A Search Theory of Dowry

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Abstract

Dowries have traditionally been viewed in economics as arising from a supply imbalance of the marriage market which disadvantages women. In this thesis, a different cause is proposed. Dowries are modelled as arising from an intertemporal bargaining process in a frictional search market, with differential aging in favour of men. This extends the insights of the standard model and is able to explain several puzzling stylised facts. Most notably, dowries may occur when there are more men than women in the market, and dowry and brideprice can coexist in the same market. The model is extended to include heterogeneous males of different quality.

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Statement of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at University of Sydney or at any other educational institution, except where due acknowledgement is made in the thesis.

Any contribution made to the research by others, with whom I have worked at University of Sydney or elsewhere, is explicitly acknowledged in the thesis. I also declare that the intellectual content of this thesis is the product of my own work, except to the extent that assistance from others in the project's design and conception or in style, presentation and linguistic expression is acknowledged.

SIGNED ....

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Chapter 1

Introduction

The phenomenon of dowry has long been of interest to social scientists. The practice is an ancient one- records dating to the 5th Century B.C. describe its occurrence in Ancient Greece, and later the rising Roman Empire. Its mirror image, brideprice (a payment from a male to a female at the time of marriage), appears to have an even longer history, being documented in Ancient Egypt, Mesopotamia and the Incan Empire. As such it is no mystery that as far back as the 19th Century, it became an object of serious study for anthropologists and sociologists (Quayle, 1988).

In contrast, it took economists a little longer to embrace this area of study. The first coherent theoretical framing of the problem arises in the work of Becker (1981) on the economics of the family. Why it took so long is a little puzzling. Unlike other parts of Becker's ground-breaking work in this area (such as the division of labour in a marriage), physical cash payment from one marital party to another *obviously* carries an economic flavour. Perhaps the culprit was the traditional reluctance in economic thought to take the market to the bedroom (a reluctance which Becker, apparently, never had).

Regardless of this curious blindspot, once the lens of economic analysis was shone on the problem, open season began. What shall be termed here the 'standard model of dowries' was quickly established. This model posits the existence of a 'marriage market' operating in society, where prospective brides and grooms with perfect information will seamlessly come together in order to form matches, with the aim of maximizing self-gain. Dowry (or brideprice) will emerge in this market whenever there is an oversupply of brides (or grooms), in order to equilibrate the demands of both sides.

However, the standard model has not been without problems. They are mentioned here briefly in two categories, empirical and theoretical, with further analysis undertaken later in the thesis.

1.1 Problems with the Standard Model - Empirical

If one takes the standard model as correct, then dowry should occur when, for whatever reason, an imbalance of men and women looking for partners occurs. The women will compete on price until those with the highest marginal benefit of marrying exactly equals the number of available men.

A cursory first glance at the stylized facts of dowry seems to contradict this theory. Somewhat counter-intuitively, dowry seems to occur in modern times in that small subset of countries where *men* outnumber *women*, specifically South Asian countries such as India and Pakistan. Due to its size, treating India as one country obscures much of interest. If one looks at the data by region, dowries are shown to be higher in the northern states, where there are far more men than women (Das Gupta and Bhat, 1997; Dalmia and Lawrence, 2005).

This fact is well-recognized in the literature, and the response has been to argue that men and women marry at different ages. Thus, if women begin to marry younger than men, there may actually be a *surplus* of eligible women in the marriage market, even when the gross ratio of females to males is less than one.

However, this has proved unsatisfactory. Even when one does condition cohort size on marriage ages, the result is that local gender ratios are not empirically significant determinants of dowries. This raises a very fundamental question for adherents to the standard model of dowries that is often overlooked....just what is causing dowries, if not supply and demand?[1] Can there be dowries when there are more men in the market than women?

Moreover, the standard model seems to rule out entirely the simultaneous occurrence of dowry and brideprice. In a frictionless market context, the two should engage in a struggle driven by the rational pursuit of self-gain, and like a battle of matter and anti-matter, one should eliminate the other. However, it appears that dowry and brideprice may occur in the same region simultaneously (Murdock, 1967). Murdock documents over a dozen historical societies which have experienced this concurrence, something which the standard model lacks an explanation for.

1.2 Problems with the Standard Model - Theoretical

Regardless of the record of the standard model in data, it also retains a somewhat unsatisfactory feel. On deeper examination, one cannot escape the conclusion that, except in the most abstract of senses, there is no such thing as a marriage market. In no society on Earth is it possible to go to a centralized exchange, view all prospective mates at once,

[1]Similarly unsatisfactory is an appeal to cultural or historical norms, such as the banal "to give a dowry is simply the custom, nothing more". Such norms are malleable across time, and should not arise in isolation, without some fundamental behavioural cause. The author rejects this explanation *prima facie*

and then compete with other "buyers" on price to gain a spouse [2].

How does marriage really happen? It may be obvious, but humans devote a considerable portion of their time and energy to searching for a mate, with search being the operative word. This process is not perfect- far from it. This author identifies two significant frictions that operate to the detriment of the searchers. First, search is *noncertain*, and secondly, search is *nondirected.*

Search is said to be *noncertain* in that the probability of meeting anyone at all (desirable or not) given a decision to search has been made is not unity. Search is also *nondirected*, in that one does not know where one's perfect match is located. .One may have an idea, but the process is still inescapably one of screening selected applicants for the desired attributes.

A true theory of dowry should reflect the way in which individuals look for partners.

1.3 Searching for a Mate

The key question explored in this thesis arises from such an examination, and may be stated succinctly as, "how do dowries arise in a world where partner search is costly"?

The explanation offered is that, in a developing country context, a woman's worth may be declining faster than a man's with age. In a world where search is costly, this is a significant asymmetry. If a young woman meets a man and wishes to marry him, in order to avoid having to go back to the search market as an older woman, she may be willing to transfer some utility to the man (through a cash payment), and settle now.

It is worthwhile spending some time to justify this assumption, for much depends on it. Consider the way marriage is modelled by Becker, as a joint production decision to maximise output. What are the arguments of this function, and what is exactly meant by output? Becker is refreshingly vague about this point, so here an interpretation will be offered with specific reference to developing economies, which without exception are where we observe dowries today. In general, one may imagine that some of the inputs into a good marriage consist of productive activity- that is, the economic production, domestic production and child raising undertaken by both parties.

One of the stylized facts about dowries outlined by Anderson (2007a) is that they occur primarily in traditional societies where women do not take part in agricultural production.

[2] The reader may well wonder if perhaps something akin to a marriage market exists in the world of online dating. After all, it is relatively costless to attain an account at EHarmony.com or Rsvp.com.au and compare and communicate with many potential partners at once. However, anyone with even the most cursory experience with such websites will highlight the informational problems that bedevil them, occasionally leading to their total collapse. While such a topic is profoundly interesting to an economist, it is beyond the scope of this thesis-suffice it to say that Akerlof's Lemons have electronic counterparts among both men and women.

So though they may be increasing in prominence worldwide, this author does not believe that online dating websites have fundamentally changed the dating world just yet, and thus will continue on the presumption that perfect marriage markets are a beautiful abstraction from the real world.

This is rather unusual among developing economies, where it is estimated that around 70% of agricultural work is undertaken by women (FAO, 2011). However, they remain united with other developing economies in one sense by the fact that women also have very limited *labour market* opportunities.

The dearth of both labour market and agricultural opportunities mean that it is conceivable women in dowry-practising countries contribute little in the way of market production to a household, and instead specialize in domestic production and child rearing. In a sense (if one can be so crude), women trade children and domestic work with a man in exchange for the economic resources necessary for survival.

This, however, introduces an asymmetry between men and women. It is a well-established biological fact that the reproductive ability of women declines much faster then that of males (see, for example,(Wood, 1989) and (Piette, De Mouzon, Bachelot, and Spira, 1990)). A healthy woman's most fertile period is from her late teens to her early twenties, and she becomes, except in rare cases, practically unable to have children around her forty-fifth birthday. A man, on the other hand, is able to continue conceiving children well into old age (even though the above papers note a decrease in the quality of sperm).

Therefore, it is likely that an old woman is worth less in a marriage in such developing countries than a young woman, controlling for mitigating aspects such as looks and wealth, precisely because her reproductive abilities are lessened and she can produce less children.

But, as a young woman knows she will one day be old, she may pay a man a dowry in order to marry now. This, it will be shown, provides a powerful explanation for the dowry phenomenon.

1.4 Results

This thesis demonstrates that such an ageing effect could be a significant determinant of dowries. It is also demonstrated that dowries can indeed occur when there are more men than women in the market. Furthermore, it shows that falling search costs are likely to increase dowries, which has useful implications for policy.

It is further shown in this thesis that brideprice and dowry can coexist in one society. Very simply, a low quality man and high quality female match can sustain a brideprice, even if the average dowry paid in the economy is positive, because the cost resulting from the man rejecting the match in search of a dowry make such an action infeasible. Lastly, it is demonstrated that older women will pay a higher dowry, and men will on average marry at an older age than women.

The remainder of the thesis is presented as follows. Chapter 2 reviews the relevant literature, while Chapter 3 presents the theoretical model. Chapter 4 presents an extension on the basic model, and Chapter 5 develops some implications of the results obtained.

Chapter 2

Literature Review

2.1 The Purpose of Dowries

In the economic literature, the phenomenon of dowries has typically been studied in two different conceptual frameworks- as a groom price, the function of which is to clear the marriage market, or as a bequest to daughters, the function of which is an intergenerational transfer of wealth. These frameworks are entirely distinct and separate manners of understanding what is occurring when a dowry is paid.

2.1.1 The Standard Model - Dowry as a Price

In Becker's seminal work on the economics of the family, he modelled marriage as a joint production decision between a man and a woman to maximise output (both market and household) (Becker, 1981). One famous result is that in the absence of imperfections, then the market will exhibit *assortative matching* (that is, higher quality men will match with higher quality women). Becker also notes that "this model contrasts sharply with other models of the marriage market"(*ibid*, pg 127), such as in Gale and Shapley (1962), as preferences for partners are not given ex-ante, but emerge ex-post from the equilibrium generated.

This marriage model also allowed him to construct the first formal statement of the conditions under which dowries may arise. He argued that if the division of output is inflexible, (that is, determined in some way *outside* the marriage market, such as through culture, law or customs), then transfers at marriage should take place to ensure each partner receives their shadow price.

One intuitive appeal of this explanation for dowries is that it can also be used to explain brideprices, which have historically been common in Sub-Saharan Africa (Goody and Tambiah, 1973; Anderson, 2007a), and in parts of rural China and Thailand (Brown, 2009; Cherlin and Chamratrithirong, 1988). A key deficiency of the "Dowry as a Bequest" approach, outlined below, is that it has no such mirrored and elegant explanation for brideprices.

An implication of this is that if there is a surplus of partners on either side of the market, transfers at marriage should emerge to ensure that the market clears- that it is optimal for some men or women to remain single with the emergent brideprice/dowry. This concept is the basis for much of the work in this area (see, for example, (Rajaraman, 1983; Rao, 1993b; Esteve-Volart, 2004; Dalmia, 2004)). It is then important to ask whether this imbalance based approach is sufficient to explain the phenomenon of dowries in South-Asia. Firstly, the predominant dowry-generating countries of South Asia such as India have a highly skewed sex ratio at birth, in favour of *men*. First documented by Sen (1990), this is referred to as the "Missing Women" Phenomenon, and has been studied by a range of disciplines, from economics and demography to anthropology (see, for example, Johansson and Nygren (1991); Klasen and Wink (2002); Qian (2008)). With time, this has resulted in unusual population demographics for these countries. For example, the gross ratio of males to females between the age of 15-64 is 1.06 : 1 for both India and Pakistan (C.I.A, 2011).

The response has been to argue that because women begin to marry at a younger age then men, even though the overall ratio of men to women is skewed, there still may be more women of marriageable age in the market than there are potential husbands. These hypothesis is known as the "marriage squeeze". The seminal paper is given by Rao (1993b), whose asked if dowries are rising with time, and how this might be explained with the standard model. It is pursued in (Bhat and Halli, 2001) and (Maitra, 2006), among others.

However, the empirical evidence for such a squeeze is mixed, to say the least. If one looks on a micro-level, it has been shown that local gender ratios are not empirically significant determinants of dowries (Edlund, 2000; Anderson, 2000; Dalmia and Lawrence, 2005; Arunachalam and Logan, 2006). Factors such as the education levels of the pair, their respective ages and the wealth and caste of the groom play a much greater role. As it is probably local ratios that matter more for marriage market dynamics that state or country-wide ratios, this is a problem with the standard theory of dowries.

2.1.2 Dowry as a Bequest

An alternative to modelling dowries as a price that has been explored extensively in the literature is viewing dowries as bequests. Their function here is not to clear the marriage market, but to transfer wealth from one generation to another.

In particular, Botticini and Siow (2003) argue in an influential study that dowries overcome an important free riding problem in virilocal societies (societies where the son/s will stay with the family and work with family resources, whereas the daughter will leave the family). They also posit this as an explanation for why dowries decline in importance with modernization, which is a well-documented occurrence in the anthropological literature (Queller and Madden, 1993; Self and Grabowski, 2009). In their model, as development and labour market opportunities increase for both sons and daughters, there is less instance of working with the family resources, and thus less of a free-riding problem.

Other notable studies of dowry as a bequest include Zhang and Chan (1999) and Suen, Chan, and Zhang (2003). Zhang and Chan propose that in societies with cultural and legal barriers to female inheritance of property, dowries play an important role in intra-generational altruism between parents and daughters, and thus are important tools to maximise female welfare. Suen *et al* emphasize that in an altruistic setting, parents are incentivised to transfer more property to a married child than a single one due to greater efficiencies in consumption. Such bequests also increase the stability of marriage.

2.1.3 Reconciling the two approaches

Arunachalam and Logan (2006) provide a novel test for which approach is valid for understanding the problem. They model an exogenous switching regression for both frameworks using data from rural Bangladesh, and "find robust evidence of heterogeneity of dowry motives in the population" (*ibid*, pg. 27). That is to say, *both* price and bequest dowry regimes are present in the data, with dowries as a price being more common, in around 71% of marriage transactions. Moreover, they found that dowries as bequests have decreased both in prevalence and magnitude over time, while the incidence of dowries as a price has increased. Anderson (2000) reveals similar findings for Pakistan.

Using this empirical motivation, this thesis will abstract from dowries which form bequests, and focus on the price notion.

2.2 Central Issues in Dowry Economics

2.2.1 Are Dowries Rising?

Much of the study of dowries in the economic literature is motivated by inquiry into a singular phenomenon- whether dowries in South Asia, and especially India, are rising over time. The original paper by Rao (1993b) suggested that they were, using data from villages in rural India.

This study spawned a large body of work on dowry inflation. See, for example, (Caldwell, Reddy, and Caldwell, 1982; Billig, 1992; Rao, 1993a; Maitra, 2006; Sautmann, 2009). All these studies are attempts (both theoretical and empirical), to account for dowry inflation using some variant of the marriage squeeze outlined above- where a rising number of women of marriageable age drives an increase in the dowry level.

