}, \bar{x}^c) = (1, 1)$ until it becomes perpendicular at $\theta = \frac{1}{2}$. A *sufficient* condition (always assuming an interior solution for suitable values of α, β, and *k*) for the department to prefer the best separating tenure policy to pooling on children is that the $\Delta V^L = 0$ and the $\Delta P = 0$ lines do not intersect above the $\bar{x}$ axis;[28] in Figure 9 the critical signal quality for that to happen is denoted by $\hat{\theta} < 1$.

[28] Since the location of the $P^t = k$ line depends on θ, the sufficient condition is formulated in terms of the $\bar{x}$-axis.

<u>The $\Delta P = 0$ line</u>

The department (weakly) prefers separation to pooling (on children) if

$\Delta P = P(H|t)^s - P(H|t)^c =$

$$\frac{1}{(2-z_c^H-z_c^L)N}[Y(1-\bar{x}^c) - W(1-\bar{x})] \geq 0 \iff \bar{x}^c \leq \left(1-\frac{W}{Y}\right) + \frac{W}{Y}\bar{x}, \text{ where}$$

$$Y = (2\theta - 1)(1-z_c^H)(1-z_c^L) > 0,$$

$$W = \theta(1-z_c^H)(1-z_{nc}^L) - (1-\theta)(1-z_{nc}^H)(1-z_c^L) > 0,$$

$$N = (1-\bar{x}^c)[\theta(1-z_c^H) + (1-\theta)(1-z_c^L)] +$$

$$(1-\bar{x})[\theta(1-z_{nc}^L) + (1-\theta)(1-z_{nc}^H)] > 0.$$

Separation is superior to pooling if the separation-inducing policy $(\bar{x}^c, \bar{x})$ lies below the $\Delta P = 0$ line. Since, for $\Delta P = 0$, $\bar{x} = 1$ implies $\bar{x}^c = 1$, the $\Delta P = 0$ line goes through the point $(\bar{x}^c, \bar{x}) = (1, 1)$.

Next, notice that $W = \left[\frac{\theta(1-z_c^H)}{(1-z_{nc}^H)} - \frac{(1-\theta)(1-z_c^L)}{(1-z_{nc}^L)}\right](1-z_{nc}^H)(1-z_{nc}^L)$ is positive because $\frac{1-z_c^H}{1-z_{nc}^H} > \frac{1-z_c^L}{1-z_{nc}^L}$ (assumption Z3) and $\theta > 1-\theta$. Since both W and Y are positive, the slope

$$\frac{W}{Y} = \left[\frac{\theta}{2\theta-1}\frac{1-z_{nc}^L}{1-z_c^L} - \frac{1-\theta}{2\theta-1}\frac{1-z_{nc}^H}{1-z_c^H}\right]$$

of the $\Delta P = 0$ line is positive. For $\theta = 1$ we have $\frac{W}{Y} = \frac{1-z_{nc}^L}{1-z_c^L} = s^L(\theta = 1)$ and the $\Delta P = 0$ line is parallel to the $\Delta V^L = 0$ locus. This implies that for $\theta = 1$ the equilibrium is indeed separation inducing. Differentiating W/Y above with respect to θ and using again assumption Z3 shows that the slope of the $\Delta P = 0$ line varies negatively with θ. As θ decreases, the $\Delta P = 0$ line thus turns counterclockwise around the point (1, 1).

<u>The $\Delta V^L = 0$ locus</u>

Differentiating the slope $s^L = \frac{1-(1-\theta)z_{nc}^H-\theta z_{nc}^L}{1-(1-\theta)z_c^H-\theta z_c^L}$ of the $\Delta V^L = 0$ locus with respect to θ and using assumption Z3 shows that s^L varies positively with θ:

$$\frac{\partial s^L}{\partial \theta} = \frac{(1-z_{nc}^L)(1-z_{nc}^H)}{D_L^2}\left(\frac{1-z_c^H}{1-z_{nc}^H} - \frac{1-z_c^L}{1-z_{nc}^L}\right) > 0$$

Differentiating $\bar{x}_L^c(\bar{x} = 1) = \frac{1-(\frac{\alpha}{2}+\beta)[(1-\theta)(z_c^H-z_{nc}^H)+\theta(z_c^L-z_{nc}^L)]}{\beta(1-(1-\theta)z_c^H-\theta z_c^L)} + s^L$ with respect to θ yields

$$\frac{1}{\beta D_L^2}\left[\left(\frac{\alpha}{2}+\beta\right)(1-z_c^L)(\Delta z^H - \Delta z^L) + \beta(z_{nc}^H(1-z_c^L) - z_{nc}^L(1-z_c^H)) + (1+\beta)(z_c^L - z_c^H)\right].$$

The first expression in the square bracket is negative because of Z3, the second one because of Z1, and the last one is positive because of Z1. For α sufficiently large, the entire expression is therefore negative, implying together with $\frac{\partial s^L}{\partial \theta} > 0$ that the $\Delta V^L = 0$ locus shifts upwards as θ decreases.