However, many of these studies rely on a handful of small and limited datasets. The difficulty of finding empirical data for marriage transactions in South Asia is well known, as the practice of dowry has been technically illegal in India since 1961, and is now illegal in Pakistan and Bangladesh. In practice this has meant that until recently, a comprehensive investigation into dowry inflation has not been forthcoming.

It is to this end that Arunachalam and Logan (2008) attempted a systematic study of the empirical evidence for rising real dowries. They do not include an estimate of a dowry function such as in (Rao, 1993b), but use the correlation of the year of marriage with the real dowry amount (deflated by the price of rice, a method used in the development literature as standard price indices may not reflect the prices for goods actually used by the poor (Banerjee and Duflo, 2007)). This simple measure gives them access to a larger range of datasets from across South Asia. They "do not find any evidence of rising real dowries" (Arunachalam and Logan, 2008, page 2).

In another interesting study, Edlund attempts to replicate Rao's results, and is unable to (Edlund, 2000), though Rao contends that this is because Edlund used a different estimate of the sex ratio than him (Rao, 2000). Dalmia also attempts to model a hedonic dowry function with a different dataset, and in doing so, she conclusively rejects the hypothesis that real dowries in India have been rising with time (Dalmia, 2004).

2.2.2 Why Do Dowries Matter?

Though recent papers have shown that there is mixed evidence for rising dowries, as Anderson (2007b) notes, this is in one respect a moot point. The evolution of this subfield of economics has developed new tools and methods for analysing marriage transactions and has thus advanced the state of scholarly inquiry, regardless of the veracity of the phenomenon.

This author contends that the concern about rising dowries stems from the same angst about the phenomenon itself that motivates the entire subfield, and is then in some sense misguided. The more important question is not whether dowries are rising or falling, but why they exist in the first place,and what welfare implications they have. This is still an open scholarly question.

Several recent moves towards the welfare impacts of the practice of dowry deserve to be noted here. Bloch and Rao (2002) model the incentives towards domestic violence against women that dowries generate, and find they are significant. The popular press is also fixated on the violence that notoriously follows dowries, with 'dowry death' attracting widespread outrage and condemnation (Van Willigen and Channa, 1991). In a related manner, Srinivasan and Bedi (2007) find that the practice of dowry in Southern India is likely fueling sex-selective abortion and infanticide against baby girls, adding weight to the urgency of the "Missing Women" phenomenon outlined above. In another intriguing study, Lahiri and Self (2007) develop a theoretical two-period model which purports that the practice of dowry, which under Becker's marriage model may be exacerbated by lack of opportunities in the labour market for women, can itself lead to more labour market discrimination, thus entrenching the practice.

An economist may view these facts as evidence that the practice of dowry generates negative externalities, in that the costs of the decision to marry are not borne entirely by the bride and groom. The extent and magnitude of these externalities have not been formally studied in the economic literature, and would make an intriguing study. But before this can be done, it is of paramount importance that economists have a coherent model of dowries which accords both with data and intuition, because a deep understanding of what is causing the phenomenon is a prerequisite for optimal policy, and even the decision not to implement any policy at all. It is to this end that we now turn to search models of marriage.

2.3 Search Costs and Matching

2.3.1 Search Costs and the Marriage Model

The marriage model begun by Becker has been rewritten extensively over the last few decades to incorporate search costs, following the success this lens of analysis had in the realm of labour economics.

Smith (2006) extends Beckers work by adapting the marriage model to a world where search is costly. Smith finds that in the presence of search costs,one can no longer guarantee positively assortative matching. The intuition is that one be willing to settle for a less than perfect partner in a frictional market, simply to avoid coming back to the market and searching again in the future. This work is further developed and formalised in Shimer and Smith (2000)[1]. Other novel examples of this literature include Cornelius (2003), who allows for the possibility of divorce in the marriage market, and Brien, Lillard, and Stern (2006) which examines household formation and co-residential habitation in a search framework.

The key to the result by Smith is that search costs as modelled as a cost of time only, which enter via a discount rate for expected future utility, and the fact that an agent does not meet every other agent in every period. An alternative approach is to introduce search costs explicitly, as an additive cost that must be paid in each period that search is undertaken. A prominent example is Atakan (2006), who constructs a search cost model of the marriage market with transferable utility and an explicit search cost which must be paid as a fee in each period. This is particularly useful in the study of dowries as it allows for the possibility of transfer payments at the time of marriage from one side to another. Other examples of the fixed-fee approach but with non-transferable utility include (Chade, 2001) and (Bloch and Ryder, 2000).

For simplicity's sake, this thesis will use the fixed fee approach to search costs.

2.3.2 Dowries and Search Costs

Surprisingly few attempts have been made to integrate the theory on dowries with the extensive literature on marriage markets in the presence of search costs. As far as this author is aware, only one paper attempts to build a model that contains both search

[1] Note that though Smith's original paper is listed as appearing in the JPE in 2006, it was written long before in 1993 as an MIT working paper.

costs and dowries. This is given by the groundbreaking work of Sautmann (2009), who developed a search model of the Indian marriage market which included a dowry function, but whose purpose was to analyse demographic shocks and the effects of the marriage squeeze on marriage age and the size of the dowry.

This thesis shares several of Sautmann's modelling techniques, such as steady state population dynamics, matching probability functions and Nash Bargaining for dividing the marriage surplus. However, the purpose of the paper is quite different. Sautmann does not attempt to examine the root of the dowry phenomenon, but merely takes its existence as granted, and instead studies theoretically and empirically its response to demographic shocks.

This thesis examines a deeper question. What is it exactly that *causes* dowry, in a world where search is costly? It is to answer this question that we now turn to the model.

Chapter 3

Theoretical Model

The economy consists of two types of agents, men and women, denoted by type m and type w. Both types are infinitely lived, and form marriages between types whose output is denoted $f(m, w)$. Only marriage yields utility; an unmarried agent receives nothing. If a pair decide to marry, they negotiate over the output through symmetric Nash Bargaining. Once they are married, they are married forever (there is no divorce).

Time is discrete in periods of t, and each agent is indexed by their age $t \in \{0, 1, ...\infty\}$. To begin with, assume that the marriage output depends on the age of the partners, such that $f(m, w) = f(m_t, w_t)$. There is perfect information, in that the age of any agent is perfectly observable to any other agent.

Each period, an agent may search for a partner with whom to negotiate a marriage. If at any period there are M men and W women, then let $g = W/M$. Then let $\lambda_m(g)$ (resp $\lambda_w(1/g)$) denote the probability that a man will meet a woman (resp. a woman will meet a man), where each function is increasing in its argument. Further assume that if $M = W$, then $\lambda_m = \lambda_w = \lambda$.

There is a fixed cost c that must be paid to search in every period, which is constant across time and common to all agents. Each period nature adds a fixed number X of agents of age $t = 1$ to the populations of each gender. Also, each period $1 - \delta$ agents of both sexes die, with this proportion invariant to age.

Thus a man who decides to enter the search market in a given period at age t and look for women of an age he finds acceptable (and who also find him acceptable) will receive an expected payoff of:

$$V_t' = \lambda_m \sum_{t=\tau}^{T} \mu_t^w R_{t,t}^m + (1 - \lambda_m)\delta V_{t+1}^* - c \tag{3.1}$$

where μ_t^w is the probability of finding a woman of any age t, τ is the minimum and T is the maximum age of a mutually acceptable partner, and V_{t+1}^* is the continuation value in the next period. $R_{t,t}^m$ is the reward for a successful match, which is determined by Nash

Bargaining between a man and a woman pair. The equivalent equation for a woman of age t is

$$U'_t = \lambda_w \sum_{t=1}^{T} \mu_t^m R_{t,t}^w + (1 - \lambda_w)\delta U_{t+1}^* - c \tag{3.2}$$

The symmetric Nash bargaining operates as follows. If a man and woman decide to get married, they bargain over the marriage output in such a way that each party receives their outside option (which are the continuation values V_{t+1}^* and U_{t+1}^* resp.), discounted by the death rate, plus *half* the surplus of the marriage. Formally, the payoff to a man and a woman of ages t from an agreed marriage is

$$R_{t,t}^m = \delta V_{t+1}^* + \frac{f(m_t, w_t) - \delta V_{t+1}^* - \delta U_{t+1}^*}{2} \tag{3.3}$$

$$R_{t,t}^w = \delta U_{t+1}^* + \frac{f(m_t, w_t) - \delta V_{t+1}^* - \delta U_{t+1}^*}{2} \tag{3.4}$$

V_{t+1}^* and U_{t+1}^* can be thought of as the shadow prices of the man and woman respectively, or what they are able to receive in the next period if a match does not take place. They are determined by the aggregate behaviour of all the agents in the model.

3.1 Solution Concept

The solution concept is described here somewhat informally, and then presented formally in a later section.

Agents of both sides must choose two things to maximise utility; whether they will enter the search market in the first place and whom they will marry if they do so. They solve through backwards induction, deciding who is an acceptable match first out of all agents of the opposing side, and then whether to enter the market. In doing so, they take the continuation values V_{t+1}^* and U_{t+1}^* as given, as these depend on the aggregate number of men and women who enter in the next period, and the aggregate choices over who is acceptable to whom.

Let the probability that a man (woman) will accept a woman (man) of age t be denoted $q_{t,t}^m$ (*resp.* $q_{t,t}^w$) $\in [0, 1]$. Then let the probability that a man (woman) enters the market at age t be denoted by p_t^m (*resp.* p_t^w) $\in [0, 1]$.

An equilibrium occurs when:

1. All agents choose their strategies optimally, given their continuation values.
2. $V'_t = V_t^*$ and $U'_t = U_t^*$ for all agents of age t, for all t, and are consistent with the optimally chosen strategies

3. The population of agents in the market attains a steady state

A steady state occurs when the number of new agents who are born in a given period and decide to search are exactly offset by those who are matched or die. This causes the population to reach a constant level, and with optimal strategies of identical agents ensures that the probabilities λ_m and λ_w are constant. More is given on the determination of this later.

Observation 3.1. A no search equilibrium always exists.

Proof. Fix all women's strategies as "not enter". Then if a man were to enter the market, he would receive a negative payoff, as there would be no-one there for him to meet. Applying the same logic when fixing a man's strategy as "not enter" reveals that this is a Nash equilibrium, for any parameter values. Thus we may have the unusual situation that because no-one believes others will search, no-one will search. □

As such an equilibrium is not of practical relevance for the task at hand, attention will be restricted to positive search equilibria throughout the remainder of the thesis, where at least some agents enter the market.

3.1.1 The Dowry Function

The dowry paid in a match between a man of age t and a woman of age t will be defined by the function-

$$D_{t,t} \equiv 1/2(R^m_{t,t} - R^w_{t,t}) \tag{3.5}$$

iff a match takes place, where R_t is the payoff to an individual from matching. If the value is negative it is termed a "brideprice".

The intuition behind this function follows Becker (1981). Becker stipulated that if the division of the gains of marriage is determined exogenously (in some way outside the marriage market), then cash transfers will arise to restore the necessary equilibrium. Intuitively, many societies stipulate certain roles for men and women about what and how much each should contribute to the marriage.

Here, for simplicity it is implicitly being assumed that some outside force (perhaps society, culture or religion) forces an ex-ante division of marriage output for the duration of the marriage as a 50-50 split. Then, to ensure that each side receives their continuation utility, one side will transfer utility to the other side in the form of a cash gift at the time of marriage. Thus we can recursively construct the dowry from half the difference in their payoffs, if they decide to match.

There are two notions of dowry-paying society which follow intuitively from this definition. The first is a market where $D_{t,t} > 0$ for all women and men pairs that emerge in equilibrium. This notion will be used extensively throughout the results that follow.

The second is a society where the *average* dowry is positive. That is, even though some men may pay a brideprice in equilibrium, the average magnitude of the dowry payments outweigh any brideprice effects. This notion will also be explored later.

3.2 Symmetric Agents

Let us begin by giving the symmetric solution for the sake of introduction, with equal numbers of identical men and women and no change in their worth as they age.

Proposition 1. *If:*

- *f(m,w) is independent of t*
- $f(m,w) > \frac{2c}{\lambda}$
- λ_w *and* λ_m *are homogeneous of degree zero*

then there is a unique positive search equilibrium- $p^w = p^m = 1$ *and* $q^w = q^m = 1$

Proof. If $f(m,w)$ is independent of t and all men and women are identical it can be written simply as f. Consider the strategy profile where every man matches with the first woman he meets, and vice versa, such that $q^m = q^w = 1$, and all agents enter in each period such that $p^m = p^w = 1$

The payoff for any man who meets any woman is given by the chance of meeting (λ_m), the Nash Bargaining Solution and the chance of continuing on:

$$V = \lambda_m(\delta V + \frac{f - \delta U - \delta V}{2}) + (1 - \lambda_m)\delta V - c$$

V will be constant at this strategy profile, as there are no age effects, so this simplifies to:

$$V = \frac{\lambda_m(f - \delta U) - 2c}{2 - 2\delta + \delta\lambda}$$

Similarly we can also write the payoff for a woman who meets any man as:

$$U = \frac{\lambda_w(f - \delta V) - 2c}{2 - 2\delta + \delta\lambda}$$

If $p^m = p^w = 1$, then it must be the case that $\lambda_w = \lambda_m = \lambda$. From our condition above, this also implies that:

$$M = W = \frac{X}{1 - (1 - \lambda)\delta}$$

which are the steady state numbers of men and women. Each period, the proportion λ of women and men are matched and $1 - \delta$ proportion of the population dies, so $(1 - \lambda)\delta$

proportion of the agents search again. If X agents of each gender are born every period, the total number in the market is given as above, and is constant.

Lastly, we have the value functions:

$$V = U = \frac{\lambda f - 2c}{2 + 2\delta(\lambda - 1)} \tag{3.6}$$

which is positive iff $f > 2c/\lambda$. If this condition is met, it is validated that $p^w = p^m = 1$.

This satisfies all the intuitive conditions we might expect from the model. The payoff off both sides is increasing in the value of a match and in the chance of finding a partner, and decreasing in the cost of search.

Now consider a deviation from this strategy by a player (either man or woman), holding all other player's strategies constant. If the player refuses to marry a person he/she meets in period t, he/she incurs a cost of c for searching and continues on to $t+1$. In $t+1$ he/she faces an identical situation to in period t. If he/she meets someone and marries, he/she receives a positive payoff by Equation (3.6). However, it is strictly preferable to marry in period t and not incur the cost of an extra period of search. This establishes that this is indeed an equilibrium.

The proof of uniqueness is as follows. First note that given a man and woman meet, it is always optimal to accept one another as a match, so that $q^w = q^m = 1$. This is because men and women are all the same, and having met someone is preferable to returning to the market to search for the same situation.

It also must be the case that if $f > 2c/\lambda$, $p^w = p^m = 1$.

Suppose not, and that there is another equilibrium for entering strategies. Let $\hat{V}$ and $\hat{U}$ denote the equilibrium payoffs in this other equilibrium (since f is independent of t, these values must be constant).

Now if in this equilibrium the number of men and women who search in every period are equal, then $\lambda_m = \lambda_w = \lambda$, and then because $f > 2c/\lambda$, all agents must search.

Thus, if this is a different equilibrium, the number of men and women cannot be the same, and so some agents must not search in equilibrium. Without loss of generality, assume that there are more women who search at this equilibrium. If this is the case, then some men must drop out of the market. For this to happen, $\hat{V}$ must equal 0 (it cannot be negative, because then all men drop out and women will not search at all).

Moreover, $\lambda_m(g) > \lambda$, and so

$$0 = \hat{V} > \lambda/2(f - \delta\hat{U}) - c \tag{3.7}$$

Now as $g > 1$,

$$\hat{U} < \lambda/2(f + \delta\hat{U}) + (1 - \lambda)\delta\hat{U} - c$$

$$= \lambda/2(f - \delta\hat{U}) + \delta\hat{U} - c \tag{3.8}$$

But then using Equations (3.7) and (3.8) implies $\hat{U} < \delta\hat{U}$, which is a contradiction.

So the unique equilibrium must have $g = 1$, and $p^w = p^m = 1$.

□

Observation 3.2. Homogeneity of degree 0 for the matching functions is required to rule out certain unstable knife edge equilibria that occur if the size of the market is important.

To see this, suppose that λ depends on the size of the market $\Pi = M + W$. Then suppose only a fraction of searchers $p^w = p^m \in (0, 1)$ of both sides enter in equilibrium. This will require $V = U = 0$. If $\lambda(\Pi)$ is decreasing in Π, it may be the case that $\lambda(\Pi)f - 2c = 0$, validating that agents randomise in equilibrium. If so, there may be multiple equilibria, but the mixed-strategy equilibria will clearly be unstable, as a small perturbation of the system will drive it to either a no-search situation, or the pure strategies derived above.

There is also no dowry paid at this unique equilibrium. To see this, note that because $V = U$ from Equation (3.6), it must be the case from that $R^w = R^m$ (dropping the age subscripts), and then $D_{t,t} = D = 0$ from Equation (3.5).

So to obtain a model which predicts dowries are paid in equilibrium, an asymmetry between men and women is necessary. For the remainder of the thesis, the assumption is made that a woman's worth declines with age, but a man's does not. Formally:

Assumption 1. *The output function of marriage $f(m, w_t)$ is nonincreasing in t, and*

- $inf\{f(m, w_t)\} = \alpha$
- $f_1 > \alpha$

This assumptions states that a woman's worth in marriage must decline over time, and in the limit reaches some minimal value.

As at this stage, the output function of marriage only depends on the woman, and they are only differentiated by age, it serves to write $f(m, w_t)$ as f_t.

There are two cases for this assumption that will be explored below.

3.3 Asymmetric Ageing - Case 1

The first case is when $\alpha < 2c$.

If this is true, we know that there must exist an age T^* where a woman of age T^* and a man can never be matched. A sufficient condition for this is that $f_{T^*} < 2c$. This is because one partner at least must get less than their cost of search, and so in a positive search equilibrium men will prefer to reject the match and keep searching. Thus beyond this point, it is certain that a woman will not enter the market. However note that women may drop out before this date, as her value might be too low for a man to accept, taking his continuation value as given.

It is imperative to find the age T, the last age where a woman will enter the marriage market in equilibrium.

Her payoff in period T will be :

$$U'_T = p^w_T \{q^m_T \lambda_w [R^w_T] + \delta(1 - \lambda_w) \times 0 - c\}$$

Where R^T_w is given by the Nash Bargaining Solution so

$$R^w_T = 1/2[f_T - 0 - \delta V^*_m] + 0$$

as she has no continuation value by the definition of T. Then define:

$$U^*_T = max(p^w_T \{q^m_T \lambda_w [R^w_T] - c\}, 0)$$

where p^w_T is the argmax of the expression, taking all other variables as given.

Note that the men are all the same, so in a steady state equilibrium their continuation payoff V^*_m must be constant. Of course, if $f_T < V^*_m$, then $q^m_T = 0$ and the match does not take place. Also, the homogeneity of men implies that if a woman finds it in her interest to enter in a given period, she will marry any man, so $q^w_t = q^w = 1$.

This allows us to recursively characterize the payoffs for the women, so

$$U'_{T-1} = p^w_{T-1} \{q^m_{T-1} \lambda_w [R^w_{T-1}] + \delta(1 - \lambda_w) U^*_T(w)\}$$

where

$$R^w_{T-1} = 1/2[f_{T-1} - \delta U^*_T(w) - \delta V^*_m] + \delta U^*_T(w)$$

and so on for U'_{T-2}.... up to U'_1. Thus if we know what V^*_m and the vectors of p^w_t and q^m_t are, all payoffs are determined in equilibrium.

The men's problem follows the following process. First, they must decide whether to enter in a given period, which is modelled by the probability $p^m \in [0, 1]$. They will do this as long as they do not receive a negative payoff (for a zero payoff, they will randomise between entering and not entering).

They must also decide whether to accept a match with a woman of age t upon meeting her, which determines the vector of probabilities q_t^m. They will accept a match with a woman as long as they receive at least their continuation value from a match. Noting that the surplus from marriage is split by Nash bargaining, their maximization problem can be written with the Bellman

$$\max_{q_t^m, p^m} p^m[\lambda_m \mu_t q_t^m \{1/2(f_t - \delta U_{t+1}^* + \delta V_m^*)\} + (1-\lambda_m)\delta V_m^* - c]$$

where they solve backwards by choosing q_t^m first, and then p^m, taking V_m^*, λ_m and U_{t+1} as given as they are determined by aggregate behaviour. μ_t denotes the probability of meeting a woman of age t. In a steady state equilibrium, this is equivalent to:

$$\mu_t = \frac{(\delta(1-\lambda_w))^t p_t^w X}{W}$$

The solution to the marriage choice problem is then:

$$q_t^m = \begin{cases} 1 & \text{if } \frac{f_t}{\delta} - U_{t+1}^* > V_m^* \\ 0 & \text{if } \frac{f_t}{\delta} - U_{t+1}^* < V_m^* \\ \in [0,1] & \text{if } \frac{f_t}{\delta} - U_{t+1}^* = V_m^* \end{cases} \tag{3.9}$$

The numbers of Men and Women in a steady state equilibrium are given by:

$$M = \frac{p^m X}{1-(1-\lambda_m)\delta p^m}, \quad W = X \sum_{t=1}^{T} (p_t^w ((1-\lambda_w)\delta)^{t-1} \prod_{t=1}^{t-1} p_{t-1}^w) \tag{3.10}$$

as men continue searching (up to forever) to find a partner if it is profitable to enter in the first instance, whereas women will drop out after age T.

Lastly, to close the model, we need to describe how the aggregate behaviour determines the shadow price V_m^* (and thus by extension, all U_t^*).

To do this, a mapping is constructed that takes as its argument $(< p_t^w >, V_m^*)$ and maps it onto $(< p_t' >, V')$ for all values of $t \in \{1, 2, ..., T^*\}$. This determines the supply side dynamics.

The mapping is defined as follows: $\phi(< p_t^w >, V^*) = (< p_t' >, V')$, where:

$$p_t' = argmax\ p_t^w [\lambda_w R_t^w + \delta(1-\lambda_w) U_{t+1}^* - c]$$

The solution is then:

$$p'_t = \begin{cases} 1 & \text{if } \lambda_w R^w_t + \delta(1-\lambda_w)U^*_{t+1} > c \\ 0 & \text{if } \lambda_w R^w_t + \delta(1-\lambda_w)U^*_{t+1} < c \\ \in [0,1] & \text{if } \lambda_w R^w_t + \delta(1-\lambda_w)U^*_{t+1} = c \end{cases} \tag{3.11}$$

V' is defined as

$$V' = \lambda_m[\sum_{t=1}^{T} \mu_t q^m_t R^m_t] + \delta(1-\lambda_m)V^*_m - c \tag{3.12}$$

such that $f_T > V^*_m$. R^m_t as before is the utility for the man of a match with a woman of age t.

Observation 3.3. If $p^w_t > 0$ in equilibrium, then it must be the case that $p^w_{t-1} = 1$. Thus if a woman enters in some period t, she must enter in all previous periods.

Proof. By A.1, f_t is non-increasing in t, and V^*_m is constant in equilibrium, so U^*_t is monotonically decreasing in t. This follows from the fact that even if $f_t = f_{t-1}$, a woman of age t is closer to a decline in the function than a woman of age t-1, and thus has less opportunity. Thus it must be the case that if $p^w_t > 0, p^w_{t-1} = 1$

□

Observation 3.4. If $q^m_t = 0$, then $q^m_{t+n} = 0$ for all $n \in [1, ..., \infty]$. Thus if a man does not accept a match with some woman of age t in equilibrium, he will never accept a match with a woman older than t.

Proof. Immediate from examining A.1, and noting that V^*_m is constant in equilibrium.

□

Observation 3.5. $q^m_t = 0 \Rightarrow p^w_t = 0$. Thus if a man will not accept a woman of age t in equilibrium, she will never enter at age t

Proof. First note Observation 3.4. Then by Equation (3.11), $q^w_t = 0$ implies that the expression $\lambda_w R^w_t + (1-\lambda_w)U_{t+1} = 0 < c$. Thus $p^w_t = 0$.

□

3.4 Characterizing Asymmetric Equilibria

An equilibrium consists of a set of strategies $p^m, < p^w_t >, < q^m_t >$ where-

1. Given V^*_m and U^*_t, no-one has any incentive to deviate from their chosen strategy.

2. $V' = V_m^*$ and $U_t' = U_t^* \ \forall\ t$
3. The age distribution of the population attains a steady state

Proposition 2. *There always exists an equilibrium in the marriage market described above. Moreover, iff $\lambda_m(T=1)f_1 > 2c$, then a positive search equilibrium always exists*

Proof. This proof proceeds by establishing the existence of a fixed point, where $V_m^* = V'$ and jointly determines and is determined by $< p_t' >$.

Lemma 3.1. *The mapping $\phi(< p_t^w >, V^*)$ is convex-valued and upperhemicontinuous for all values of $t \in \{0, ..., T^*\}$*

Before proceeding with the proof of the lemma, let us describe more fully the nature of the correspondence

As stated above, p_t' lies on the interval between $[0, 1]$. Moreover, there may be some value for t where it can take any and all values on this interval.

Now, $< p_t' >$ is fully determined by choosing a V_m^*. To see this, all one must do is examine Equation (4) and note that choosing a V_m^* fully determines all the payoffs in the set of U_t^*.

The graph of the correspondence in $< p_t' >$ for all values of t, with a fixed V_m^*, may appear as in Figure 3.1 when T is large.

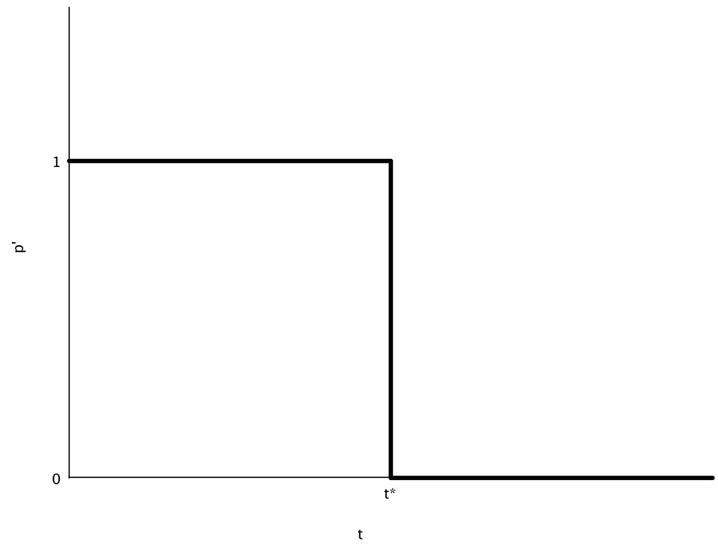

Figure 3.1: Probabilities of a woman entering for an arbitrary V_m^*

Now consider V'.

It is useful to rewrite Equation (3.12) so that V_m^* is fully visible in the equation. To do this, remember that $R_t^m = (1/2(f_t - \delta V_m^* - \delta U_{t+1}^*) + \delta V_m^*)$. Thus:

$$V' = \lambda_m[\sum_{t=1}^{T} \mu_t(1/2(f_t - \delta U^*_{t+1}) + \frac{\delta}{2}V^*_m)] + \delta(1-\lambda_m)V^*_m - c$$

We can then solve expand out U^*_{t+1} by considering a woman's payoff in period $t+1$, so:

$$V' = \lambda_m[\sum_{t=1}^{T} \mu_t(1/2(f_t - \delta p'_t(\lambda_w(1/2(f_{t+1} - \delta V^*_m) + \frac{\delta}{2}U^*_{t+2})$$

$$+\delta(1-\lambda_w)U^*_{t+2} - c) + \frac{\delta}{2}V^*_m] + (1-\lambda_m)\delta V^*_m - c$$

Doing this for all periods up to T gives one:

$$V' = \lambda_m[\sum_{t=1}^{T} \mu_t(\frac{\delta}{2} + \frac{\delta^2\lambda_w}{2}\sum_{\tau=0}^{T}(\delta(1-\frac{\lambda_w}{2}))^{\tau}\prod_{\tau=0}^{T} p'_t V^*_m] + \delta(1-\lambda_m)V^*_m + \Omega - c \qquad (3.13)$$

Where

$$\Omega = \lambda_m[\sum_{t=1}^{T} \mu_t(\frac{f_t}{2} - \frac{\delta\lambda_w}{2}\sum_{\tau=0}^{T}(\delta(1-\frac{\lambda_w}{2}))^{\tau}\prod_{\tau=0}^{T} p'_t f_{t+\tau} + \frac{\delta c}{2}\sum_{\tau=0}^{T}(\delta(1-\frac{\lambda_w}{2}))^{\tau})\prod_{\tau=0}^{T} p'_t]$$

While seemingly quite complex, this allows one to see that V' is in fact *linear* in V^*_m for a fixed vector of probabilities $< p'_t >$. Figure 2 illustrates the characterization-

1. Pick any real V^*_m
2. This determines a vector of probabilities $< p'_t >$
3. This vector then gives a linear relation by Equation (3.13)

One last point, which will soon become apparent; in the case that $\lambda_m R^w_t + \delta(1-\lambda_w)U^*_t = c$ at this chosen V^*_m, then we will actually have a family of linear relations, as p'_t can take any value on the interval $[0, 1]$.

We are now ready to begin the proof of the Lemma.

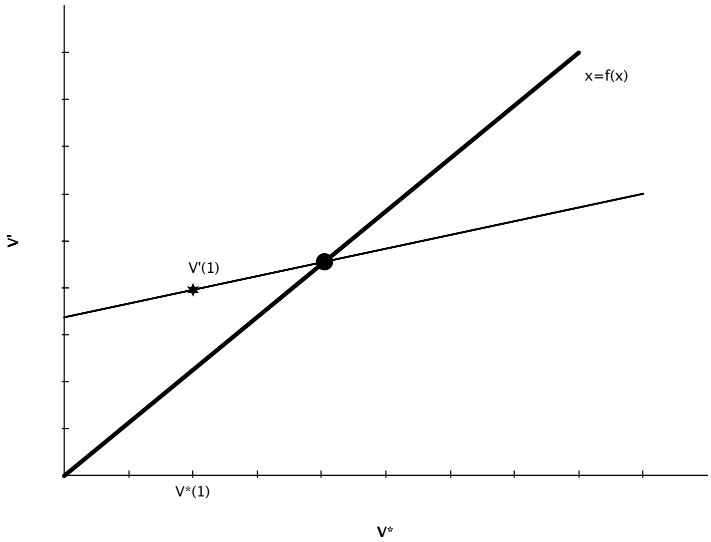

Figure 3.2: Graph of V' for an arbitrary V^*_m

Proof. Upperhemicontinuity requires that the correspondence in question has a closed graph, such that

1. $x_n \in X$ converges to $x^* \in X$
2. $y_n \in f(x_n)$ and
3. y_n converges to y^* such that $y^* \in f(x^*)$

Take a sequence of V^*_m converging to any limit point in the set of V^*_m (call it $\bar{V}$). We have two possible cases.

In the first case, the vector of probabilities does not change during the convergence (such that $p^w_T = 1$), and we have an unchanged linear relation for V'. If this is the case, then it must be so that $\bar{V}' \in \phi(< p^w_t >, \bar{V})$, for one is simply moving along the continuous line depicted in Figure 3.2.

However, in the second, more interesting case, $\bar{V}$ lies on that crucial juncture where $p^w_T \in [0, 1]$. At this point there is a family of linear relations, all of which are implied by $\bar{V}$.

The set of p^w_T is a closed set, such that it includes its own limit points (0 and 1). Thus as the continuous convergence reaches $\bar{V}$, one of the family of linear relations implied by the value for $\bar{V}$ must be based on $p^w_T = 1$. So $\bar{V}'$ is in the correspondence $\phi(< p^w_t >, \bar{V})$.

We can also see that if we start the convergence at such a V^*_m which implies a continuum of values for p^w_T, and go from there to a higher $\bar{V}$, the logic holds true, because there is a linear relation where $p^w_T = 0$. The V' is "coming out the bottom" of the correspondence.

Thus the mapping $\phi(< p^w_t >, V^*_m)$ must be upperhemicontinuous.

It must also be convex-valued. This is trivially so for the vector of probabilities, lying as they do on [0,1]. It must also be so for V', as we can represent any V' through a combination of another two in the set.

This proves Lemma 1.1.

□

Now, by the application of Kakutani's fixed point theorem for a correspondence [1], there must exist a fixed point such that $(< p'_t >, V^*_m) = (p^w_t, V^*_m)$. This establishes the existence of an equilibrium.

Lemma 3.2. *Iff* $\lambda_m(T = 1)f_1 > 2c$*, then there exists a positive search equilibrium*

Proof. To give sufficient conditions on the existence of a positive search equilibrium, it serves to ask, when is it profitable for some agents to enter? The absolute minimum we require is that a match between a man and the very youngest woman could be profitable.

In such a world, with only the youngest woman entering the market, the probability of a man finding a woman is given by $\lambda_m(T = 1)$, which is computable by assuming a specific form on the probability functions (which will be done below). In order to have any hope of entering, we then must have the potential gain from entering, $\lambda_m(T = 1)/2\ f_1$, greater than the cost, c.

As $W < M$ in such a world, $\lambda_w > \lambda_m$, and so this also serves as a sufficient condition for women to enter profitably. They may then divide the surplus between them using Nash Bargaining and get positive payoffs.

□

Moreover, if a positive search equilibrium exists, then the no-search equilibrium will be unstable. This is intuitive- a small shock to the system will cause the no search equilibrium, if attained, to subsequently collapse.

Lastly, note that at a fixed point, the age distribution of the population will attain a steady state. This is because, following from Observation 3.5, if a woman is unacceptable at the equilibrium, she will not enter. Thus everyone who meets a partner, man or woman, in any period t, will marry them as they will receive their continuation value. Following this logic:

$$L_m = (1 - (1 - \lambda_m)p^m)M$$

men will leave the market each period (or die), and

$$L^t_w = [1 - (1 - \lambda_w)\delta p'_{t+1}]w_t$$

[1]The theorem is stated here for convenience, from Mas-Colell, Whinston and Green (1995). Suppose that $A \subset \mathbb{R}^{\mathbb{N}}$ is a non-empty, compact, convex set, and that $f : A \to A$ is an upperhemicontinuous correspondence from A into itself with the property that the set $f(x) \subset A$ is non-empty and convex for every $x \in A$. Then $f(.)$ has a fixed point; that is, there is an $x \in A$ such that $x \in f(x)$

women of every age t will also leave.

As every man gets matched with the first woman he meets, we have M given as in Equation (3.10) and

$$w_t = X((1-\lambda_w)\delta)^t \prod_{t=1}^{t} p'_t.$$

A little algebraic manipulation reveals-

$$L_m = p^m X \qquad \text{and} \qquad \sum_{t=1}^{T} L_w^t = p'_1 X$$

So those that leave and are matched are offset by new agents who are born and enter the market for the first time in every period, and we must have a steady state age distribution. This ensures that the λ_w and λ_m are constant in each period, ensuring that the optimally chosen strategies above can be constant.

□

One can give a constructive procedure for finding an equilibrium, which helps give the intuition behind the claim.

Begin by setting p_1^w=1 and all other $p_t^w = 0 \ \forall \ t \in T^*$. Calculate V_m^* at this vector of probabilities from Equation (3.12), and use the fact that in equilibrium $V' = V_m^*$ and $U'_t = U_t^*$.

First ensure that V_m^* is positive, so that all men enter. Then check the women's choice. If U_1^* is negative at this equilibrium, so that it does not make sense for a woman to enter, stop, as the equilibrium is a no search equilibrium.

However, if U_1^* is positive, then the original assumption that $p_1^w = 1$ is justified.

Now check the women's choice for age $t = 2$. If $p_2^w = 0$ at this V_m^*, then stop, as you have found the equilibrium. However, if the implied value of $p_2^w > 0$, then allow women of age 2 to enter and recalculate V_m^*.

If $p_1^w > 0$ and $p_2^w > 0$ at this new V_m^*, but p_t^w for $t \neq 1, 2$ is 0, then stop, as you have found the equilibrium.

The interesting case is where p_2^w now equals 0 at this new V_m^*, implying a contradiction. Instead what must happen is that women of age 2 must randomise. In doing so, she will pick a value for p_2^w which causes $\lambda_w R_t^w + \delta(1-\lambda_w)U_{t+1} = c$ (there can be only one of these between 0 and 1). Thus in this last period, only a fraction of the women will enter, and this will be an equilibrium.

As we are now certain of the existence of an equilibrium, we can impose the condition that $V' = V_m^*$ and solve for V_m^* explicitly, as a function of the parameters of the model-

$$V_m^* = \frac{\Omega - c}{1 - (\lambda_m \Theta + (1 - \lambda_m)\delta)} \tag{3.14}$$

where

$$\Theta = \sum_{t=1}^{T} \mu_t \left(\frac{\delta}{2} + \frac{\delta^2 \lambda_w}{2} \sum_{\tau=0}^{T} \left(\delta \left(1 - \frac{\lambda_w}{2}\right)\right)^{\tau} \prod_{\tau=0}^{T} p_t' \right)$$

and Ω is as before. A handy way of writing this that will be used later is the simpler form

$$V_m^* = \frac{\frac{\lambda}{2} \sum_{t=1}^{T} \mu_t (f_t - \delta U_{t+1}^*) - c}{1 - (1 - \frac{\lambda}{2})\delta} \tag{3.15}$$

3.5 Asymmetric Ageing - Case 2

The second case is when $\alpha > 2c$. Under this assumption, it is possible that an equilibrium exists where women never drop out of the marriage market, in contrast to above.

Using this assumption yields the following result.

Proposition 3. *If $\alpha > 2c$, given a small c and $\lambda, \delta \in (0, 1)$, there is always a sequence of values $f_1 \geq ... \geq \alpha$ for the production function such that an equilibrium exists where $p_t = 1 \ \forall \ t$*

Proof. For a pure strategy equilibrium to exist where women enter with probability 1 at any age, a man must be able to profitably marry any woman woman given he has met her. Thus we require

$$\alpha > \delta V_m^*(T = \infty)$$

imposing the condition that $T = \infty$, and solving for V_m^*.

Looking at the definition for V_m^* in Equation (3.15), a sufficient condition for this is-

$$\alpha > \ h(\mu_t[f_1, f_2, ..., \alpha])$$

h is a scalar, given by

$$h = \frac{\delta\lambda/2}{1 - (1 - \lambda/2)\delta}$$

which is always less than one given $\lambda, \delta < 1$.

In other words, α must be bigger than a fraction of the weighted average of all values of the production function (including itself).

Given δ and λ are strictly less than one, it will always be possible to choose a sequence that satisfies this restriction.

We also require $V_m^* > 0$ (or $p^m = 1$) , which is equivalent to saying that the values of the production function must be sufficiently larger than the search cost c. This can also be accommodated in the sequence.

Lastly, the above also serves as a sufficient condition for $U_{T^*}^* > 0$ (the utility of the woman with the lowest output value α), which is required for the pure-strategy equilibrium.

Note that

$$U_{T^*}^* = U_{T^*+1}^* = \frac{\lambda/2(\alpha - \delta V_m^*) - c}{1 - (1 - \lambda/2)\delta}$$

This will be positive if search costs are sufficiently small. Intuitively, if an old woman meets a man, after he has taken his cut of the marriage output α, the leftover for her must be greater than the search costs. This can be accommodated if search costs are sufficiently small.

While necessary, this sequence and a small c also serves as a sufficient condition for such an equilibrium to exist. To check this, all one must do is impose the strategy that all men and women enter at all ages, and men marry any woman. Working backwards, all that is required for this to be an equilibrium are the conditions given above.

So such a sequence can always be found which ensures that an equilibrium exists where women enter in all periods with probability one.

□

The intuition of this result is that if women do not decay in worth too fast, then it may be profitable for a man to marry any woman when taking into account the costly and uncertain nature of the market.

Now that the existence of an equilibrium in the marriage market has been established, its uniqueness must be examined.

Proposition 4. *The equilibrium found by the mapping $\phi(< p_t' >, V_m^*)$ may not generally be unique.*

In order to give a specific example of the marriage market, it is necessary to give a form to the probability functions λ_m and λ_w, so a closed form solution can be obtained. The following simple assumption is used-

Assumption 2.

$$\lambda_m = \begin{cases} \lambda & \text{if } W > M \\ \lambda \frac{W}{M} & \text{if } M > W \end{cases} \quad \lambda_w = \begin{cases} \lambda & \text{if } M > W \\ \lambda \frac{M}{W} & \text{if } W > M \end{cases}$$

It is designed to capture a "congestion friction"- in that, when one side outnumbers the other, the larger side has a lower chance of finding a mate. These forms are overwhelmingly similar to those used in Sautmann (2009). This assumption will be used throughout the rest of the thesis when closed-form solutions are required.

Proof. It suffices to give one counter example.

Let the marriage output be given as

$$f_t = \begin{cases} 100 & \text{if t=1} \\ 90 & \text{if t=2} \\ 70 & \text{if t =3} \\ 0 & \text{if t > 3} \end{cases}$$

where t denotes the age of the woman.

Let $c = 1$. This establishes that no matches will take place with any woman older than $t = 3$.

The Women's bargaining equations are given by

$$U_3^* = \lambda_w(1/2(70 - \delta V^*)) - 1$$

$$U_2^* = \lambda_w(1/2(90 - \delta V^*) + \frac{\delta V_3}{2}) + (1 - \lambda_w)\delta U_3 - 1$$

$$U_1^* = \lambda_w(1/2(100 - \delta V^* + \frac{\delta V_2}{2}) + (1 - \lambda_w)\delta U_2 - 1$$

Let $\lambda_w = \lambda = 9/10$, $\lambda_m = \lambda \times W/M$ and $\delta = 9/10$, and X=1

The S.S distributions of men and women are therefore

$$M = \frac{X}{1 - \delta(1 - \lambda_m)} = \frac{1}{1 - 9/10(1 - 9/10 * W/M)}$$

$$W = Xp_1^w + \delta(1 - \lambda)p_2^w X + (\delta(1 - \lambda))^2 p_3^w X$$

$$= 1p_1^w + 9p_2^w/20 + (9/20)^2 p_3^w$$

$$V_m^* = 9/10 \times W/M\{p_1^w/W(1/2(100 - \frac{9U_2}{10}) + \frac{9V_m^*}{20}) + \frac{p_2^w 9}{20W}(1/2(90 - \frac{9U_3}{10}) + \frac{9V_m^*}{20})+$$

$$+\frac{p_3^w(9/20)^2}{W}(1/2(70) + \frac{9V_m^*}{20}))\} + 9/10(1 - 9/10 \times W/M)V_m^* - c$$

Now let us solve for the equilibrium by setting $p_1^w = p_2^w = 1$ and $p_3^w = 0$.

This gives us a value of $V_m^* = 80.6$. At this V_m^*, all women of ages up to 2 will enter, but U_3^* will be negative, and thus such a woman will not rationally enter. This establishes that this is an equilibrium.

However, consider what happens if we impose the condition that a woman of age 3 *does* enter (i.e $p_3^w = 1$). Then the new calculated V_m^* will be lower, with a value of 75.1. At this new V_m^*, it now makes sense for for the older woman to enter, as $U_3^* = 0.12$. Thus this too is an equilibrium.

□

The intuition of this result comes from examining what happens to the relative bargaining power of men and women as we increase T. The bargaining power of women must always increase under the specification adopted above, as they have a higher continuation value if they can search for more periods. The payoff of men depends on two things- λ_m and (negatively) on U_t^*. In the above example, when moving T from 2 to 3, λ_m only increases by a minuscule amount. However, because the women can search for an extra period, all U_t^* rise by a notable amount. Thus we have the result that V_m^* decreases, and multiple equilibria arise.

This result leads us into a characterization of when a unique equilibrium will arise. It turns out that a simple condition can be derived which guarantees uniqueness of the equilibrium.

Proposition 5. *If $V_m^*(T)$ is increasing in $T \, \forall \, T$, than the fixed point found by the mapping $\phi(< p_t^w >, V_m^*)$ is the unique equilibrium*

Proof. Consider finding one equilibrium, where $V_m^* > 0$, $p_{T+1}^w = 0$, $p_T^w > 0$ and $< p_{t<T}^w >= 1$. Assuming the condition in Proposition 2 is satisfied, such an equilibrium must exist.

Now consider imposing the equilibrium condition that a woman enters at an age of $T+1$. If V_m^* increases, then U_{T+1}^* must be negative, violating the imposition that such a woman can profitably enter. Similarly, impose the equilibrium condition that women enter up to the age of $T-1$. If V_m^* decreases, then it must be rational for a woman of age T to enter, violating that $T-1$ is an equilibrium.

As T was arbitrary, if $V_m^*(T)$ is increasing in $T \; \forall \; T$, then there can only be one unique equilibrium.

□

It should be noted that the generality of the above results does not depend on the specific nature of the Nash Bargaining Solution. The model has assumed that both suitors receive their continuation value plus *half* the surplus of the match if they decide to partner up. In general, there is no reason why such an assumption should be the case. The Generalised Nash Bargaining Solution instead assigns the share of the surplus as π to one side and $(1-\pi)$ to the other side, with this parameter determined outside the model. In some sense, it represents a socially determined "bargaining power" which does not reflect endogenous factors.

The original Nash Bargaining Solution with equal division of surplus was chosen because it intuitively felt natural. Also, examining dowries by assuming that men have more bargaining power is unsatisfactory and trivial, equivalent to assuming one's results.

3.6 The Emergence of Dowries

We are now ready to examine the phenomenon of dowries in the model. As men are all identical, $D_{t,t}$ will be written simply as D_t, denoting the dowry paid by a woman of age t. To begin with, consider the following numerical example which illustrates intuitively the emergence of dowries.

Example 1. Let the marriage output be given as above-

$$f_t = \begin{cases} 100 & \text{if t=1} \\ 90 & \text{if t=2} \\ 80 & \text{if t =3} \\ 0 & \text{if t > 3} \end{cases}$$

where t denotes the age of the woman.

Let $c = 1$. This establishes that no matches will take place with any woman older than t=3.

Also, let $\lambda_w = \lambda = 1/2$, $\lambda_m = \lambda W/M$ and $\delta = 9/10$, and X=1.

The process of solving for an equilibrium is similar to above, and is omitted in the interest of brevity. The unique equilibrium has $V_m^* = 51.55$ and $p_1^w = p_2^w = p_3^w = 1$ and $p_{>3}^w = 0$.

Using the definition of dowries in Equation (3.5), we can thus calculate the dowry in each period as half the difference in the payoff of the man and woman, conditional on the fact they meet. The results are given in Table 3.1.

Table 3.1: Payoffs and Dowries

Agent	Expected Payoff	R_t^w	R_t^m	D_t
Woman of t=1	20.29	31.02	60.26	14.61
Woman of t=2	13.06	26.02	57.76	15.86
Woman of t=3	7.4	14.22	65.77	25.77

As can be seen, a positive dowry is paid in all periods, despite the fact that there are more men in the search market at any period t than women (the ratio is around 2 men to every 1 woman). Note also that the dowry paid rises with age. In fact this is a general result of the model.

Proposition 6. *In any equilibrium with a finite T, it must be the case that $D_t > 0$ for some t. Furthermore, D_t is always monotonically increasing in the age of the woman.*

Proof. Recall the definition of the dowry function given in Equation (3.5). In equilibrium, we can rewrite this explicitly as

$$D_t = 1/2(\frac{f_t - \delta U_{t+1}^* + \delta V_m^*}{2} - \frac{f_t + \delta U_{t+1}^* - \delta V_m^*}{2})$$

which simplifies to

$$D_t = \delta/2(V_m^* - U_{t+1}^*)$$

As women must drop out at some date T, there is at least one t for which U_{T+1}^*=0. At such a T we must have $D_t > 0$.

As V_m^* is constant in equilibrium, but the continuation value for a woman declines with age, we have D_t monotonically increasing in t.

Thus this model predicts dowries will be higher for older women than for younger women, ceteris paribus.

□

Now, to avoid suspense, the model does not predict dowry for all values of the parameters, but in fact can see the emergence of brideprices for extreme cases if T is finite. To see why, consider the following simple example.

Example 2. Let $f_t = \begin{cases} 100 & \text{if } t = 1 \\ 90 & \text{if } t = 2 \\ 0 & \text{otherwise} \end{cases}$ and $\lambda = 0.1$, $\delta = 0.1$ and $X = 1$

The unique equilibrium has $T = 2$ and $V_m^* = 3.35$.

The payoffs are then in Table 3.2.

Table 3.2: Brideprice and Dowry

Agent	Expected Payoff	R_w^t	R_m^t	D_t
Woman of t=1	6.71	51.51	48.48	**-1.52**
Woman of t=2	3.35	43.49	46.5	1.51

As one can see, if a man meets a woman of age 1, he must pay a brideprice. If he meets a woman of age 2, he receives a dowry.

What is happening here? It turns out that in some cases supply and demand do resume their traditional importance. In the above example, the very low search probability and death rate create a huge imbalance of men and women when $T = 2$. In fact, the imbalance of men to women is *so* large (around 8 men for every 1 woman) that it outweighs the negative effect on their bargaining power of only being able to search for two periods.

The above examples show that dowry is determined by two forces in the model- the relative supply of women and their deteriorating bargaining power as they age. In order to ask when the ageing effect will fully dominate the supply effect (as Proposition 6 shows that there can never be an all brideprice equilibrium) , it serves first to turn to the special equilibrium derived under Case 2 above.

Proposition 7. *At an equilibrium where* $T = \infty$, $D_t > 0 \ \forall \ t$ *given* $f_1 > f_t$ *for some* t

This proposition demonstrates that if men and women search for the same length of time, and thus there is no relative supply imbalance, all women must pay a dowry in equilibrium.

A sufficient condition to obtain positive dowries for all ages of women is for $D_1 > 0$, as by Proposition 6, this will cause all dowries to be positive. Proposition 6 also shows that a simple requirement for this is that $V_m^* - U_1^* > 0$.

Proof. The implication of $T = \infty$ is that $\lambda_m = \lambda_w = \lambda$.

This being the case, we can write the payoffs of the women in the market as

$$U_1^* = \frac{\lambda}{2}(f_1 - \delta V_m^* + \delta U_2^*) + (1 - \lambda)\delta U_2^* - c$$

$$U_2^* = \frac{\lambda}{2}(f_2 - \delta V_m^* + \delta U_3^*) + (1 - \lambda)\delta U_3^* - c$$

$$\vdots$$

$$U_\tau^* = \frac{\lambda}{2}(f_\tau - \delta V_m^* + \delta U_{\tau+1}^*) + (1 - \lambda)\delta U_{\tau+1}^* - c$$

$$\vdots$$

This can be written as

$$
\begin{aligned}
U_1^* - \sigma U_2^* &= \frac{\lambda}{2}(f_1 - \delta V_m^* + \delta U_2^*) - c \\
\sigma U_2^* - \sigma^2 U_3^* &= \frac{\lambda\sigma}{2}(f_2 - \delta V_m^* + \delta U_3^*) - \sigma c \\
&\vdots \\
\sigma^{\tau-1} U_\tau^* - \sigma^\tau U_{\tau+1}^* &= \frac{\lambda\sigma^{\tau-1}}{2}(f_\tau - \delta V_m^* + \delta U_{\tau+1}^*) - \sigma^{\tau-1} c \\
&\vdots
\end{aligned}
$$

where $\sigma = (1-\lambda)\delta$ for notational convenience. Now taking the telescopic sum (which is possible as $\sigma < 1$), U_1^* can be written as

$$
\begin{aligned}
U_1^* &= \frac{\lambda}{2}\sum_{t=1}^{\infty}\sigma^{t-1}(f_t - \delta V_m^* + \delta U_{t+1}^*) - \sum_{t=1}^{\infty}\sigma^{t-1} c \\
&= \frac{\lambda}{2}\sum_{t=1}^{\infty}\sigma^{t-1}(f_t - \delta V_m^* + \delta U_{t+1}^*) - \frac{c}{1-\sigma}
\end{aligned}
$$

We also have an expression for V_m^*, which is given by rearranging Equation (3.16), so

$$
V_m^* = \frac{\frac{\lambda}{2}\sum_{t=1}^{T}\mu_t(f_t - \delta U_{t+1}^* + \delta V_m^*) - c}{1-\sigma} \tag{3.16}
$$

We need to be able to compare these two variables somehow. To do so, first define two new variables, $V_m^\dagger$ and $U_1^\dagger$ with minute differences to above.

$$
V_m^\dagger = \frac{\frac{\lambda}{2}\sum_{t=1}^{T}\mu_t(f_t - \delta U_1^\dagger + \delta V_m^\dagger) - c}{1-\sigma}
$$

and

$$
U_1^\dagger = \frac{\lambda}{2}\sum_{t=1}^{T}\sigma^{t-1}(f_t - \delta V_m^\dagger + \delta U_1^\dagger) - \sum_{t=1}^{T}\sigma^{t-1} c
$$

Note that $V_m^* > V_m^\dagger$ and $U_1^\dagger > U_1^*$ given $f_1 > f_t$ for at least one t.

Beginning from

$$
V_m^\dagger - U_1^\dagger = \frac{\frac{\lambda}{2}\sum_{t=1}^{\infty}\mu_t(f_t - \delta U_1^\dagger + \delta V_m^\dagger) - c}{1-\sigma} - \frac{\lambda}{2}\sum_{t=1}^{\infty}\sigma^{t-1}(f_1 - \delta V_m^\dagger + \delta U_1^\dagger) + \frac{c}{1-\sigma}
$$

we have

$$(1-\frac{\delta\lambda}{1-\sigma})(V_m^\dagger - U_1^\dagger) = \frac{\frac{\lambda}{2}\sum_{t=1}^{\infty}\sigma^{t-1}(1-\sigma)(f_t) - c}{1-\sigma} - \frac{\lambda}{2}\sum_{t=0}^{\infty}\sigma^{t-1}(f_t) + \frac{c}{1-\sigma}$$

using the definition of μ_t given earlier, or

$$(1-\frac{\delta\lambda}{1-\sigma})(V_m^\dagger - U_1^\dagger) = 0$$

Finally, because $V_m^* > V_m^\dagger$ and $U_1^\dagger > U_1^*$, we have $V_m^* > U_1^*$. So if neither men nor women drop out of the market, then all women must pay a dowry.

In one sense, this is somewhat surprising. Consider a woman of age 1, about to search. She knows, with certainty, that if she meets a man they will bargain over the largest possible output, f_1. A man however, knows that if he meets someone there is only a fractional chance she will be of the highest quality, lowering his bargaining power. *Ex-ante* it does not seem obvious that such a woman would have to pay a dowry. However, *ex-post* we see this result derives from the fact that a man will *always* have a chance to meet the best women, whereas the woman is only going to grow older.

□

3.7 A Sufficient Condition for Dowries

Now one is ready to turn to asking under what condition we will have dowry in every period even when women drop out of the market.

The first thing to note is that, in an equilibrium where $T = \infty$, Proposition 7 guarantees that all dowries will be positive.

We can also note that the difference between V_m^* and U_1^* is monotonic in T under A.2. That is, moving from any one pure strategy equilibrium to another (i.e $p_T^w = 1$ to $p_{T+\tau}^w = 1$), the difference will change in a monotonic fashion. To see this, write

$$V_m^* = \frac{\frac{\lambda W}{2M}[\mu_t(f_t - \delta U_{t+1}^* + \delta V_m^*)] - c}{1-\sigma_m}$$

where $\sigma_m = (1-\lambda_m)\delta$.Using the definition for μ_t, and noting that $M = \frac{X}{1-\sigma_m}$, we can write-

$$V_m^* = \frac{\lambda}{2}\sum_{t=1}^{T}\sigma^{t-1}(f_t - \delta U_{t+1}^* + \delta V_m^*) - \frac{c}{1-\sigma_m}$$

Taking the telescopic sum version of U_1^* derived above,

$$U_1^* = \frac{\lambda}{2}\sum_{t=1}^{T}\sigma^{t-1}(f_t + \delta U_{t+1}^* - \delta V_m^*) - \sum_{t=1}^{T}\sigma^{t-1}c$$

As in the last section, define two new variables, $V_m^\dagger$ and $U_1^\dagger$, such that

$$V_m^\dagger = \frac{\lambda}{2}\sum_{t=1}^{T}\sigma^{t-1}(f_t - \delta U_1^\dagger + \delta V_m^\dagger) - \frac{c}{1-\sigma_m}$$

$$U_1^\dagger = \frac{\lambda}{2}\sum_{t=1}^{T}\sigma^{t-1}(f_t + \delta U_1^\dagger - \delta V_m^\dagger) - \sum_{t=1}^{T}\sigma^{t-1}c$$

Solving for the difference yields

$$V_m^\dagger - U_1^\dagger = \frac{\sum_{t=1}^{T}\sigma^{t-1}c - \frac{c}{1-\sigma_m}}{1-\lambda\delta\sum_{t=1}^{T}\sigma^{t-1}}$$

This difference is monotonic in T, as the top of the fraction is converging towards zero faster than the bottom fraction is converging to its limit point.

Returning to $V_m^* - U_1^*$, it can be written as

$$V_m^* - U_1^* = V_m^\dagger - U_1^\dagger + \lambda\sum_{t=1}^{T}\sigma^{t-1}(U_1^\dagger - U_t^*) + \lambda\sum_{t=1}^{T}\sigma^{t-1}(V_m^* - V_m^\dagger)$$

Using the above fact, the whole difference is monotonic in T, as $V_M^* > V_m^\dagger$ and $U_1^\dagger > U_t^*$. This takes care of the pure strategy equilibria where women enter with probability 1 in the last period T.

As for any mixed strategy equilibria, we can write

$$V_m^\dagger - U_1^\dagger = \frac{\sum_{t=1}^{T}p_t^w\sigma^{t-1}c - \frac{c}{1-\sigma_m}}{1-\lambda\delta\sum_{t=1}^{T}p_t^w\sigma^{t-1}}$$

As we increase p_T^w from 0 towards 1 (and noting that if $p_T^w > 0$, than $p_{t<T}^w = 1$ by Observation 3.3), this difference is clearly montonic in p_T^w, for the speed of convergence reason outlined above.

Then we can see,

$$V_m^* - U_1 = V_m^\dagger - U_1^\dagger + \lambda\sum_{t=1}^{T}p_t^w\sigma^{t-1}(U_1^\dagger - U_t^*) + \lambda\sum_{t=1}^{T}p_t^w\sigma^{t-1}(V_m^* - V_m^\dagger)$$

is also montonic in p_T^w.

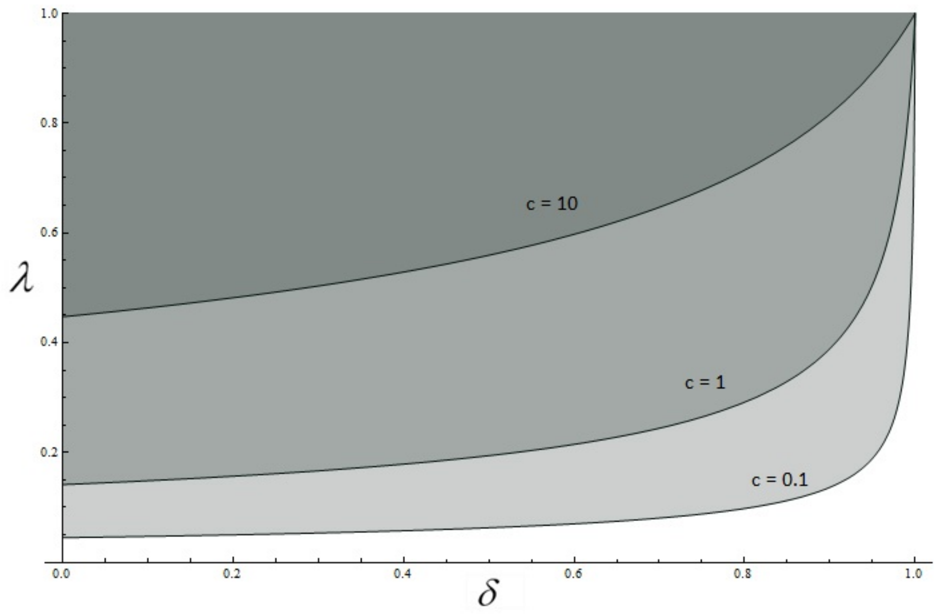

Figure 3.3: Region of All Dowries for $f_1 = 100$

So then, a sufficient condition for dowries is that $V_m^* > U_1^* \mid_{T=1}$, as it will always be within positive bounds for any T. All dowries will be positive in any equilibria if this condition holds.

A closed form of this condition can be derived as

$$V_m^* - U_1^* \mid_{T=1} = \frac{\delta((1-\delta)\lambda^2 f_1 - c(2-\delta\lambda)(1+\lambda))}{(1-\delta)(2-\delta\lambda)} > 0 \qquad (3.17)$$

While apparently quite complex, this condition has an intuitive explanation. Consider graphing the function for the parameter value used in the earlier numerical examples, namely $f_1 = 100$ and different values of c.

The shaded region in Figure 3.3 indicates values for λ and δ where the condition holds. The implication is clear- for higher values of λ and moderate values of δ, we will have all women paying a dowry, in all possible equilibria.

The intuition for this result is relatively straightforward. When λ is very low, the chance of finding a mate is correspondingly low, and the supply of men will be significantly higher than that of women if men search to infinity. However, as λ becomes higher, the supply imbalance diminishes, and the importance of the ageing effect of women becomes more important. Moreover, as δ increases, the value of searching for more periods decreases if the chance of dying is higher.

Another result is also of interest. As c decreases relative to f_1, the shaded region increases in size, meaning the set of parameter values for which dowries exist in all equilibria increases. So lower search costs in some sense make all-dowry equilibria more likely, for a simple intuition elaborated on below. As well, if search costs go to zero, the condition is always satisfied. Thus if search is not costly, there is *no* equilibrium where a brideprice is paid between a woman and a man.

3.8 Comparative Statics

It also serves to ask how a change in c will change an *established* equilibria. The following result is of prime importance.

Proposition 8. *If women stay in the market for a finite number of periods T, a marginal increase in search costs will cause all dowries to fall, in any equilibrium*

Proof. Recall the Dowry function given in Equation (3.5). One can then see that-

$$\frac{\delta D_t}{\delta c} = 1/2[\frac{\delta V_m^*}{\delta c} - \frac{\delta U_t^*}{\delta c}]$$

Take the second argument first.

Beginning from the telescoped version of U_1 outlined above, we can derive

$$U_t^* = \frac{\lambda}{2}\sum_{t=\tau}^{T}\theta^{t-1}(f_t - \delta V_m^*) - \sum_{t=\tau}^{T}\theta^{t-1}c$$

where $\theta = (1 - \frac{\lambda}{2})\delta$.

Taking the derivative w.r.t c yields

$$\frac{\delta U_t^*}{\delta c} = -\frac{\lambda\delta}{2}\sum_{t=\tau}^{T}\theta^{t-1}\frac{\delta V_m^*}{\delta c} - \sum_{t=\tau}^{T}\theta^{t-1}$$

Now consider V_m^*. Manipulating Equation (3.16), we can show

$$V_m^* = \frac{\frac{\lambda_m}{2}\sum_{t=1}^{T}\mu_t[f_t - \delta U_{t+1}^*] - c}{1 - \theta_m}$$

where $\theta_m = (1 - \frac{\lambda_m}{2})\delta$. Taking the partial derivative,

$$\frac{\delta V_m^*}{\delta c} = -\frac{1}{1-\theta_m} - \frac{\frac{\lambda_m\delta}{2}\sum_{t=1}^{T}\mu_t[\frac{\delta U_{t+1}^*}{\delta c}]}{1-\theta_m}$$

When T=1, solving these equations gives

$$\frac{\delta V_m^*}{\delta c} - \frac{\delta U_1^*}{\delta c}|_{T=1} = \frac{-1}{1-\theta_m} - \frac{\lambda\delta}{2}(\frac{1}{1-\theta_m}) + 1 < 0$$

When $T = \infty$, $\frac{\delta U_t^*}{\delta c} = \frac{\delta U_{t+1}^*}{\delta c} = \frac{\delta U_1^*}{\delta c}$, as a woman entering the market in period t will expect to search just as many times as a woman in period $t + 1$.Thus we will have

$$\frac{\delta V_m^*}{\delta c} = -\frac{1}{1-\theta} - \frac{\frac{\lambda}{2}\frac{\delta U_t^*}{\delta c}}{1-\theta}$$

$$\frac{\delta U_t^*}{\delta c} = -\frac{1}{1-\theta} - \frac{\frac{\lambda}{2}\frac{\delta V_m^*}{\delta c}}{1-\theta}$$

Of course, when $T = \infty$ then $\theta_m = \theta$ as $\lambda_m = \lambda_w$.

Solving these equations yields

$$\frac{\delta V_m^*}{\delta c} - \frac{\delta U_t^*}{\delta c}|_{T=\infty} = 0$$

Lastly, $\frac{\delta D_t}{\delta c}$ is monotonically increasing in T, and so must lie between these bounds.

To see this, first note that $\frac{\delta U_t^*}{\delta c} < 0 \ \forall \ T$. This is because $\frac{\lambda\delta}{2}\frac{\delta V_m^*}{\delta c} < 1$, even evaluated at the maximal effect of $\frac{1}{1-\theta_m}$. This also establishes that $\frac{\delta U_t^*}{\delta c}$ is monotonically decreasing in T.

Now take $\frac{\delta V_m^*}{\delta c}$. It is clear it is monotonically increasing in T. This follows from the fact that $-\frac{1}{1-\theta_m}$ is increasing in T, as λ_m always increases with T, $-\frac{\frac{\lambda\delta}{2}}{1-\theta_m}$ is decreasing for the same reason, and as outlined above, $\frac{\delta U_t^*}{\delta c}$ is decreasing.

So the first term in $\frac{\delta D_t}{\delta c}$ is increasing, minus a decreasing term, so all up $\frac{\delta D_t}{\delta c}$ must be monotonically increasing in T.Thus it must always be within negative bounds.

□

The intuition behind this result is straightforward. If women must drop out in some period T, then they spend less time on average searching for a mate. If this is the case, then women can expect to pay the fixed fee c less times in the future, and thus a rise in the fee will have proportionally less of an effect on their continuation value than it will on males'. As dowries are negotiated through continuation values, they must then fall.

However, it is not quite as strong a result as one might hope. It can be seen that if the rise in c is large enough, it can knock the market into another equilibrium. That is, a sufficient rise in c will cause a woman of age T to drop out of the market. This will shrink the supply of women, and the effect on dowries is ambiguous.

Chapter 4

Extension- Heterogeneity of Males

One obvious simplification of this search theory of dowries is that men are all identical, whereas women are heterogeneous. As explained above, this was done to capture the effect of a decaying worth of women over time. In real life, however, men are obviously not identical, and the theory should attempt to capture this heterogeneity.

One way in which to do this is to allow the worth of men to decline with age as well, but at a slower rate than women. However, in the infinite horizon case the model quickly becomes intractable.

Instead, another way to proceed is to allow for different *qualities* of men, whose worth is static through time. This is modelled by assuming that there are two types of men, *educated* and *uneducated* [1].These qualities are exogenous and are determined in some away outside the marriage market.

It is further assumed that an educated man has more to bring to a marriage (perhaps through higher wages in the labour market, or more stimulating dinner conversation), and thus his output when matched with any woman of age t is always more than that of an uneducated man.

Consider the following model.

There are two types of men, Educated and Uneducated. Each period nature adds X_e Educated men and X_n Uneducated men to the market, with $X_e + X_n = X$. Nature also adds X women to the market each period.

If a woman marries an educated man, the surplus is $Y_{t,e}$, and if she marries an uneducated man, the surplus is $Y_{t,n}$, with $Y_{t,e} > Y_{t,n}$.

Women age as follows: up to period T, a match with her will produce $Y_{1,j}$, and then in period T and onwards she will produce $Y_{2,j}$, with $Y_{1,j} > Y_{2,j}$. Call a woman Young if $t < T$, and Old if $t \geq T$

This is a significant simplification on A.1, but is implemented for two reasons. Firstly, the situation where old women drop out of the market and affect the overall supply of

[1]One could also use the distinction Wealthy and Poor, with little difference.

women has been studied above, and the point of this extension is instead to study the effect of introducing different types of males. Thus the simplest specification possible is used. Secondly, it is believed that this form of the production function well captures the underlying ageing dynamics. The reason is that though the drop is sudden at some date T, women can see it coming, and as they approach this date, their continuation value worsens, lowering their bargaining power.

So there are then four cases for the marriage surplus-

$$Y = \begin{cases} Y_{1,e} & \text{if man is Educated an } t < T \\ Y_{2,e} & \text{if man is Educated and } t \geq T \\ Y_{1,n} & \text{if man is Uneducated and } t < T \\ Y_{2,n} & \text{if man is Uneducated and } t \geq T \end{cases} \tag{4.1}$$

with $Y_{1,e} > Y_{2,e} > Y_{1,n} > Y_{2,n} > 2c$, which ensures a woman of any age will always prefer to be married with an educated man. The surplus is split by Nash bargaining, as before.

The solution concept is virtually identical to that presented in the baseline case. Both men and women will attempt to maximise utility in any period t by solving their problems backwards- first choosing who to marry, and then whether to enter the search market. They take the shadow prices V_E^*, V_N^* and U_t^* as given, as they are determined by aggregate behaviour.

Now, the payoff of an Old woman who searches in period T must be given by

$$U_T^* = max[p_T^w\{\lambda_w(\frac{\rho}{2}q_N^T q_T^N(Y_{2,n} - \delta V_N^*) + \frac{1-\rho}{2}q_T^E(Y_{2,e} - \delta V_E^*)) + (1 - \frac{\lambda_w}{2})\delta U^*\}, 0]$$

where $\rho = \frac{X_n}{X}$, or the chance that a woman will meet an Uneducated man, conditional on meeting someone at all, and V^* (resp. U^*) is the constant continuation value for a man (Old woman).

q_t^E is the probability that an Educated man will marry a woman of age t, the solution of which is

$$q_t^E = \begin{cases} 1 & \text{if } \frac{Y_{t,e}}{\delta} - U_{t+1}^* > V_E^* \\ 0 & \text{if } \frac{Y_{t,e}}{\delta} - U_{t+1}^* < V_E^* \\ \in [0,1] & \text{if } \frac{Y_{t,e}}{\delta} - U_{t+1}^* = V_E^* \end{cases}$$

q_t^N and q_N^t are the probabilities that an Uneducated man will marry a woman of age t, and the probability that a woman of age t will marry an Uneducated man respectively. They follow identical logic to above. Note that it must be the case that $q_E^t = 1$.

As before, the payoffs of all the Young women can be characterized as:

$$U^*_{T-1} = max[p^w_{T-1}\{\lambda_w(\frac{\rho}{2}q^{T-1}_N q^N_{T-1}(Y_{1,n}-\delta V^*_N)+\frac{1-\rho}{2}q^E_{T-1}(Y_{1,e}-\delta V^*_E))+(1-\frac{\lambda_w}{2})\delta U^*_T-c\},0]$$

$$\vdots$$

$$U^*_1 = max[p^w_1\{\lambda_w(\frac{\rho}{2}q^1_N q^N_1(Y_{1,n}-\delta V^*_N)+\frac{1-\rho}{2}q^E_1(Y_{1,e}-\delta V^*_E))+(1-\frac{\lambda_w}{2})\delta U^*_2-c\},0]$$

Once again, we wish to know how the continuation V^*_E, V^*_N and $< U^*_t >$ emerge as a result of the aggregate decisions over entering and matching decisions.

To do this, a mapping is constructed, which takes as its arguments $(< p^w_t >, V^*_N, V^*_E)$ and maps it onto $(< p'_t >, V'_N, V'_E,)$ for all values of $t \in \{1, 2, ..., T\}$.[2]

This mapping is defined as follows: $\Psi(< p^w_t >, V^*_N, V^*_E) = (< p'_t >, V'_N, V'_E)$, where

$$p'_t = argmax\ p^w_t\{\lambda_w(\frac{\rho}{2}q^t_N q^N_t(Y_{t,n}-\delta V^*_N)+\frac{1-\rho}{2}q^E_t(Y_{t,e}-\delta V^*_E))+(1-\frac{\lambda_w}{2})\delta U^*_{t+1}-c\}$$

The solution is thus:

$$p'_t = \begin{cases} 1 & \text{if } \lambda_w(\frac{\rho}{2}q^t_N q^N_t(Y_{t,n}-\delta V^*_N)+\frac{1-\rho}{2}q^E_t(Y_{t,e}-\delta V^*_E))+(1-\frac{\lambda_w}{2})\delta U^*_{t+1} > c \\ 0 & \text{if } \lambda_w(\frac{\rho}{2}q^t_N q^N_t(Y_{t,n}-\delta V^*_N)+\frac{1-\rho}{2}q^E_t(Y_{t,e}-\delta V^*_E))+(1-\frac{\lambda_w}{2})\delta U^*_{t+1} < c \\ \in [0,1] & \text{if } \lambda_w(\frac{\rho}{2}q^t_N q^N_t(Y_{t,n}-\delta V^*_N)+\frac{1-\rho}{2}q^E_t(Y_{t,e}-\delta V^*_E))+(1-\frac{\lambda_w}{2})\delta U^*_{t+1} = c \end{cases}$$

V'_E is given by

$$V'_E = p^m_E\{\frac{\lambda_m}{2}(\sum_{t=1}^{T-1}\mu_t q^E_t(Y_{1,e}-\delta U^*_{t+1})+(1-\sum_{t=1}^{T-1}\mu_t)q^E_T(Y_{2,e}-\delta U^*))+(1-\frac{\lambda_m}{2})\delta V^*_E-c\} \quad (4.2)$$

where μ_t is the probability of meeting a Young woman of age t, given by $\frac{((1-\lambda)\delta)^{t-1}p^w_t}{W}$, and $(1-\sum_{t=1}^{T-1}\mu_t)$ is the probability of meeting an Old woman.

Analogously,

[2] It is only necessary to define the mapping up to T, because all Old women are identical. If one enters, they all enter, so to speak, and so though they may keep coming back to the market at any date after T, p_T captures the relevant information for all of them.

$$V'_N = p^m_N\{\frac{\lambda_m}{2}(\sum_{t=1}^{T-1}\mu_t q^N_t q^t_N(Y_{1,n}-\delta U_{t+1})+(1-\sum_{t=0}^{T-1}\mu_t)q^N_T q^T_N(Y_{2,n}-\delta U^*))+(1-\frac{\lambda_m}{2})\delta V^*_N - c\} \tag{4.3}$$

The first task is to establish the existence of an equilibrium in the marriage market. Again, this equilibrium takes the form of a fixed point where $V^*_N = V'_N$, $V^*_E = V'_E$, and $U^* = U^*_T = U^*_{T+i}$.

Proposition 9. *There exists an equilibrium in the marriage market with heterogeneous males. Moreover, under A.2, if* $\frac{\lambda-\delta\lambda}{(1-\rho)-\delta\lambda}Y_{1,e} > 2c$ *and* $\rho < \delta(1-\lambda)$, *then there is a positive search equilibrium*

Proof.

Lemma 4.1. *The mapping* $\Psi(.)$ *is convex-valued and upperhemicontinuous for all* $t \in T^*$

Proof. See Appendix

□

Then, by the application of Kakutani's fixed point theorem, there must exist a fixed point. This is the equilibrium.

Above all, we are interested in a positive search equilibrium, where some agents engage in search for partners. The following Lemma gives a sufficient condition for this.

Lemma 4.2. *Under A.2, if*

- $\frac{\lambda-\delta\lambda}{(1-\rho)-\delta\lambda}Y_{1,e} > 2c$ *and*
- $\rho < \delta - \lambda\delta$,

then at least some agents will enter the market

This Lemma is the multiple male type form of Lemma 3.7, explored under the specific probability functions in A.2. The general sufficient condition is

$$\lambda_m(M, W|T = 1, V^*_N = 0)Y_{1,e} > 2c$$

but in the interest of exposition and clarity, the closed form solution is explored.

Proof. All that is required for a positive search equilibrium is that some agents find it in their interest to enter. A natural angle of attack is to examine the minimum conditions necessary for the highest quality agents to enter.

What do we need for the very youngest women, and the educated men, to enter and pair up profitably? If women of age t=1 enter, then for a man to be able to bargain over positive surplus requires

$$\lambda_m Y_{1,e} > 2c$$

Using our previous assumption on λ_m,

$$\lambda_m = \lambda \frac{W}{M}$$

$$= \lambda \frac{X}{\frac{X((1-\rho)-\delta\lambda)}{1-\delta}} = \frac{\lambda - \lambda\delta}{(1-\rho)-\lambda\delta}$$

For this equation to hold true, there needs to be less women then men, or $W < M$, which requires $\frac{1-\delta}{(1-\rho)-\lambda\delta} < 1$. Alternatively, we need

$$\rho < \delta(1-\lambda)$$

Obviously, if potential gain is positive from the men's perspective ($\lambda_m Y_{1,e} > 2c$), then it must also be from the women's perspective ($\lambda Y_{1,e} > 2c$). So if both women of age $t = 1$ and educated men meet, they can match with positive gain, and we will have a positive search equilibrium.

□

□

From here it serves to examine the types of possible equilibrium that may emerge. As stated above, in this section the case of most interest is where Old women enter with probability 1, such that the only effect driving dowries is the ageing effect. One result is immediately of interest.

Proposition 10. *A fully separating equilibrium can never exist in this marriage market*

Proof. There are two types of fully separating equilibrium which are conceptually possible here. Consider the interesting one first, where Young women marry Educated men and Old women marry Uneducated men, and all enter with probability one.

The continuation value for an Old woman would be constant if such an equilibrium existed, and given by-

$$U^* = \lambda(\rho(1/2(Y_{2,n} - \delta V_N^* + \delta U^*))) + (1-\lambda)\delta U^* - c$$

$$= \frac{\frac{\lambda\rho}{2}(Y_{2,n} - \delta V_N^*) - c}{1 - \delta\lambda(1 - \frac{\rho}{2}) - \delta} \tag{4.4}$$

The continuation value for an Uneducated man is also constant, and given by-

$$V_N^* = \lambda(b(1/2(Y_{2,n} - \delta U^* + \delta V_N^*))) + (1 - \lambda)\delta V_N^* - c$$

$$= \frac{\frac{\lambda b}{2}(Y_{2,n} - \delta U^*) - c}{1 - \delta\lambda(1 - \frac{b}{2}) - \delta} \tag{4.5}$$

where

$$b = 1 - \sum_{t=1}^{T-1} \mu_t$$

Assume for the moment that these expressions are positive, so it is optimal for a woman of any age to enter, and for the Uneducated men to enter as well.

We want to ask if this strategy can hold in equilibrium. The answer is no.

To see this, examine the expected payoff of a woman of age T-1. If a fully separating equilibrium existed, she should only marry an Educated man.

Her expected payoff is then

$$U_{T-1} = \lambda((1 - \rho)(1/2(Y_{1,e} - \delta V_E^* + \delta U^*))) + (1 - \lambda)\delta U^* - c$$

However, what if she also married an Uneducated man were they to meet? Then her payoff would be-

$$\widetilde{U}_{T-1} = \lambda((1 - \rho)(1/2(Y_{1,e} - \delta V_E^* + \delta U^*)) + \rho(1/2(Y_{1,n} - \delta V_N^* + \delta U^*))) + (1 - \lambda)\delta U^* - c$$

And as $\widetilde{U}_{T-1} > U_{T-1}$, she can profit by such a deviation.

Would such a man accept her if he met her?

In dividing the marriage output, she would get at least δU^*, and he would need at least δV_N^*. This is eminently possible since $Y_{1,n} > Y_{2,n}$. So he would take her offer if they met.

Then his continuation value would be given by

$$\widetilde{V_N^*} = \lambda(b(1/2(Y_{2,n} - \delta U^* + \delta\widetilde{V_N^*})) + \mu_{T-1}(1/2(Y_{1,n} - \delta U^* + \delta\widetilde{V_N^*}))) + (1 - \lambda)\delta U^* - c$$

which is greater than V_N^*.

This establishes that there can never be an equilibrium where educated men marry only young women, and uneducated men marry only old women. What about the converse situation? This can also never be the case, for if an educated man and young woman met, it is in both their interests to match and deviate from such a strategy, by the same logic above.

Thus there can never be a fully separating equilibrium in this marriage market.

□

This is somewhat intriguing. Firstly, it contradicts the work of Becker (1991) on frictionless marriage markets, a key result of which is that matching should be perfectly assortative (higher quality men will match with higher quality women), and accords with Shimer and Smith (2000). Because of the vagaries of the search market, a young woman must be willing to broaden the set of men she finds acceptable.

However, while the model admits the possibility of a pooling equilibrium (conditions of which are omitted here, but relatively easy to derive), from an intuitive standpoint we are more interested in a least a partially assortative matching result- for this is precisely how the romantic world works in practice. The model admits this possibility as well.

Define $d_1 = Y_{1,e} - Y_{2,e}$ and $d_2 = Y_{1,n} - Y_{2,n}$

Proposition 11. *If d_1 and ρ are sufficiently large and d_2 and c sufficiently small,a partially separating equilibrium exists where:*

- *Old women will enter with probability 1*
- *Educated men will only marry young women, but all other actors will marry whomever they meet.*

Proof. This proof is analogous to the proof of Proposition 3, so in the interest of brevity is only sketched.

If Old women enter with certainty, then $\lambda_w = \lambda_m = \lambda$.

For an Educated man not to marry an Old woman if he meets her, we must have

$$\delta V_E^* = \frac{\delta \frac{\lambda}{2}(Y_{1,e} - \delta \sum_{t=1}^{T-1} \mu_t U_t) - c}{1 - \theta} > Y_{2,e}$$

This is clearly possible if d_1 is large and c is small.

For an Uneducated man to agree to marry an Old woman, we must have

$$Y_{2,n} > \delta h V_N^*(Y_{1,n}, Y_{2,n})$$

which will be possible if d_2 is sufficiently small.

For a Young woman to agree to marry an Uneducated man, it must be that

$$Y_{1,n} > \delta h U_t^*(\rho Y_{1,n}, (1-\rho)Y_{1,e})$$

This will be possible if ρ is sufficiently large, that is, if the number of educated men in the market is low.

Other conditions we require are that $U^*, V_N^* > 0$ sot that both Old women and Uneducated men enter the market with probability 1, which can also be solved out as functions of the parameters. This rests on the fact that c is sufficiently small.

Again, as in Proposition 3, these serve as sufficient conditions as well.

□

Feeling that this equilibrium is very natural, its properties are now studied to examine dowries.

Proposition 12. *At this equilibrium-*
i) if a woman of any age marries an educated man, she must pay a dowry.
ii) the average dowry of the system is positive

Proof. The proof of part i) follows similar logic to the proof of Proposition 7, and thus appears in the Appendix.

The intuition is familiar- because $\lambda_m = \lambda_w$ at this equilibrium, the ageing effect ensures that when a woman matches with a high-quality man, she *must* pay a dowry. However, this is not true for an Uneducated man. If such a man meets a very young woman, the chance of meeting a higher-quality man next period is factored into her decision. If they are to marry, it is possible he may have to transfer some utility to her to convince her to settle.

As for part ii), one can think of the average dowry of the system as the dowry payments of each woman of age t weighted by the size of her age cohort, conditional on meeting a man of a certain education. Thus, denoting average dowry as Δ, we have

$$\Delta = \sum_{t=1}^{\infty} \mu_t D_{j,t} = \delta/2 \sum_{t=1}^{\infty} \mu_t [\rho V_N^* + (1-\rho)V_E^* - U_t^*]$$

$$= \frac{\delta}{2}[\rho V_N^* + (1-\rho)V_E^* - \sum_{t=1}^{\infty} \mu_t U_t^*]$$

This expression must be positive. To see this, a woman's expected payoff at age t at this equilibrium is given by

$$U_t^* = \frac{\lambda}{2}[\rho(Y_{t,n} - \delta V_N^* + \delta U_{t+1}^*) + (1-\rho)(Y_{t,e} - \delta V_E^* + \delta U_{t+1}^*)] + (1-\lambda)\delta U_{t+1}^* - c$$

Rearranging U_{t+1}^* in the expression and multiplying both sides by $\sum_{t=1}^{\infty} \mu_t$ gives

$$\sum_{t=1}^{\infty} \mu_t U_t^* = \frac{\lambda}{2} \sum_{t=1}^{\infty} \mu_t[\rho(Y_{t,n} - \delta V_N^* - \delta U_{t+1}^*) + (1-\rho)(Y_{t,e} - \delta V_E^* - \delta U_{t+1}^*)] + \delta \sum_{t=1}^{\infty} \mu_t U_{t+1}^* - c$$

noting, of course, that $\sum_{t=1}^{\infty} \mu_t c = c$, as the probabilities must sum to one.

However, as $U_{t+1}^* \leq U_t$, with this holding with strict inequality $\forall\ t < T$, we may write

$$(1-\delta) \sum_{t=1}^{\infty} \mu_t U_t^* < \frac{\lambda}{2} \sum_{t=1}^{\infty} \mu_t[\rho(Y_{t,n} - \delta V_N^* - \delta U_{t+1}^*) + (1-\rho)(Y_{t,e} - \delta V_E^* - \delta U_{t+1}^*)] - c \quad (4.6)$$

Now Equations (4.2) and (4.3) can be rewritten as

$$(1-\delta)V_E^* = \frac{\lambda}{2}(\sum_{t=1}^{T} \mu_t(Y_{t,e} - \delta U_{t+1}^* - \delta V_E^*)) - c$$

$$(1-\delta)V_N^* = \frac{\lambda}{2}(\sum_{t=1}^{\infty} \mu_t(Y_{t,n} - \delta U_{t+1}^* - \delta V_N^*)) - c$$

It is the easy to verify that the R.H.S of (4.6) is less than
$(1-\delta)(\rho V_N^* + (1-\rho)V_E^*)$. So, cancelling the common $(1-\delta)$ gives

$$\sum_{t=0}^{\infty} \mu_t U_t^* < \rho V_N^* + (1-\rho)V_E^*$$

Thus we have $\Delta > 0$.

□

This is an intriguing result. The logic of part i) of Proposition 12 should convince the reader that there is no reason why a young woman may not receive a brideprice from an uneducated man in equilibrium. However, part ii) assures us that even if this is the case, the average dowry of the system will still be positive. The expectation of declining worth for young women is enough to convince them to settle now with anyone, before it is too late.

Observation 4.1. This result can also be shown to shown to hold in any equilibrium (pooling or partially separating) where women enter at all ages, so that $\lambda_w = \lambda_m$.

The obvious next step is to obtain a sufficient condition for dowries in any equilibrium as was done in the baseline case. However, due to time constraints this was not possible.

4.1 Generalization to a Continuum of Male Worth

It is simple to extend this argument to n types of males, as all the same methods outlined above can be used (with clearly exponential computational complexity). On reflection, Propositions 9 - 12 will also hold in an n-type economy.

What is interesting is considering a *continuum* of male worth. This too should in principle be possible. Consider indexing males on an atomless continuum of fitness $[0, 1]$.

We will then have U_t given by

$$U_t = \frac{\lambda_w}{2}[\int_0^1 g(i)(Y_{t,i} - \delta V_i^* + \delta U_{t+1})di] + (1 - \lambda_w)\delta U_{t+1} - c$$

where $g(i)$ is the probability density function of male worth.

The problem arises from trying to apply the standard fixed point theorem to this problem, to prove the general existence of an equilibrium. The author is not sure how this might be done.

4.2 A Note on Multiple Searches per Period

A simplifying assumption of this thesis is that women and men may only search once per period. One must ask, how realistic is this? A man or a woman in the real world will search for years (or even decades) for the perfect partner. While we can make T arbitrarily large to cover this situation, the question still arises, what would change if we incorporate this possibility of multiple searches per period?

Here a preliminary answer will be given- functionally nothing.

Let us return to the baseline model, with homogeneous men, and define the output function of marriage a little more generally. Permit agents to search z times in period t, but have the output function $f(m, w_t)$ defined over t only.

A modeling problem immediately arises, in that now the matching probabilities are functions of the time period in which one finds oneself, or more specifically the particular z. This owes to the fact that if X agents are entering in period t, assuming some matches in z_1 there will be less agents in z_2. So one then must make the simplifying but natural assumption that instead of X agents of both sexes entering in period t, x agents of age 1 enter in each sub-period z, with $x = \frac{X}{z}$.

However, if one makes this assumption, the problem is formally identical to the model derived above, with all the same results.

Chapter 5

Implications of Results

5.1 What Really Causes Dowries?

As has been outlined, most of the economic literature has assumed that dowries arise as a price to clear an imbalanced marriage market. Indeed, much of the most recent work (e.g Self and Grabowski (2009)) merely assumes the existence of a dowry system, and then asks how various attributes of the bride and groom (caste, age, wealth) will change the level.

This thesis has provided a new explanation for the source of dowries, based on differential ageing in favour of men. The model presented is consistent with the standard model, while extending its insights. Supply and demand of men and women may be important factors, but ageing effects may be even more important, and go some way to explaining the poor record of the standard model on a micro-empirical level.

5.2 Empirical Applications

This thesis throws up some eminently testable empirical applications, some of which are confirmed by existing studies and others which will require new work.

The first relates to the age structure of dowries that this thesis has constructed. The model predicts that older women will pay higher dowries than younger women, as a result on having limited options and a declining value of search. This prediction is confirmed by some studies, for example (Edlund, 2000), who found that dowries rise with a woman's age. There is also support that this ageing effect is not a uniquely South Asian phenomenon, in that it occurred in other historical dowry paying societies, such as Renaissance Tuscany (Botticini, 1999), which lends generality to the results. Specifically, Botticini reports that each additional year in the bride's age led to a statistically significant increase of 8 gold florins in the dowry paid (around 6% of average dowry size).

The data also supports the corollary of A.1, that the worth of men does not similarly decay with time. In fact, it has been well-documented empirically that average dowry size in fact increases with groom age (Dalmia, 2004; Edlund, 2000), even controlling for wealth which usually rises with age.

However, there is a problem with simply regressing dowry size on bridal age and using it to justify this hypothesis. There remains the possibility that older women pay higher dowries simply because men find them less attractive, and not because they are less productive in the marriage. It would require some serious thought on how one separate the ageing effect due to declining reproductive ability from any taste-based discrimination that occurs from physical beauty. The issue, is of course, complicated by the simultaneous interaction of both effects due to evolution- it is likely men find younger women more attractive precisely because of the higher chances of conception.

In a perfect world, the empiricist would like to gather a dataset on dowries that also contains an objective measure of the bride and groom's physical appearance (perhaps based on the aggregation of several subjective opinions). Such objective measures of beauty have been used before in labour economics, most notably in the famous study by Hamermesh and Biddle (1994) on the effect of physical beauty on labour market outcomes. One might then be able to control for such simultaneous interaction with standard empirical techniques, and separate out the hypothesized general age effect for women.

The second relates to the issue of search costs. This issue is (empirically speaking) virgin land for economists. It would form interesting research in its own right to investigate the hypothesis raised in this thesis, that dowries may increase with a decline in search costs. *Prima facie*, this should be be testable.

How one would go about it is the unique joy of empirical work. One possible dimension to explore is that of communication technology, and another is greater population density, which enhances the possibility of random meetings between sexes. Both of these intuitively would imply that search costs should be lower in urban areas and dowries higher, controlling for individual characteristics, which could well be verifiable.

5.3 Banning Dowries- Some Theoretical Insight

As explained above, it is theorised that dowries generate significant externalities which fall on the families of both parties, and the wider society. Studying and specifying these externalities is a task that has barely begun, and models such as this are necessary to move forward. However, while we wait for a more generally specified model, some small things of interest may be said.

Let us for now make the simplifying conjecture that the externalities generated by dowries outweigh the benefits derived from the free exchange of two consenting adults, such that the phenomenon is a negative one, on balance. Banning the practice is the logical conclusion.

Yet it is patently obvious that, in the case of India at least, the government is not capable of fully banning the practice. Despite being illegal since 1961, the practice appears no less prevalent than it was back then, and has perhaps spread to areas and castes where it was not observed before (Anderson, 2007a). So a more realistic way of evaluating the policy is the following.

Suppose the government imposes a heavy penalty on those families it catches which have participated in dowry, but there is a non-certain probability that it will be able to catch the,. One can easily imagine that this marginally raises the fixed fee c that a party must pay to search. As Proposition 8 shows, this would have the effect of lowering the dowry level in an established equilibrium, as well as decreasing the set of equilibria where all women pay a dowry. Thus even an ineffective dowry ban may be doing some good.

5.4 Why Do Dowries Decline With Modernisation?

The results could also be used to shed a sliver of light on the holy grail of dowry economics. It is a truly magnificent and robust empirical phenomenon that the practice of dowry declines with industrialisation and a sustained rise in the standard of living (Self and Grabowski, 2009), such that no country with a GDP per capita over $US PPP 10,000 observes dowry or brideprice[1]. Several explanations have been proposed (Becker, 1981; Anderson, 2003), but none is undisputed in the economics literature.

This thesis makes one potential explanation less plausible. One defining characteristic of modernisation is that search costs in the marriage market are likely to fall. Increasing urbanisation means that people are clustered closer together, and highly developed communications technology makes it easier for them to communicate. However, this thesis has showed that the most likely effect of falling search costs is an increase in dowry.

However, perhaps the decline has something to do with a change in the production function. Specifically, suppose it is the case that as a country enters the modern world, labour market opportunities increase for women. This will alter the production function of marriage, as women may also choose to produce some market income. If this is the case, their worth will depend less and less on their unique ability to bear children, and the ageing effect may disappear.

[1]In Europe, the practice declined at much lower levels of per capita income, sometime in the 18th Century.

Chapter 6

Conclusions

As with any research, this piece is not without weaknesses. Before concluding, it serves to briefly mention them in order to contextualise the model and its usefulness.

A reader familiar with South Asian culture is likely to point to two observations which this thesis abstracts from. The first is the importance of caste in marriage. In this search model, caste is entirely absent, but this is not considered to be a serious defect. For one, the interaction of caste and dowries has been well-studied in the literature by many authors. Furthermore, the model is well able to bear the imposition of caste without too much difficulty. One can consider caste as a quality or desirableness indicator, in which case it can be modelled just as education was. A more interesting question arises if marriage is difficult or impossible between castes, which will fragment the search market. This too is unproblematic in the basic case (if castes cannot intermarry, each may be studied in isolation). However, there is a possibility that marriages between different castes are asymmetric based on sex. There exists convincing evidence that women in India are encouraged to marry into a higher caste than their own, but severely penalised for marrying into a lower caste (so-called hypergamy). This problem has been well studied by Anderson (2000; 2003; 2007b), and the author does not believe that this model has any value to add to the question.

The second observation revolves around the fact that dowries and marriages are often not the result of decisions by the bride and groom, but by the *families* of both parties, who are instrumental in the entire matching process. How does the search model account for this? If one is willing to make a single simplifying assumption- that households will try and maximise the utility of their children- the problem is a non-issue, and all the techniques above will apply.

One assumption in the model is clearly unsatisfying, in the sense that it perhaps abstracts too far from reality. This is the assumption on a fixed birth rate- that each period nature adds X agents of age $t = 1$ to the market. A nice aspect of this assumption is that it allows a steady state to emerge in equilibrium, which is perhaps why it was also used by Sautmann (2009). However, it also means that the children born in a period are independent of the matches that formed in the previous period, something that is at best unusual and at worst a flaw in the description of the marriage model. Matters are further complicated if one considers that a higher level of dowries may induce female infanticide, and thus affect the birth rate. Trying to formally account for more realistic birth dynamics proved unfruitful, as as a steady state was unable to be obtained with the author's abilities.

The other way that search models deal with this problem is to fix the population size and allow for exogenous dissolution of matches in each period, so that some fraction of searchers must return to the market in each period. In a labour market this means a random separation decision (Mortensen and Pissarides, 1999), in a marriage market this means divorce (Smith, 2006). However, considering the nature of the model and the huge focus on ageing dynamics, the utility of this approach was limited; and old women who divorces might have no prospect of returning to the market, meaning the market shrinks over time and eventually collapses without births.

This thesis has critiqued the standard model of dowries for not accounting for search frictions, and has showed that doing so can substantially change the conclusions of theory. However, in emphasising the frictional nature of the process, it is possible one has gone too far in abstracting from the role of competition. In this model, competition with agents of the same sex only enters through the matching probability functions. This is somewhat undesirable, for competition seems to be a central feature of romantic interaction.

In further research, it may be of some interest to construct a hybrid search model, which still features some competition. That is to say, a search model without the feature of single pair meetings in time t. How one may do this is an open question, for it would not be a trivial exercise, and the author is not aware of any previous work done on the subject. One potential way forward is to keep the notion of a market, but introduce an element of randomness in the process of *arrival* at the market, such that once a decision to search has been made, the probability of participating in the market is not unity. One may then use the techniques developed in this model (asymmetric ageing and intertemporal bargaining) to construct a complete statement of dowries.

The model presented herein is a small part of a well-established trend in economics to consider all aspects of human interaction within its domain. Applying economic methodology to questions of family life and emotional interaction has been very successful in the past. It is the hope of this author that investigations such as this will continue to illuminate the remarkable complexities of human relationship.

Appendix A

Appendix

Proof of Lemma 4.1

The logic of the proof is similar to Lemma 3.1.

Before beginning, consider the nature of the mapping more closely. Choosing any pair of V_N^* and V_E^* will fully determine the vector of probabilities p_t^w, and then Equation (4.2) will imply a linear relation for V_E' in V_E^* (or a family of linear relations) and V_N' in V_N^*

Now consider taking a sequence of V_N^* and V_E^*. As both increase, the value of U_T' must decrease. We also know that the intercepts of V_E' and V_N' will be changing, due to the change in the other part of the pair. This change is, of course, continuous- an ϵ change in V_E^* will cause the intercept of V_N' to move by $\frac{\lambda_m \lambda_w \delta^2 \rho}{4}\epsilon$, and vice-versa.

We move along the continuous path in V_E' and V_N' until we reach the point where U_T' reaches zero. At this point, they will randomise, and there will be a family of linear relations for both V_N' and V_E', which include the possibility of $p_T' = 1$ and $p_T' = 0$. As demonstrated earlier, at this point the correspondence is no longer continuous, but it is still upperhemicontinuous. Moving past this point, the correspondence collapses again into a single valued mapping for V_E' and V_N', until we reach the point where $U_{T-1}' = 0$ and the process repeats.

This demonstrates the mapping is upperhemicontinuous. It is also convex valued, as any point in V_N' and V_N' can be represented by a convex combination of another two points. This derives from the fact that a linear relation is convex valued, and at the vertical line points in the correspondence, all points can be represented by a convex combination.

This proves the lemma.

Proof of Proposition 12, Part i)

If a woman of any age marries an educated man, she must pay a dowry.

Proof. We can write the payoffs of all women as

$$U_1^* = \frac{\lambda}{2}(\rho(Y_{1,N} - \delta V_N^* + \delta U_2^*) + (1-\rho)(Y_{1,E} - \delta V_E^* + \delta U_2^*)) + (1-\lambda)\delta U_2^* - c$$
$$U_2^* = \frac{\lambda}{2}(\rho(Y_{1,N} - \delta V_N^* + \delta U_3^*) + (1-\rho)(Y_{1,E} - \delta V_E^* + \delta U_3^*)) + (1-\lambda)\delta U_3^* - c$$
$$\vdots$$
$$U_T^* = \frac{\lambda}{2}(\rho(Y_{2,N} - \delta V_N^* + \delta U_T^*)) + (1-\lambda)\delta U_T^* - c = U_{T+1}^* = U_{T+\dots}^*$$

U_1^* then telescopes to

$$U_1^* = \frac{\lambda}{2}\sum_{t=1}^{T}\sigma^{t-1}[\rho(Y_{1,N} - \delta V_N^* + \delta U_{t+1}^*) + (1-\rho)(Y_{1,E} - \delta V_E^* + \delta U_{t+1}^*)] + \frac{\lambda}{2}\frac{\sigma^T\rho(Y_{2,N} - \delta V_N^* + \delta U_T^*)}{1-\sigma} - \frac{c}{1-\sigma}$$

V_E^* and V_N^* can be written as

$$V_E^* = \frac{\frac{\lambda}{2}(\sum_{t=0}^{T}\mu_t(Y_{1,e} - \delta U_{t+1}^* + \delta V_E^*)) - c}{1-\sigma}$$

$$V_N^* = \frac{\frac{\lambda}{2}(\sum_{t=0}^{\infty}\mu_t(Y_{t,n} - \delta U_{t+1}^* + \delta V_N^*)) - c}{1-\sigma}$$

By revealed preference (Proposition 11) ,

$$V_E^* > \bar{V_E^*} = \frac{\frac{\lambda}{2}(\sum_{t=0}^{\infty}\mu_t(Y_{t,e} - \delta U_{t+1}^* + \delta V_E^*)) - c}{1-\sigma}$$

and of course, $\bar{V_E^*} > V_N^*$

Now define two new variables, such that

$$U_1^\dagger = \frac{\lambda}{2}\sum_{t=1}^{T}\sigma^{t-1}[(\rho Y_{1,N} + (1-\rho)Y_{1,E} - \delta V_{EN}^\dagger + \delta U_1^\dagger] + \frac{\lambda}{2}\frac{\sigma^T\rho(Y_{2,N} - \delta V_{NE}^\dagger + \delta U_1^\dagger)}{1-\sigma} - \frac{c}{1-\sigma}$$

$$V_{EN}^\dagger = \frac{\frac{\lambda}{2}\sum_{t=1}^{\infty}\mu_t(\rho Y_{t,N} + (1-\rho)Y_{t,E} - \delta U_1^\dagger + \delta V_{EN}^\dagger) - c}{1-\sigma}$$

Using the definition of μ_t (as it sums to infinity), we can write,

$$V_{EN}^{\dagger} = \frac{\lambda}{2}\sum_{t=1}^{\infty}\sigma^{t-1}(\rho Y_{t,N} + (1-\rho)Y_{t,E} - \delta U_1^{\dagger} + \delta V_{EN}^{\dagger}) - \frac{c}{1-\sigma}$$

One can note that $V_E^* > V_{EN}^{\dagger}$ and $U_1^{\dagger} > U_1$

First of all, if $T = 2$ (a woman becomes old almost immediately), taking the difference $V_{EN}^{\dagger} - U_1^{\dagger}$ yields

$$V_{EN}^{\dagger} - U_1^{\dagger}|_{T=2} = \frac{\lambda(1-\rho)\sigma Y_{2,E}}{2-\sigma(2+\delta\lambda(1+\rho))}$$

which is unambiguously positive, given $\rho < 1$.

Secondly, if $T = \infty$ (that is to say, a woman never ages), then]

$$V_{EN}^{\dagger} - U_1^{\dagger}|_{T=\infty} = 0$$

Lastly, the difference $V_{EN}^{\dagger} - U_1^{\dagger}$ is monotonically decreasing in T, so it must lie with these bounds. To see this, note a one period increase in T will increase $V_{EN}^{\dagger}$ by $\frac{\lambda}{2}\sigma^T(\rho Y_{1,N} + (1-\rho)Y_{1,E} - (\rho Y_{2,N} + (1-\rho)Y_{2,E}))$, which is positive given the specifications on the production function of marriage. But $U_1^{\dagger}$ will increase by even more, specifically $\frac{\lambda}{2}\sigma^T(\rho Y_{1,N} + (1-\rho)Y_{1,E} - \rho Y_{2,N})$ So the difference $V_{EN}^{\dagger} - U_1^{\dagger}$ will decrease by a net $\frac{\lambda}{2}\sigma^T((1-\rho)Y_{2,E})$

This shows that for any finite $T \neq 1$, $V_{EN}^{\dagger} - U_1^{\dagger} > 0$. Now as $V_E^* > V_{EN}^{\dagger}$ and $U_1^{\dagger} > U_1$ at any T, then we have $V_E^* > U_1$ at any T.

As $U_1 > U_t$, then $V_E^* > U_t$. Going from the dowry function in Equation (3.5), if a woman of any age marries an educated man, she must pay a dowry.

□

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